IOWA GEOLOGICAL SURVEY

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with

Accompanying Papers

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THIRTIETH AND THIRTY-FIRST ANNUAL REPORTS OF THE STATE GEOLOGIST.

IOWA GEOLOGICAL SURVEY,
DES MOINES, DECEMBER 31, 1922.

To Governor Nathan E. Kendall and Members of the Geological Board:

GENTLEMEN: I transmit to you herewith a report on The Stratigraphy of the Mississippian Formations of Iowa by Dr. Francis M. Van Tuyl, and a report on The Mineral Production in Iowa in 1921 and 1922 by Dr. James H. Lees.

The report by Doctor Van Tuyl is based on field and laboratory studies extending over several years. The formations which are described are of economic as well as scientific importance. They contain valuable deposits of clay, building stones, road material, and cement rock; several of the formations are known the world over for their profusion of fossil remains. Furthermore, the type sections of the Burlington and Keokuk limestones which represent members of the standard Mississippian column of North America occur in this State. It was discovered also that one formation exists in Iowa which had not previously been known to be in the State, and many new facts were obtained regarding the thickness, character, stratigraphic relations, fauna, and distribution of the deposits which had not been recognized by earlier investigators. The remarkably well developed geodes of the Warsaw formation, specimens of which appear in many of the mineralogical museums of the world, are described in detail, and many puzzling features regarding their origin are explained. The diagonal belt-like outcrops of the Mississippian formations in Iowa are ascribed to a late Mississippian tilting and erosion which outlined the Western Interior Geosyncline, later occupied by a sea from which rocks of Coal Measures age were deposited.

I recommend that the papers of Doctor Van Tuyl and Doctor Lees be published as Volume XXX of the Survey. This volume will constitute the Thirtieth and Thirty-first Annual Reports of the Iowa Geological Survey.

Respectfully submitted,

GEORGE F. KAY,
State Geologist.

Mineral Production in Iowa in 1921 and 1922

by

JAMES H. LEES

Mineral production in Iowa in 1921 and 1922[1]

Products	*Unit*	*Quantity*	*Value*
	1920		
Cement	Bbl. of 376 lb.	4,421,783	$ 8,742,854
Clay products			10,489,232
Coal	short tons	7,774,916	30,793,847
Gypsum	short tons	571,895	4,422,965
Mineral waters	gallons	38,877	3,419
Natural gas	M cubic feet	827	290
Sand and gravel	short tons	2,467,644	1,993,441
Stone and lime	short tons	620,565	840,544
			57,250,317

1921

Cement	Bbl. of 376 lb.	4,151,439	$ 7,439,983
Clay products			5,711,583
Coal	short tons	4,531,392	17,256,800
Gypsum	short tons	301,587	2,922,700
Mineral waters	gallons	21,100	2,105
Natural gas	M cubic feet	700	300
Sand and gravel	short tons	2,641,982	1,726,958
Stone and lime	short tons	423,279	563,427
			35,625,170

1922

Cement	Bbl. of 376 lb.	4,475,074	$ 7,709,313
Clay products			5,739,449
Coal	short tons	4,335,161	16,119,000
Gypsum	short tons	452,451	4,146,182
Mineral waters	gallons	25,561	3,788
Natural gas	M cubic feet	460	230
Sand and gravel	short tons	2,690,798	1,752,233
Stone and lime	short tons	627,443	719,203
			36,189,398

The value of mineral production in Iowa in 1921, $35,625,170, represents a decrease of $21,437,147 from the peak production of the preceding year. In fact it dropped below the production of both 1918 and 1919, the years which represented war and immediately postwar conditions. This decrease from the 1920 figures is due chiefly to the great reduction in the output

[1] The statistics for these years were collected by the Iowa Geological Survey in coöperation with the United States Geological Survey, with the exception of data on clay products, which were compiled by the Bureau of the Census.

of coal, though a sharp restriction is evident in other lines also, notably clay products, gypsum and cement.

During 1922 the production of coal suffered a slight further decline, but clay products and cement sales increased slightly and the output of gypsum products was much larger than during 1921. There was a slight gain also in the minor products. These changes made an increase of $564,228 in the output over that of 1921. Coal held the chief place in the list of producers and accounted for nearly half of the total value of the output. It is noteworthy, however, that whereas in previous years clay products have been second in the list, during both years here considered the output of cement exceeded that of clay wares and gave it rank as the second mineral product of the state.

The production of minerals in Iowa in the last decade is shown in the following table.

Production of minerals from 1913 to 1922

Year	Coal	Clay wares	Gypsum	Cement	Other (a)	Total
1913	$13,496,710	$ 5,575,581	$1,157,930	$3,972,876	$1,409,239	$25,612,345
1914	13,364,070	6,405,995	1,321,457	4,008,915	1,201,428	26,301,865
1915	13,577,608	6,749,088	1,278,128	4,119,952	1,338,174	27,062,950
1916	13,530,383	7,383,289	1,496,795	5,063,647	1,692,367	30,210,284
1917	21,096,408	7,540,213	2,041,997	6,870,863	1,663,206	39,336,372
1918	24,703,237	5,315,143	1,946,414	5,423,926	1,353,289	38,742,009
1919	17,352,620	8,125,324	2,634,444	7,798,347	1,977,048	37,882,183
1920	30,793,847	10,489,232	4,422,965	8,742,854	2,837,694	57,250,317
1921	17,256,800	5,711,583	2,922,700	7,439,983	2,294,104	35,625,170
1922	16,119,000	5,739,449	4,146,182	7,709,313	2,475,454	36,189,398

COAL

The production of coal in 1921 fell below that of 1920 by 3,282,524 tons, a decrease of 42 per cent from the banner production of the preceding year. The value of the output naturally decreased also, the drop being from the record figure of $30,793,847 in 1920 to $17,256,800 in 1921. The diminished value was due both to the smaller output and to the lower price per ton received—$3.81 in 1921 as compared with $3.94 in 1920. These figures represent a reaction from business and industrial conditions in 1920, when there was a temporary recovery from the relatively unfavorable situation of 1919.

The coal output of 1922, moreover, did not show the recovery

(a) Includes iron ore, lead and zinc, mineral waters, natural gas, potash, sand and gravel, stone and lime, ferroalloys.

that was in evidence in other lines of the mineral industry. The tonnage showed a slight decline—196,231 tons—and both the total value and the value per ton were lower—by $1,137,800 and nine cents respectively. The tonnage produced in 1922 was the lowest since that of 1896. For some reason it took 1471 more men to get out the smaller output of 1922, as compared with that of 1921, although they worked only 131 days in 1922 as against 148 days in 1921. It is evident that some stabilizing element is needed to allow these men to work and the mines to produce coal more than about forty per cent of the total number of work days available.

The following table shows the production in Iowa during 1921 and 1922.

Coal Production in 1921 by Counties

COUNTY	No. Producers	Loaded at mines for shipment		Sold to local trade and used by employees		Used at mines for steam and heat		Total		No. of employees			Average number of days worked	Average price per ton
		Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value	Under-ground	Surface	Total		
Appanoose	52	540,191	$2,057,000	57,003	$217,000	12,203	$ 27,000	609,397	$ 2,301,000	2,925	273	3,198	92	$3.81
Boone	4	152,968	727,000	43,179	249,000	2,591	6,000	198,738	982,000	502	46	548	159	4.94
Dallas	3	299,324	1,150,000	6,618	30,000	3,946	15,000	309,888	1,195,000	600	55	655	179	3.86
Greene(2), Guthrie(1)	3	--------	----------	7,913	38,539	----------	------------	7,913	38,539	35	1	36	153	4.92
Jasper	3	Incl. in "Local trade"		101,401	407,000	8,009	24,000	108,410	431,000	276	41	317	140 124	3.98
Jefferson (1), Keokuk(1), Van Buren(2)	4	incl. in "Local trade"		11,590	39,100	----------	------------	11,590	39,100	22	4	26	230 120	3.37
Lucas	3	Incl. in "Local trade"		226,012	847,000	10,811	40,000	236,823	887,000	394	45	439	205 211	3.78
Mahaska	9	Incl. in "Local trade"		46,660	167,000	1,091	4,000	47,751	170,000	88	10	98	139	3.58
Marion	13	527,561	1,939,000	37,159	136,000	18,468	65,000	583,188	2,140,000	972	96	1,068	149	3.67
Monroe	10	1,447,902	5,302,000	31,546	118,000	39,843	81,000	1,519,291	5,501,000	2,702	217	2,919	172	3.62
Polk	16	519,549	2,001,000	213,044	1,017,000	17,758	52,000	750,351	3,070,000	1,514	141	1,655	179	4.09
Adams(2), Page(2), Taylor(1)	5	Incl. in "Local trade"		25,821	102,436	----------	------------	25,821	102,436	68	6	74	180 277	3.95
Wapello	8	2,700	4,000	47,799	131,000	Incl. in "Loaded at Mines"		50,499	135,000	85	10	95	60 175	2.67
Warren(1), Wayne(3)	4	56,183	202,158	15,549	62,179	Incl. in "Loaded at Mines"		71,732	264,337	229	29	258	143	3.84
	137	3,891,368	14,663,000	521,465	2,269,200	118,559	324,600	4,531,392	17,256,800	10,412	974	11,386	148	3.81

Coal Production in 1922 by Counties

COUNTY	Producers	Loaded at mine for Shipment	Sold to local trade and used by employees	Used at mine for steam and heat	Total		Average value per ton	Number of employees			Average number days worked
		Short tons	Short tons	Short tons	Short tons	Value		Under-ground	Surface	Total	
Adams(3), Page (2), Taylor(1)	6	7,809	30,512	--------	38,323	$ 178,000	$4.57, 4.46, 5.09	85	4	89	186, 199, 260
Appanoose	47	761,209	48,240	12,854	822,303	3,187,000	3.88	2,979	260	3,239	120
Boone	5	176,024	39,900	7,868	223,792	1,058,000	4.72	659	53	712	140
Dallas	4	299,640	11,289	1,842	312,771	1,137,000	3.64	646	62	708	154
Greene(2), Guthrie(2), Hardin(1)	5	Incl. in "Local trade"	8,049	Incl. in "Local trade"	8,049	39,000	5.44, 3.50, 5.00	41	7	48	143, 155, 60
Jasper	3	73,739	7,395	Incl. in "Shipped"	81,134	331,000	4.08	270	41	311	79
Jefferson(1), Keokuk (1) Van Buren(2)	4	Incl. in "Local trade"	14,477	Incl. in "Local trade"	14,477	44,000	3.00, 2.94, 3.78	21	2	23	198, 180, 257
Lucas(2), Warren(1)	3	454,424	5,616	14,120	474,160	1,449,000	3.02, 3.45	1,560	80	1,640	119, 170
Mahaska	10	29,288	Incl. in "Shipped"	Incl. in "Shipped"	29,288	98,000	3.36	95	9	104	111
Marion	14	483,125	36,935	13,847	533,907	1,930,000	3.62	1,154	111	1,265	135
Monroe	9	978,614	30,055	27,629	1,036,298	3,675,000	3.55	2,560	191	2,751	137
Polk	17	340,059	265,840	17,973	623,872	2,505,000	4.02	1,621	175	1,796	134
Wapello	8	1,263	23,939	Incl. in "Shipped"	25,202	81,000	3.23	70	7	77	128
Wayne(2), 48 small mines	50	52,273	59,312	--------	111,585	407,000	3.45, 4.00	85	9	94	155
	185	3,653,352	579,907	101,902	4,335,161	16,119,000	3.72	11,846	1,011	12,857	131

The production of coal in Iowa during the last ten years, which includes the war period, is shown in the subjoined table.

Production of Coal in Iowa, 1913 to 1922.

Year	Tons	Value
1913	7,525,936	$13,496,710
1914	7,451,022	13,364,070
1915	7,614,143	13,577,608
1916	7,260,800	13,530,383
1917	8,965,830	21,096,408
1918	8,192,195	24,703,237
1919	5,624,692	17,352,620
1920	7,813,916	30,793,847
1921	4,531,392	17,256,800
1922	4,335,161	16,119,000

In the tables showing production by counties those in the southwestern field, mining the Nodaway coal, have been grouped together to avoid revealing individual production. This grouping also shows the output from this small but interesting field. The Nodaway coal averages only about sixteen inches in thickness and owes its value to its distance from other fields and the constancy of its occurrence. It is noteworthy that in number of days worked these counties stand among the highest in the state.

Monroe county was the leader in both tonnage and total value. Polk and Appanoose occupied second and third places in 1921 but reversed positions in 1922.

The statistics for 1921 show that during this year 71.2 per cent of the coal mined, or 3,227,867 tons, was shot off the solid; 12.7 per cent, or 572,754 tons, was mined by hand; and 15.4 per cent, or 698,443 tons, was mined by machine. The method of production of 0.7 per cent, 32,328 tons, was not specified. The corresponding percentages in 1920 were 62.7, 15.2, 20.7 and 1.4. It will be seen that the proportion mined by machine was 5.3 per cent less in 1921. There were 100 machines in use in 1920 and 98 in 1921. The number of machines in the bituminous mines of the country in 1921 was 16,618, and the amount of coal mined by their use was 272,702,389 tons.

The year 1921 was one of the quietest of recent years in the industry in Iowa so far as strikes and lockouts were concerned. There were only 897 men out on strike for a total of 1,840 man-days.

The table showing the leading coal producing states, which follows, shows that Iowa was not alone in the slight decline in 1922, but that several others experienced similar conditions. All of these states shown in the table as having a smaller output in 1922 are central and western states, and the same condition held true of most of the western producers, Washington and North Dakota being notable exceptions. This would seem to indicate that, in general, business conditions had not improved so much in the west as in the east. Estimates of production in 1923 indicate that most of these central and western states will have an increased output. Iowa's output is estimated at 6,500,000 tons.

Production of coal in the United States in 1921 and 1922.

	1921			1922		
STATE	Value	Av. per ton	Number employees	Value	Av. per ton	Number employees
Pennsylvania	$ 322,538,300	$2.78	190,643	$ 351,777,000	$3.11	188,838
West Virginia	206,661,500	2.84	101,850	236,162,000	2.93	110,014
Illinois	190,986,000	2.74	95,431	168,925,000	2.89	96,336
Kentucky	85,092,600	2.69	50,521	127,037,000	3.02	60,924
Ohio	84,686,500	2.65	51,785	87,056,000	3.23	54,194
Indiana	52,269,000	2.57	32,687	54,524,000	2.85	33,208
Alabama	38,713,000	3.08	25,809	42,856,000	2.34	28,169
Colorado	32,377,000	3.55	14,529	31,701,000	3.16	13,506
Wyoming	23,358,500	3.24	8,484	18,162,000	3.04	9,045
Virginia	22,947,700	3.06	11,922	27,083,000	2.58	13,399
Iowa	17,256,800	3.81	11,386	16,119,000	3.72	12,857
U. S.	1,199,983,600	2.89	663,754	1,274,820,000	3.02	687,958
Anthracite	452,305,000	5.00	159,499	273,700,000	5.01	156,849
Total	1,652,288,600	3.26	823,253	1,548,520,000	3.25	844,807

The average tonnage per man per day ranged in 1921 from 2.42 in Texas to 6.10 in Utah. Both of these figures, however, are somewhat abnormal and the average in most of the states is between three and four tons. Physical conditions in the mines have much to do with the tonnage average. For example the high average of Utah is due to the great thickness of the seams, some of which are sixteen feet or more in thickness. The average recovery by each Iowa worker was 2.69 tons.

CLAY PRODUCTS

The output of clay wares in 1921 and 1922 was much less than that of the two preceding years. The year 1920 had been the record year in clay production as it was with coal, and the production during the next year fell from the value of $10,489,-232 reached in 1920 to that of $5,711,583 in 1921. This was no doubt due to irregularity and depression in the building trades during 1921, conditions which continued, apparently, in large measure into 1922, as the output increased only very slightly during that year. The following table will show the amount and value of the various products during 1921 and 1922.

Production of clay wares by classes in 1921 and 1922

1921

CLASS	Plants	Quantity	Value	Average price per unit	Per cent of total of U. S.
		Thous.			
Common brick	65	48,844	$ 680,689	$13.94	1.2
Face brick	14	10,196	189,568	18.59	1.0
		tons			
Hollow building tile or block	56	161,136	1,209,180	7.50	8.1
Drain tile	77	269,554	2,412,849	8.95	28.8
Sewer pipe	5	49,564	783,429	15.81	3.6
Other products(a)	10		435,868		
	103		5,711,583		2.1

1922

CLASS	Plants	Quantity	Value	Average price per unit	Per cent of total of U.S.	Per cent increase Quantity	Per cent increase Value
		Thous.					
Common brick	50	56,030	$ 728,508	$13.00	1.0	14.7	7.0
Face brick	11	18,510	354,041	19.13	1.3	81.5	86.8
		tons					
Hollow building tile or block	40	308,366	2,170,368	7.04	11.0	91.4	79.5
Drain tile	52	176.894	1,495,116	8.45	29.0	—39.1	—38.5
Sewer pipe	4	38,359	681.233	17.76	2.9	—22.6	—13.0
Other products(a)	6		310,183				
	69		5 739,449		1.8		0.5

These tables when compared with those for the two preceding years show several facts of interest. One is the important drop in the quantity and value of common brick as compared with the production in 1920, which was 60,270,000 bricks valued at $1,146,182. Another is the fluctuation in pro-

(a) Includes: fancy brick, vitrified brick, miscellaneous products.

duction of face brick. In 1919 this had risen to 20,603,000. In 1920 it declined to 13,678,000 and in 1921 it went still lower, but it witnessed a large rise in 1922. Probably the manufacture and sale of drain tile is a fairly accurate barometer of agricultural conditions. If this be true the following facts are worthy of note. In 1919 the sales of drain tile amounted to $3,127,378, in 1920 to $4,760,115, in 1921 to $2,412,849, in 1922 to $1,495,116. This last figure marks the lowest value of the drain tile output since 1904, when it was $1,321,745. It must be remembered, too, that unit values were much lower then than now.

The production of clay wares in Iowa during the last ten years may be summarized as follows:

Production of clay wares in Iowa, 1913 to 1920.

CLASS	1913	1914	1915	1916
Common brick	$1,052,036	$1,067,746	$ 898,851	$ 947,247
Vitrified brick	222,105	211,905	300,785	393,038
Face brick	181,911	148,394	153,324	283,559
Drain tile	2,798,816	3,180,836	3,802,599	3,986,163
Sewer pipe	503,360	558,751	448,721	494,428
Fireproofing or hollow block	762,563	1,083,397	1,008,457	1,141,291
Other products	52,890	150,716	130,878	127,563
	5 575.581	6.405,995	6,749,088	7,375.716

CLASS	1917	1918	1919	1920
Common brick	$ 947,247	$ 749,325	$ 941,489	$ 1,146,182
Vitrified brick	83,310	116,522	179,969	176,430
Face brick	282,840	188,041	449,491	346,164
Drain tile	4,004,989	2,256,200	3,127,378	4,760,115
Sewer pipe	455,561	398,848	902,008	918,669
Fireproofing or hollow block	1,542,884	1,550.076	2,475,291	3,048,776
Other products	72.145	32,206	49,698	92,896
	7.543.225	5 318.848	8.125.324	10.489 232

The production of clay wares in the leading states of the Union during 1922 is shown by the following table.

Production of clay wares in the ten leading states of the United States in 1922

STATE	Rank	Brick, tile, etc.	Pottery	Total	Per cent of total
Ohio	1	$ 38,128,927	$ 33,218,387	$ 71,347,314	22.2
Pennsylvania	2	35,760,030	5,923,014	41,683,044	13.0
New Jersey	3	17,243,445	20,881,443	38,124,888	11.8
Illinois	4	23,041,251	3,743,012	26,784,263	8.3
New York	5	14,862,925	5,685,884	20,548,809	6.4
California	6	12,680,942	2,008,888	14,689,830	4.6
Indiana	7	10,451,027	3,491,112	13,942,139	4.3
West Virginia	8	3,158,123	9,821,258	12,736,172	4.0
Missouri	9	11,649,495	96,513	11,746,008	3.7
Iowa	10	5,739,449	....	5,739,449	1.8
United States		229,508,106	91,986,297	321,494,403	100.0

There were 1,797 plants producing brick, tile and other wares, and 301 pottery plants, a total of 2,098 for the nation.

CEMENT

The production of Portland cement in 1921 dropped to five per cent below that of 1920 as compared with a drop of one per cent for the industry throughout the United States. At the same time the shipments dropped six per cent. The decrease in production continued in 1922 and brought it down to seven per cent under that of 1921. However, the shipments during 1922 were eight per cent greater than those of 1921 and the consumption in 1922 was greater than that in 1921 also. The following table will give the data for the state in detail.

Production of cement in Iowa, 1920 to 1922

	1920	1921	1922
Production, bbls.	4,849,228	4,590,920	4,272,432
Stock, Dec. 31, bbls.	553,607	993,090	790,447
Shipments, bbls.	4,421,783	4,151,439	4,475,074
Shipments, value	$8,742,854	$7,439,983	$7,709,313
Average factory price per bbl.	$1.98	$1.79	$1.72
Consumption, bbls.	3,360,089	3,118,469	3,246,436
Population, est.	2,422,485	2,440,948	2,459,411
Consumption per capita, bbl.	1.39	1.28	1.32

During both 1921 and 1922 the commercial district which includes eastern Missouri, Iowa and Minnesota, and which contains nine active plants, ranked third in production, with an output of 11,393,552 barrels in 1922. In value of shipments, however, this district ranked fourth, as California's shipments reached a higher value, though the amount was less. The following table will show the production in the leading states.

Cement production in the United States in 1921 and 1922

STATE	Active Plants		Production, barrels			Shipments	
					Inc. per cent	1921	
	1921	1922	1921	1922	1922	Barrels	Value
Pennsylvania	22	22	27,628,598	33,276,093	20	26,622,367	$ 46,881,625
California	9	9	7,302,784	8,711,515	19	7,180,700	16,856,258
Michigan	11	12	5,777,533	6,243,805	8	5,680,156	10,300,289
Illinois	4	4	5,587,825	6,407,129	15	5,237,510	9,092,982
New York	8	9	5,294,188	5,922,706	12	4,993,341	9,403,015
Missouri	5	5	4,446,091	6,170,633	39	4,375,712	8,034,540
Iowa	4	4	4,590,920	4,272,432	—7	4,151,439	7,439,983
Kansas	7	7	3,781,494	4,634,287	23	3,643,583	7,253,944
Texas	5	5	2,668,741	3,628,756	36	2,514,045	5,902,863
Ohio	5	5	2,563,773	2,835,243	11	2,518,723	4,615,492
Total for U. S.	115	118	98,842,049	114,789,984	16	95,507,147	180 778,415

STATE	Shipments, Cont.				Consumption			
	1922				1921		1922	
	Barrels	Value	Average factory price per bbl.					
			1921	1922	Barrels	Per capita	Barrels	Per capita
Pennsylvania	34,023,695	$ 55,528,002	$1.76	$1.63	9,268,804	1.04	10,457,809	1.16
California	9,041,788	20,478,577	2.35	2.26	6,173,132	1.69	8,356,362	2.23
Michigan	6.349,751	11,145,573	1.81	1.76	6,112,986	1.59	6,196,586	1.58
Illinois	6,554,945	10,584,171	1.74	1.61	6,366,563	0.96	9,667,741	1.43
New York	6,194 663	10,694,426	1.88	1.73	10,301,525	0.97	13,272,157	1.23
Missouri	6,239,144	10.457.557	1.84	1.68	2,236,368	0.65	3,017,859	0.83
Iowa	4,475,074	7,709,313	1.79	1.72	3,118,469	1.28	3,246.436	1.32
Kansas	4,556,517	8,138,268	1.99	1.79	2,292,363	1.28	2,692,345	1.50
Texas	3,730,477	7.515,932	2.35	2.01	2,303,573	0.48	2,892,922	0.59
Ohio	2,913,035	5,243,687	1.83	1.80	6,737.835	1.12	7.770,331	1.28
Total for U. S *	117.701.216	207.170 430	1.89	1.76	94.286.002	0.87	116.306.997	1.06

* Other producing states are Alabama, Colorado, Georgia, Indiana, Kentucky, Maryland, Minnesota, Montana, Nebraska, New Jersey, Oklahoma. Oregon, Tennessee, Utah, Virginia, Washington and West Virginia.

A comparison of this table with that for the two years preceding will show that Indiana has dropped out of second place, which has been assumed by California, also that the latter state during both years here considered held first place in per capita consumption—perhaps due to California's aggressive road building program. Iowa may well take notice and climb out of fifth place. Mississippi consistently kept her position at the foot of the list of consumers.

An estimate of consumption of Portland cement in 1922 as furnished to the United States Geological Survey by the Portland Cement Association is of interest as showing the distribution of this material.

	Barrels
Public and commercial buildings	29,000,000
Dwellings	11,000,000
Sidewalks and private driveways	8,000,000
Miscellaneous farm uses	24,000,000
Concrete pipe	5,000,000
Paving and highways	28,000,000
Railways	6,000,000
Bridges, river and harbor work, dams and water power projects, storage tanks, reservoirs	3,500,000
Miscellaneous uses	2,000,000
	116,500,000

The four plants in operation in Iowa are those of the Gilmore Portland Cement Company at Gilmore City, Pocahontas county; the Northwestern States Portland Cement Company and the Lehigh Portland Cement Company at Mason City, Cerro Gordo county; and the Hawkeye Portland Cement Company at Des Moines, Polk county. The figures show that the average factory price received by these plants decreased during both 1921 and 1922 until it was twenty-six cents per barrel less than the average price for 1920, $1.98, which was the record price for recent years. Similar conditions prevailed throughout the producing districts of the United States.

GYPSUM

Following the great increase in the production and sales of gypsum in 1920 the industry experienced the slump which seemed to be common to the mineral industry in general. The sales of gypsum and gypsum products in 1920 amounted to 432,239 tons with a value of $4,422,965. Then in the succeeding year the production dropped to 301,587 tons valued at $2,922,-700. There was a slight decline in the production of the country at large although only in Kansas and Wyoming was this decline comparable with that in Iowa. Several states experienced an advance in 1921, as a result of which Ohio passed Iowa and took second place, next to New York, both in tonnage mined, in tonnage and value of calcined products and in total value of material sold. In the value of the crude gypsum sold for agricultural uses Iowa was the leader in both 1921 and 1922, although the value in both years was less than the corresponding figure for 1920, which was the highest thus far reached for sales of this commodity. Iowa ranked fourth in the amount and value of crude gypsum sold for Portland cement and other purposes in 1921 and third in 1922.

In 1922 Iowa regained very nearly the ground she lost in 1921. The tonnage mined was somewhat less than that of 1920 —536,905 tons as compared with 571,895 in 1920, the largest figure so far attained in the history of the industry—but the tonnages sold for agriculture, for cement and as calcined products were all larger than during 1920. Owing, however, to somewhat lower prices per unit the values of all these items were somewhat lower than during the banner year 1920. Iowa also regained second place in total production as Ohio made but slight gain while as stated above Iowa made a gain which brought her back nearly to normal production.

The Iowana Gypsum Company began the construction of a mill near Fort Dodge in 1920 and put it in operation during the next year. This mill uses the method of making plastic gypsum which is described in Doctor Wilder's report on Gypsum in volume XXVIII of the reports of this Survey.

The Universal Gypsum Company was organized in Chicago in 1922 and has taken over the properties of the Iowana and the Plymouth Gypsum companies, both at Fort Dodge.

The following table gives the details regarding gypsum production in Iowa in 1921 and 1922.

Production of Gypsum in Iowa in 1921 and 1922.

	1921		1922	
	Tons	Value	Tons	Value
Crude gypsum mined	350,247		536,905	
Sold crude—				
to Portland cement mills	58,293	$135,727	80,452	$ 223,187
agricultural gypsum	26,364	98,311	45,062	136,451
Total sold crude	84,657	234,038	125,514	359,638
Sold calcined—				
as stucco	37,383	387,528	11,691	98,608
as mixed wall plaster	133,717	1,346,452	260,167	2,272,290
as paster of Paris, molding, casting, etc	1,369	15,041	3,263	33,341
as Keenes cement, dental plaster, etc	582	13,363	3,927	75,635
as plaster board and wall board	20,610	598,700	23,720	862,061
as tile and block	23,269	327,578	24,169	444,509
Total sold calcined	216,930	2,688,662	326,937	3,786,544
Total sold	301,587	2,922,700	452,451	4.146,182

The production of gypsum in different states is shown below.

Gypsum production by states.

STATE	1920 Sold crude	1920 Sold calcined	1920 Total Value	1921 Sold crude	1921 Sold calcined	1921 Total value
Iowa	$ 414,431	$ 4,008,534	$ 4,422,965	$ 234,038	$ 2,688,662	$ 2,922,700
Kansas	103,964	864,334	968,298	89,792	574,601	665,164
Michigan	268,968	3,252,060	3,521,028	369,185	2,942,911	3,312,096
Nevada	32,123	1,036.158	1,100,261	45,477	1,471,960	1,533,037
New York	987,503	5,451,426	6,438,929	694,518	5,715,703	6,410,221
Ohio	35,707	2,122,223	2,161,038	28,672	3,163,265	3,191,937
Oklahoma	64,019	772,749	816,768	242,382	1,046,844	1,289,226
Texas	47,961	1,391,382	1,439,491	33,068	1,732,463	1,765,600
Wyoming	125	410,599	410,724	1,298	222,960	224,258
Other states([a])	778,502	2,658,405	3,253,563	531,496	1,874,910	2,386,051
	2,565,195	21 967.870	24,533,065	2.265.011	21.434.279	23,700,290

STATE	1922 Sold crude	1922 Sold calcined	1922 Total value
Iowa	$ 359,638	$ 3,786,544	$ 4,146,182
Kansas	86,612	604,093	690,740
Michigan	291,295	2,551,822	2,843,117
Nevada	57,187	1.971,709	2,043,974
New York	851,385	7,955.981	8,807,366
Ohio	37,331	3,938,769	3,976,100
Oklahoma	118.997	1,532.825	1,651,837
Texas	50,791	2,030.688	2,081,479
Wyoming	14,016	290.546	304,562
Other states([a])	640.901	1,994,009	2,546,220
	2 443.346	26.917.805	29.361 151

([a]) 1920 and 1921: Alaska, Arizona, California, Colorado, Montana, New Mexico, Oregon, South Dakota, Utah and Virginia. 1922: same states with Arkansas in addition.

The total quantity of gypsum mined in the United States in 1921 was 2,890,784 tons and that mined in 1922 was 3,779,-949 tons. Sixty-two plants were reported as operating in 1921 and sixty-four in 1922. The amount sold without calcining for agricultural uses decreased from 104,966 tons, valued at $490,902, in 1921 to 101,904 tons, valued at $387,203, in 1922. During the same time the amount sold for cement and other purposes increased from 537,978 tons, valued at $1,775,109, to 668,821 tons, valued at $2,056,143. In both years New York was the chief contributor to the supply for cement mills and furnished nearly a third of the total.

SAND AND GRAVEL

The sand and gravel industry suffered a decline in 1921, although this decline was not so serious as was that in some other lines of the mineral industry. The greatest drop was in the amount and value of the sand used for building and in fact the amounts and values of paving sand and of gravel were larger in 1921 than in 1920. Lower prices prevailing in 1921 tended to reduce the increase in the values of these commodities below what it would have been otherwise. Most of Iowa's sand and gravel deposits occur as beds in the glacial drift or in the valleys of the larger streams. Such materials are by nature better fitted for the coarser uses than for finer ones such as glass making, molding, polishing and filter sands. However, some of these finer purposes are served by carefully selecting and preparing some of the finer and better grades of sand. Some sand and gravel is prepared by crushing and sizing, though most of that which is prepared is simply washed and sized.

The year 1922 witnessed a slight upward trend in some lines of the industry, notably those using gravel. There was a slight decline in the tonnage of both sand and gravel used in building but a large increase in the amount and value of gravel used for paving.

The following table will show the tonnage and value of the different kinds of sand and gravel produced during the past three years.

Production of sand and gravel in Iowa by uses.

CLASS	1920 Tons	1920 Value	1921 Tons	1921 Value	1922 Tons	1922 Value
Sand						
Molding	10,566	$ 13,254	13,132	$ 10,401	29,809	$ 32,613
Building	1,058,990	788,184	887,470	524,627	842,254	466,326
Grinding and polishing	....	3,248	3,403	2,454	6,225	6,961
Engine	27,334	16,366	37,042	24,443	59,778	27,568
Paving	205,893	152,337	288,163	160,478	286,303	146,030
Filter	41,084	28,130	16,465	9,339	12,255	4,682
Other	159,514	106,116	64,763	40,172	76,700	36,835
Total	1,503,381	1,108,635	1,310,438	770,914	1,313,324	721,015
Gravel						
Building	256,600	291,758	333,097	282,771	328,297	314,541
Roofing	16,677	26,202	10,390	13,893	....	....
Paving	499,072	521,360	595,229	548,576	757,329	629,549
Railroad	191,914	46,486	392,828	110,804	291,848	87,128
Total	964,263	885,806	1,331,544	956,044	1,377,474	1,031,218
Sand and gravel	2,467,644	1,993,441	2,641,982	1,726,958	2,690,798	1,752,233

No separate figures are given for roofing gravel in 1922 as these are included with those for building gravel. The production by counties so far as these figures can be made public, is given in the following table.

Production of sand and gravel in 1921.

COUNTY	Producers	Building sand	Paving sand	Other sand (a)	Gravel	Total	
						Tons	Value
Black Hawk	4	$ 17,916	....	(3)	*	55,833	31,416
Boone(1), Bremer(1), Butler(2)	4	2,470	....	(3)	*	25,002	11,465
Carroll(1), Cerro Gordo(1), Cherokee(2), Clay(2)	6	45,334	*	....	$ 184,511	469,757	232,497
Clayton(2), Clinton(4)	6	*	*	$12,587(1)(5)	19,523	37,779	33,436
Des Moines(2), Dickinson(1), Dubuque(2)	5	7,580	*	....	44,026	78,147	64,662
Emmet(1), Fayette(2), Floyd(2), Franklin(4)	9	7,703	*	(1)(5)	21,122	50,138	41,942
Fremont(1), Hardin(1), Harrison(1), Humboldt(1), Jackson(3)	7	29,098	$51,274	(4)(5)	120,888	209,057	201,936
Johnson(3), Kossuth(1), Lee(2)	6	22,590	*	....	*	52,167	26,005
Linn(3), Lyon(2), Mahaska(1)	6	58,276	*	(2)(4)	13,121	141,436	82,208
Marion(1), Marshall(2), Monroe(1)	4	10,726	*	(1)(3)	*	41,626	27,434
Muscatine	6	49,111	*	(2)(3)(4)(5)	102,739	204,299	177,107
O'Brien(2), Osceola(2), Palo Alto(2), Plymouth(3)	9	12,432	*	....	55,954	198,137	68,506
Polk	13	95,804	39,780	15,783(3)(4)(5)	145,429	423,300	296,796
Sac(2), Scott(2)	4	50,603	....	....	88,708	198,330	139,311
Sioux	6	47,827	Incl. in Grav.	....	64,676	173,716	112,503
Story(2), Wapello(3)	5	36,461	*	(1)(4)(5)	49,470	133,344	103,421
Webster(4), Winneshiek(1)	5	23,185	....	....	5,791	33,765	28,976
Woodbury(2), Wright(2)	4	*	*	(5)	20,503	116,157	52,337
Counties with less than 3 producers		6,000	69,424	57,439	28,583		
	109	524.627	160.478	85.809	956.046	2.641.982	1.726.958

* Included in: Counties with less than 3 producers.
(a) Includes: (1) molding, $10,401; (2) grinding and polishing, $2,454; (3) engine, $23,443; (4) filter, $9,339; (5) not specified, $40,172.

Production of sand and gravel in 1922.

COUNTY	Producers	Building sand	Paving sand	Other sand (a)	Gravel	Total	
						Tons	Value
Black Hawk(2), Boone(2)	4	$ 24,288	....	(3)	$ 81,140	172,501	$ 109,428
Butler (2), Cerro Gordo(1), Cherokee(2)	5	8,730	*	(3)(4)	176,643	437,899	207,950
Clay(1), Clayton(2), Clinton(5)	8	*	....	(1)(2)	21,125	61,128	57,749
Dallas(1), Des Moines(2), Dubuque(2)	5	8,280	$ 5,599	(5)	52,426	118,589	84,305
Emmet(2), Fayette(2), Floyd(1), Franklin(2)	7	18,250	*	(1)(5)	13,481	43,292	34,832
Fremont(1), Hardin(2), Harrison(1), Humboldt(1)	5	21,228	*	(3)(5)	42,126	105,010	70.945
Ida(1), Jackson(2), Johnson(3)	6	14,541	*	(3)(5)	25,778	81,027	56,414
Lee(2), Linn(5)	7	51,254	*	....	8,580	116,003	67,964
Lyon(2), Mahaska(1), Marion(1), Marshall(2)	6	29,058	*	(3)	30,007	105,003	68,640
Muscatine	5	52,529	*	(2)(3)(4)(5)	171,008	291,313	264,192
O'Brien(1), Osceola(2), Palo Alto(2), Plymouth(2)	7	5,610	*	....	19,884	53,695	26,286
Polk	15	66,215	41,405	$20,634(1)(3)(4)(5)	181,554	446,469	315,009
Sac(1), Scott(2), Sioux(6)	9	67,298	*	....	96,934	277,283	174,232
Story(2), Webster(2), Winneshiek(1)	5	12,750	....	....	11,767	86,157	24,517
Wapello	3	*	22,457	(1)(5)	35,477	116,917	87,590
Woodbury(2), Wright(3)	5	54,092	....	....	48,087	168,512	102,179
Counties with less than 3 producers		32,198	72,569	88,025			
	102	466,326	146,030	108,659	1,031,218	2,690,798	1.752.233

* Included in: Counties with less than 3 producers.
(a) Includes: (1) molding, $32,613; (2) grinding and polishing, $6,961; (3) engine, $27,568; (4) filter, $4,682; (5) not specified, $36,835.

Iowa occupied twelfth place among the states in production of sand and gravel in 1921 and tenth place in 1922. This speaks well for the development of the industry, especially in view of the fact that this is essentially an agricultural state with no very large cities. The following table may be presented as showing the comparative production in the leading states in 1921.

Leading states in the production of sand and gravel in 1921.

STATE	Total sand		Total gravel		Sand and gravel	
	Tons	Value	Tons	Value	Tons	Value
Pennsylvania	4,596,982	$ 5,674,633	2,043,352	$ 1,926,078	6,640,334	$7,600,711
Ohio	2,665,436	2,394,013	2,472,840	1,666,473	5,138,276	4,060,486
Illinois	3,343,996	2,346,236	3,115,696	1,670,570	6,459,692	4,016,806
New York	4,521,619	2,649,120	1,499,610	1,024,007	6,021,229	3,673,127
California	1,876,714	1,376,822	2,827,500	1,872,257	4,704,214	3,249,079
Michigan	1,848,784	995,894	3,666,469	2,019,402	5,515,253	3,015,296
Indiana	1,723,703	850,920	3,553,801	1,930,379	5,277,504	2,781,299
New Jersey	2,553,291	1,734,491	1,015,489	701,807	3,568,780	2,436,298
West Virginia	908,768	1,487,888	465,911	551,154	1,374,679	2,039,042
Texas	591,700	432,088	2,378,868	1,415,653	2,970,568	1,847,741
Wisconsin	1,308,967	743,746	1,590,842	1,039,432	2,899,809	1,783,178
Iowa	1,310,438	770,914	1,331,544	956,044	2,641,982	1,726,958
Total U. S.	38,294,954	29,148,329	41,550,054	27,434,295	79,845,008	56,582,624

The total production, including both sand and gravel, of these states in 1922 was as follows:

Leading states in production of sand and gravel in 1922.

STATE	Tons	Value
Pennsylvania	7,352,988	$ 7,413,686
Ohio	6,999,962	5,503,374
Illinois	8,840,293	5,411,821
New York	8,303,392	5,085,312
California	5,946,892	4,033,856
New Jersey	4,854,433	3,425,013
Michigan	5,962,916	3,222,043
Indiana	5,824,330	2,977,008
West Virginia	1,553,929	2,063,781
Wisconsin	3,433,996	1,957,624
Iowa	2,690,798	1,752,233
United States	94,867,046	64,617,664

It will be noticed that there is a wide range in the value per ton in different states. This is due in part at least to the different uses for which the material is intended. Pennsylvania's output in 1922, for example, is valued at over a dollar a ton. Over two million dollars worth of this output was used for glass making, molding, polishing and grinding. The glass sand sold for $1.86 per ton and the other grades here mentioned sold for over a dollar and a half per ton. Most of Iowa's output of both sand and gravel, on the other hand, was used for building and paving and these grades do not command nearly such high prices, only sixty-five cents per ton in this case. The average value per ton in the United States was sixty-eight cents.

STONE AND LIME

The production of stone and lime in Iowa amounted in 1921 to 423,279 tons with a value of $563,427. This was a decrease from the previous year's output of 207,386 tons and of $277,117. During 1922, however, the industry regained much of this lost ground, as the tonnage rose to 627,443 and the value to $719,-203, a gain of 204,164 in tonnage and of $155,776 in value. The tonnages of various classes of material produced during the two years were as follows:

Tonnages of stone and lime produced in Iowa.

USE	1921	1922
Building	2,470	5,560
Rubble and riprap	63,070	117,950
Concrete and road metal	299,890	417,550
Agriculture	31,090	59,720
Sugar factories	11,500	8,100
Lime, RR. ballast, flux	15,259	18,563
	423,279	627,443

Building stone is also computed in cubic feet, and in 1922 these amounted to 64,500, an average of 11.6 feet per ton.

The following table will show the production of stone and lime by counties in 1921 and 1922, so far as these may be given without revealing individual outputs.

Production of stone and lime in 1921.

COUNTY	Producers	Building	Rubble and riprap	Concrete and road metal	Agriculture	Other uses [a]	Total value
Allamakee(1), Black Hawk(1), Clayton(2), Clinton(2)	6	$2,880	*	$ 39,746	*	....	$ 48,696
Cerro Gordo	3	....	*	*	*	$17,400	18,860
Des Moines(1), Hardin(1), Henry(1) Jackson(2)	5	*	$21,400	33,454	*	*	77,472
Dubuque	4	*	7,017	*	*	*	62,855
Johnson(1) Linn(2)	3	....	....	45,000	*	*	48,175
Jones	4	....	20,520	6,547	$ 602	....	27,669
Lee	3	....	*	60,160	*	....	62,561
Madison (1), Marshall(1), Mitchell(1) Pocahontas(1)	4	*	....	45,708	*	*	51,051
Scott	4	....	17,273	120,774	18,641	9,400	166,088
Counties with less than three producers		2,246	5,816	28,524	6,822	54,497	
	36	4.126	72,026	379,913	26,065	81.297	563.427

* Included with: Counties less than 3 producers.
[a] Includes: stone sold to sugar factories, $22,400; lime, railroad ballast and flux, $58,897.

Stone and lime production in 1922.

COUNTY	Producers	Building stone	Rubble and riprap	Concrete and road metal	Agriculture	Other uses [a]	Total value
Allamakee(2), Cerro Gordo(2)	4	*	*	*	....	*	$ 39,635
Black Hawk	3	....	....	$ 50,854	Incl. in Concrete	....	50,854
Clayton(2), Clinton(1), Des Moines(1)	4	*	*	*	*	*	34,190
Dubuque	6	*	$19,341	34,978	*	*	89,168
Hardin(1), Jackson(1), Linn(2)	4	....	*	26,645	*	*	63,556
Johnson(1), Jones(2), Keokuk(1)	4	....	18,033	38,420	*	*	58,080
Madison(1), Marshall(1), Mitchell(2) Pocahontas(1)	5	....	....	39,744	*	*	42,624
Scott	4	....	43,324	184,301	$36,742	$12,271	276,638
Counties with less than three producers		$9,470	32,991	77,001	12,484	74,361	
	34	9,470	121,932	451,943	49,226	86,632	719.203

* Included under: Counties with less than 3 producers.
[a] Includes: Sandstone and lime sold, $62,047; stone sold to sugar factories, $11,670; railroad ballast and flux, $12,885.

Iowa's output of limestone does not place the state in a very high position among the producers of this material. In 1921 her rank was sixteenth in tonnage and eighteenth in value of output. The reasons for this situation are chiefly the very small amount of building stone produced and the further fact that Iowa is not so active in those lines of industry which make heavy demands on the limestone resources of some other states, especially ore smelting and certain manufacturies. Perhaps a comparison of the following table with those above which show production of stone in Iowa will make this clear.

Limestone sold in the United States, by uses.

USES	1921	1922
Building	$ 7,920,390	$12,418,873
Rubble	280,067	470,264
Riprap	1,003,399	925,760
Crushed	32,233,438	33,224,879
Flux	9,428,767	14,208,457
Sugar factories	1,019,288	634,511
Glass works	232,715	291,854
Paper mills	223,601	264,130
Agriculture	2,355,339	2,150,435
Other	3,053,590	3,808,764
Total	57,749,594	68,397,927

Crushed stone was used in 1922 as follows: for concrete and road metal $28,966,511; for railroad ballast $4,258,368. When we compare Iowa's output of $452,000 worth of stone used for concrete and road metal with the total used in the country it seems as if Iowa were scarcely contributing her share. The tonnage of limestone used in the United States for all purposes in 1921 and 1922 is shown below.

Limestone used for all purposes in the United States.

USE	Tons 1921	Tons 1922
Limestone as given in table above	45,621,000	58,928,660
Portland cement	24,400,000	30,070,000
Natural cement	90,000	148,000
Lime	5,060,000	7,280,000
	75,171,000	96,426,660

The amounts given above under cement and lime are included under those topics, hence they are not included in the total production of limestone.

The output of a few of the leading states in order of their importance is shown in the following table.

Leading states in production of limestone in 1922.

STATE	Building	Crushed	Flux	Agriculture	Total
Indiana	$11,352,690	$ 1,626,631	$ 53,095	$ 67,176	$13,203,146
Pennsylvania	50,709	3,506,610	5,569,056	339,761	9,848,290
Ohio	41,642	4,708,567	2,061,629	82,136	7,473,525
New York	101,663	5,277,871	162,570	211,292	6,512,291
Illinois	31,405	4,947,104	682,525	293,894	6,423,573
Michigan	....	695,805	2,390,692	211,192	4,533,998
Missouri	172,897	1,490,512	41,319	36,122	2,409,202
West Virginia	....	653,752	1,407,170	65,298	2,126,265
Kentucky	159,107	1,418,341	13,932	25,341	1,653,506
Virginia	....	1,169,987	36,688	53,485	1,527,430
Iowa	9,470	451,943	....	49,266	719,203
United States	12,418,873	33,224,879	14,208,457	2,150,435	68,397,927

As is suggested by this table, the leading states in production of limestone for building are Indiana, Missouri, Minnesota and Kentucky, in the order named. Minnesota's product was valused at $274,525. Other materials, chiefly crushed stone, brought the state's total production up to $583,467. Indiana owes her great preëminence to the deposits near Bedford and Bloomington, in Lawrence and Monroe counties.

There were only two operators producing lime in Iowa and these kept Iowa in twenty-ninth place by quantity and thirty-first by value. The lime sold at an average of $9.35 per ton. When all classes of stone are considered Iowa held thirty-second place among the states of the Union in 1922.

MINERAL WATERS

Three mineral springs were reported as being in use in 1921. The total sales from these amounted to 21,100 gallons valued at $2,105. In addition 122,632 gallons were used for making soft drinks.

In 1922 the sales were somewhat larger, amounting to 25,561 gallons, with a value of $3,788. The quantity used for soft drinks was 168,000 gallons. The average price for table and medicinal water was ten cents per gallon in 1921 and fifteen cents in 1922. The springs operating in 1921 were Fry's well at Colfax, Hawkeye Hygeia at Sioux City and Lime Rock at Dubuque. In addition to these the Grand Hotel of Colfax reported sales in 1922 and also stated that it operated a bathing establishment.

The mineral water industry is of considerable importance, taking the country over. In 1922 the value of water sold for medicinal and table use was $5,498,269. Wisconsin was the leading state, with a production valued at $2,120,669. The next state was New York, far in the rear with sales of $800,-831. Forty-three states reported sales during the year. The waters used for soft drinks amounted to 5,831,635 gallons. This is additional to the 38,492,881 gallons sold for medicinal and table use as discussed above.

NATURAL GAS

The production and use of natural gas from pockets in the glacial drift continued on a small scale as in previous years. The production reported in 1921 amounted to 700,000 cubic feet, with a value of $300. Six wells were productive.

During 1922 there was an estimated production of 460,000 feet with a value of $230. The active wells are in Louisa and Guthrie counties. Pockets of gas are frequently encountered in the course of well drilling. In some cases this gas is inflammable while in others it is not. In many cases the pockets are soon exhausted, but in a few instances the supply is continuous, as in the case of the wells here listed, which have been producing for many years. The wells are shallow, not much over a hundred feet deep, and some of them are being abandoned.

Attempts are continually being made to find petroleum in Iowa, but so far these have met with uniform failure. The chances are strongly against commercial production of oil in this state.

THE STRATIGRAPHY OF THE MISSISSIPPIAN FORMATIONS OF IOWA

BY

FRANCIS M. VAN TUYL

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THE STRATIGRAPHY OF THE MISSISSIPPIAN FORMATIONS OF IOWA

CHAPTER I

THE MISSISSIPPIAN SYSTEM IN IOWA

Introduction

As a result of the development of a coöperative plan of study and correlation of the Mississippian formations of the Mississippi Valley by the several state geological surveys of the area and the U. S. Geological Survey in 1913, the writer was requested by Doctor Kay of the Iowa Geological Survey to undertake a stratigraphic study and revision of these formations in Iowa under the direction of Professor Stuart Weller of the University of Chicago.

Field work was carried on during the summers of 1913, 1914, 1915 and 1917. In addition the months of October to June, 1914-1915, were spent at Walker Museum, The University of Chicago, in a study and identification of fossil collections made during the progress of the field investigations.

For encouragement and helpful suggestions the writer is indebted to both Doctor Kay and Professor Weller. Doctor A. O. Thomas of the State University of Iowa has kindly assembled and prepared the material for the plates illustrating typical Mississippian fossils.

Distribution and Importance

The Mississippian formations constitute the bed rock in a diagonal belt twenty to sixty miles wide extending from the southeastern corner of the state northwestward through the central and north-central parts into southern Minnesota. There are also a number of small patches and linear areas of these rocks to the west and southwest of this belt as a result of the erosion of the Pennsylvanian rocks by the larger streams. Drill records indicate their presence beneath younger deposits over the entire southern and southwestern parts of the state. There is evidence that they likewise formerly extended some distance northeast of the present belt of exposures as will be brought out on a later page.

Occasional small outliers of Pennsylvanian strata appear in the main Mississippian area.

The system is of considerable economic as well as scientific importance. It contains valuable deposits of clay, building stone, road material and cement rock. In addition it involves the type sections of several formations of the lower portion of the standard Mississippian column which are known the world over for their profusion of excellently preserved fossil remains.

Topography

The state of Iowa lies entirely in the Prairie Plains physiographic province. The elevation of the surface of the area in which the Mississippian formations are the highest consolidated rock ranges from a little more than 500 feet in the valley of Mississippi river below Keokuk in southeastern Iowa to about 1300 feet in the north-central part.

The Mississippian belt lies in the path of the continental glaciers and partakes of the characteristics of a glaciated region. In the southeastern and central parts of the state where the glacial deposits are of early Pleistocene age the topography is of the mature type. However, the relief is not great except adjacent to Mississippi river. Exposures of the consolidated rocks are numerous along the larger streams and their tributaries. In northern Iowa, on the other hand, the surface is underlain by glacial deposits belonging to the late Pleistocene. The topography is youthful and the relief slight. The drift is thicker and rock exposures are less common.

Drainage

The area in Iowa in which the Mississippian rocks are exposed lies entirely within the drainage basin of Mississippi river, which crosses the belt along the southeastern boundary of the state. The runoff is through four southeasterly trending tributaries of the "Father of Waters", namely: Cedar river, which parallels the Mississippian belt on the northeast; Iowa river, which crosses the belt in central Iowa; Skunk river, which crosses it in southeastern Iowa; and finally Des Moines river, which parallels the belt on the southwest. The postglacial drainage lines do not conform to the preglacial ones at many points along the stream courses. For this reason the distribution of outcrops along the valleys is often erratic. The more typical exposures are usually at those points where the streams have been diverted from their preglacial courses and have been compelled to cut new valleys through the drift and the indurated rocks below.

Character and General Relations

Relation to the Type Section.—The Mississippian succession was formerly regarded as a subdivision of the Carboniferous system, which was made to include the Mississippian at the base, the Pennsylvanian in the middle and the Permian at the top. At the present time there is a tendency to elevate each of these to the status of a distinct system.

The standard section of the Mississippian system is in the Mississippi valley, extending from southeastern Iowa into southern Illinois and southeastern Missouri.

Subdivisions.—The following classification of the Mississippian formations of the standard section, after Weller, incorporates several revisions necessitated by recent work and may be regarded as representing the latest word on the subject.[1,2]

All of the formational units of the Iowa Series are represented in Iowa. The type sections of the Burlington and Keokuk formations are at the cities of these names in southeastern Iowa, while the Warsaw beds derive their name from the town of Warsaw, Illinois, on the east bank of Mississippi river, nearly opposite Keokuk, Iowa. The Spergen, St. Louis and Ste. Genevieve formations are represented in Iowa by marginal deposits only.

None of the Chester formations is represented in the state, and it is probable that the Chester seas never extended this far north.

Thickness and Lithological Character.—The thickness and lithologic character of the formational units in southeastern Iowa, where the system attains its most complete development in the state, are indicated in the accompanying generalized

1 Illinois State Geol. Survey, Bull. 41, p. 80; 1920.
2 Jour. Geol., vol. XXVIII, p. 281; 1920.

Classification of the Mississippian Formations of the Missssissippi Valley (After Weller)

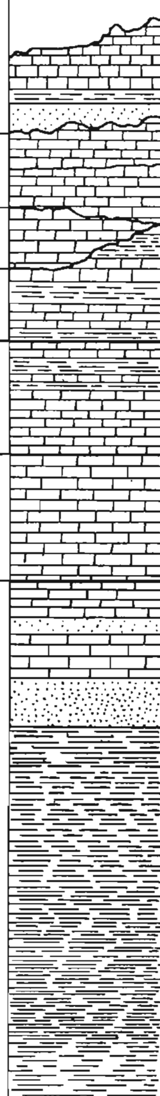
Mississippian	Chester Series	Upper Chester	Kinkaid Degonia Clore Palestine Menard Waltersburg Vienna Tar Springs
		Middle Chester	Glen Dean Hardinsburg Golconda Cypress
		Lower Chester	Paint Creek Yankeetown Renault Aux Vases
	Iowa Series	Meramec	Ste. Genevieve St. Louis Spergen Warsaw
		Osage	Keokuk Burlington
		Kinderhook	Various local formations in Mississippi Valley

columnar section (fig. 1). In central and north-central Iowa the character and succession of the formations is somewhat different as will be pointed out in later pages.

Stratigraphic Relations

The Mississippian system succeeds the Devonian in Iowa. Along the northeastern boundary of the belt of outcrops of Mississippian strata the Kinderhook is in contact with the Cedar Valley limestone except in western Butler, northeastern Franklin, southwestern Cerro Gordo, northeastern Hancock and southeastern Winnebago counties, where it rests upon the overlying Lime Creek shales. However, exposures showing the contact of the two systems are very rare, owing to the drift cover-ing and to the tendency of the basal Kinderhook shales to weather in such a way as to conceal the underlying strata.

The relation of the Mississippian system to the overlying



SYSTEM	GROUP	FORMATION	SECTION	THICKNESS (Feet)	LITHOLOGIC CHARACTER
MISSISSIPPIAN	MERAMEC	STE. GENEVIEVE (PELLA)		55	Fine-grained bluish sandstone at base succeeded by bluish shale. Fine-grained gray limestone above.
		ST. LOUIS		40-60	Fine-grained gray limestone chiefly. Lower division locally brownish and dolomitic. In places brecciated.
		SPERGEN (BELFAST)		0-35	Crinoidal limestone grading into arenaceous dolomite.
		WARSAW		20-65	Interbedded shales and gray fossiliferous limestone. Geodes in lower part.
	OSAGE	KEOKUK		63	Gray to bluish gray crinoidal limestone interbedded with shale in upper part. Cherty in lower part.
		BURLINGTON		71	Gray, crinoidal, cherty limestone interbedded with brownish fine-grained cherty magnesian limestone.
	KINDERHOOK	KINDERHOOK		300±	A thick body of shale in lower part succeeded by interbedded limestone and sandstone. A bed of oolitic limestone appears near the top.

FIG. 1.—Generalized columnar section of the Mississippian system in southeastern Iowa.

rocks is much more diversified, owing (1) to variation in the original distribution of the Mississippian formations, (2) to the profound erosion which followed the retreat of the Mississippian seas and preceded the Pennsylvanian transgression and (3) to the erosion which ensued between Pennsylvanian and Cretaceous time.

In southeastern Iowa and in Webster county the border of the main body of Pennsylvanian strata rests on the St. Louis and Pella formations but occasional outliers of the "Coal Measures" to the northeast rest on older beds ranging down to the Kinderhook. In central and north-central Iowa the Pennsylvanian beds are in contact with the Kinderhook almost everywhere along the boundary of the two systems except in Webster county as noted above, and in western Humboldt and western Kossuth counties, where the Cretaceous sediments succeed the Kinderhook.

The stratigraphic relations of the Mississippian formations among themselves are somewhat complex as a result of the oscillation of the strand line during deposition. The Burlington, Keokuk, Warsaw and Spergen formations are confined to the southeastern part of the state. The St. Louis limestone overlaps these deposits and rests directly upon the Kinderhook in

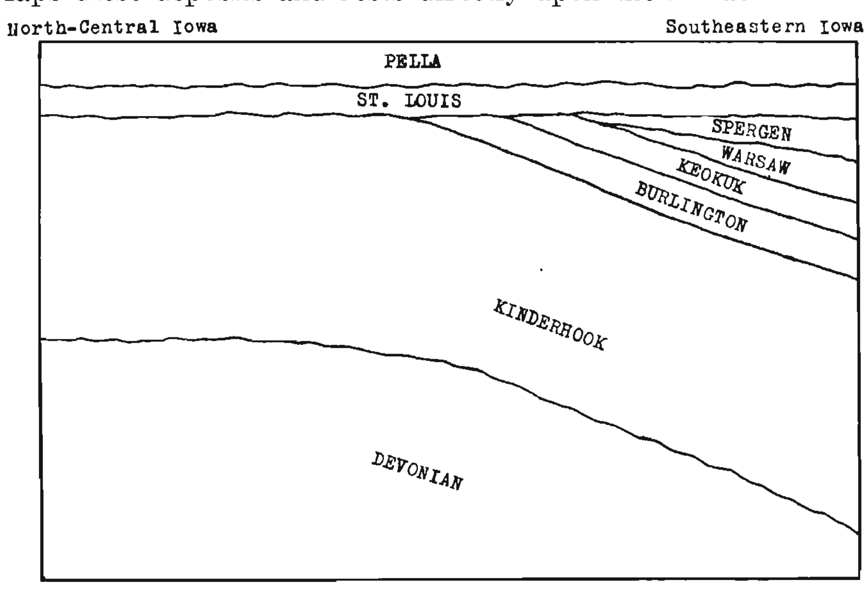


FIG. 2.—Showing stratigraphic relations of Mississippian formations in Iowa at the close of Ste. Genevieve time. The dip of the pre-St. Louis formations is exaggerated.

north-central Iowa. The Ste. Genevieve deposits extend to this section of the state also. In the Fort Dodge area they are found above the St. Louis rocks. The accompanying diagram (fig. 2) expresses the approximate stratigraphic relations of the formational units of the Mississippian of Iowa as they appeared at the close of Ste. Genevieve time.

Regional Structure

The diagonal belt in which the Mississippian formations are the highest consolidated rocks is on the flank of a large gently dipping geosyncline the axis of which plunges to the southwest through southwestern Iowa into northwestern Missouri and northeastern Kansas. The reader is referred to Norton's map[3] showing the elevation of the Saint Peter sandstone in Iowa, and to Van Tuyl's structure contour map[4] of the Western Interior geosyncline for details regarding the character and extent of this basin and its influence upon the distribution of the outcrops of the Paleozoic systems. The probable age of this basin and its influence on the present distribution of the Mississippian deposits is discussed on page 349 of this report.

Previous Work

Owen[5] was among the first geologists to study the formations in Iowa which are now referred to the Mississippian system. He grouped the beds into ten units chiefly upon the basis of their lithologic character. Several of these units correspond to formations recognized in the modern classification. He placed them in the Subcarboniferous period.

The foundation for all later work on the Mississippian of Iowa was laid by Hall,[6] whose classification and nomenclature of the formations, published in 1858, paved the way for succeeding investigations. The formations recognized by him in ascending order were as follows: Burlington limestone, Cherty limestone of Keokuk rapids, Keokuk limestone, Geode bed, Warsaw formation and the St. Louis limestone. The strata directly

3 Iowa Geol. Survey, vol. XXI (pocket): 1912.
4 Jour. Geology, vol. XXV, p. 152; 1917.
5 Rept. Geol. Survey Wisconsin, Iowa and Minnesota, p. 92; 1852.
6 Rept. Geol. Survey State of Iowa, vol. I, part I, pp. 46 and 92 ff.

below the Burlington limestone were regarded by him as Chemung in age. The Carboniferous age of these was later demonstrated by Meek and Worthen[7] who named them the Kinderhook beds because of their typical development near the town of that name in Illinois. White[8] later recognized the beds below the Burlington limestone at Burlington as Kinderhook and described other exposures of this group in central and northern Iowa. He also further enhanced our knowledge of the overlying formations. His classification differs from that of Hall in that he grouped the cherty limestone, Keokuk limestone and Geode bed all as Keokuk and the Warsaw formation and St. Louis limestone inclusive as St. Louis. Keyes' classification of 1893[9] recognizes three major divisions of the Mississippian in Iowa, namely: the Kinderhook, the Augusta and the St. Louis. The Augusta is made to include the Lower and Upper Burlington limestone, the Keokuk limestone, the Geode bed and the Warsaw shales and limestone.

The same author in the reports on the geology of Lee and Des Moines counties[10] contributed several new points on the stratigraphy of the formations in the southeastern part of the state. He designated the cherty limestones of Hall the Montrose cherts and again included all formations from the Burlington limestone to the base of the St. Louis in his Augusta series. The advisability of the use of this term, however, is questioned by Weller,[11] who points out that the name Osage as proposed by Williams[12] for deposits of the same age along Osage river in Missouri has priority.

In Gordon's report on the Geology of Van Buren county[13] the Montrose cherts of Keyes are referred to the Burlington, and the Keokuk limestone, Geode shales and Warsaw shales and limestones collectively to the Keokuk group. The overlying St. Louis is subdivided into arenaceo-magnesian beds at the base, brecciated limestone in the middle and compact and granular limestone at the top.

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7 Am. Jour. Sci., 2d series, vol. 32, p. 288; 1861.
8 Geol. of Iowa, vol. I, p. 192; 1870.
9 Iowa Geol. Survey, vol. I, p. 50.
10 Iowa Geol. Survey, vol. III, pp. 305-492; 1895.
11 Am. Geologist, vol. XXII, p. 12; 1898.
12 U.S. Geol. Survey Bull. 80, p. 169; 1891.
13 Iowa Geol. Survey, vol. IV, p. 206; 1895.

CLASSIFICATIONS OF MISSISSIPPIAN FORMATIONS OF IOWA

<table>
<tr><th>HALL 1858</th><th>WHITE 1870</th><th colspan="2">KEYES 1895</th><th colspan="2">GORDON 1895</th><th colspan="2">BAIN 1896</th><th colspan="2">PRESENT REPORT</th></tr>
<tr><td rowspan="3">St. Louis</td><td rowspan="5">St. Louis</td><td colspan="2" rowspan="3">St. Louis</td><td colspan="2" rowspan="4">St. Louis</td><td rowspan="3">St. Louis</td><td>Pella</td><td colspan="2">Ste. Genevieve (Pella)</td></tr>
<tr><td>Verdi</td><td rowspan="2">St. Louis</td><td>Upper (Verdi)</td></tr>
<tr><td>Springvale</td><td>Lower (Croton)</td></tr>
<tr><td rowspan="2">Warsaw</td><td rowspan="6">Augusta</td><td>Sonora</td><td colspan="2" rowspan="6">Augusta</td><td colspan="2">Spergen (Belfast)</td></tr>
<tr><td>Warsaw</td><td rowspan="3">Keokuk</td><td>Warsaw</td><td rowspan="2">Warsaw</td><td>Upper</td></tr>
<tr><td>Geode bed</td><td rowspan="3">Keokuk</td><td>Geode bed</td><td>Geode shales</td><td>Lower</td></tr>
<tr><td>Keokuk</td><td>Keokuk</td><td>Keokuk</td><td colspan="2" rowspan="2">Keokuk</td></tr>
<tr><td>Cherty limestone</td><td>Montrose chert</td><td colspan="2" rowspan="2">Burlington</td></tr>
<tr><td>Burlington</td><td>Burlington</td><td>Burlington</td><td colspan="2">Burlington</td></tr>
<tr><td>Chemung</td><td>Kinderhook</td><td colspan="2">Kinderhook</td><td colspan="2">Kinderhook</td><td colspan="2">Kinderhook</td><td colspan="2">Kinderhook</td></tr>
</table>

H. F. Bain, in his description of the geology of Keokuk[14] and Washington[15] counties adopted the Augusta series of Keyes for the Burlington and Keokuk limestones, which he believed to be incapable of differentiation in that part of the state. He subdivided the St. Louis of earlier workers into three units which he designated the Springvale at the base, the Verdi in the middle and the Pella at the top. Additional data regarding the Mississippian deposits of Iowa have appeared in numerous other county reports and in scientific articles published in many journals and proceedings of learned societies. Reference is made to the more important of these elsewhere in this volume.

On the accompanying chart an attempt is made to show the evolution of the present classification of the formations in Iowa.

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14 Iowa Geol. Survey, vol. IV, pp. 257-311; 1895.
15 Iowa Geol. Survey, vol. V, pp. 113-173; 1896.

CHAPTER II

THE KINDERHOOK GROUP

Definition

The name Kinderhook group was applied by Meek and Worthen[16] in 1861 to the strata between the black slate and the base of the Burlington limestone at Kinderhook, Pike county, Illinois. Similar beds at Burlington were referred to the same group. They regarded the Kinderhook as basal Carboniferous in age. Five years later Worthen [17] further defined the group and pointed out that the so-called "Chumung group" as described by Hall[18] at Burlington, Iowa, was of Kinderhook age.

In northeastern Missouri the group is represented by the following section, according to Weller:[19]

	FEET
Osage group	
4. Burlington limestone	
Kinderhook group	
3. Fine-grained, compact buff limestone	10-15
2. "Vermicular sandstone and shale" (Hannibal sandstone)	70
1. Compact blue-gray limestone with lithographic texture (Louisiana limestone)	60

He states[20] that " in central Missouri the entire Kinderhook is represented in the Chouteau limestone, about 100 feet in thickness".

In southwestern Missouri and in Jefferson county, twenty-five miles south of St. Louis, it exhibits still other variations. Weller remarks that "in no case can any formational unit be traced continuously throughout the entire basin".

Areal Distribution

The Kinderhook group is the bed rock over a larger area

16 Am. Jour. Sci., 2d series, vol. 32, p. 288.
17 Geol. Survey of Illinois, vol. I, pp. 108 ff.; 1866.
18 Rept. Geol. Survey Iowa, vol. I, part I, p. 90; 1858.
19 Monograph I, Illinois State Geol. Survey, p. 14; 1914.
20 Idem, p. 14.

than any other division of the Mississippian of Iowa. With the exception of a small outlier of shale in Muscatine county which may possibly be of this age the group forms the highest consolidated rock over a continuous belt extending from Lee county in the extreme southeastern corner of the state northeastward and thence northward along the valley of Mississippi river to Louisa county, from which area it runs northwestward in the form of a broad irregular band to the north-central part of the state and doubtless continues across the boundary into Minnesota. However, no outcrops of the formation appear north of Humboldt county, owing to the heavy drift cover in that direction.

This Kinderhook area is bordered on the northeast by Middle and Upper Devonian limestones and shales. On the southwest, however, the boundary is much more complicated, owing to the disconformable relationship of the Kinderhook with several younger formations. In southeastern Iowa it is bordered by the Burlington limestone, presumably as far northwest as Poweshiek county, although the exact extent of the latter formation to the northwest beneath the drift is unknown. From this point to Humboldt county the Pennsylvanian rocks form the southwest boundary. In Hardin and Grundy counties the Kinderhook belt is scarcely half its normal width, owing to a tongue-like extension of Pennsylvanian deposits to the northeast. Beginning in Humboldt county, Cretaceous deposits form the west boundary, the trend of which shifts from northwest to nearly due north and thence to northeast in Kossuth county near the north boundary of the state.

Lithologic Character

In southeastern Iowa the Kinderhook group is represented chiefly by clastic deposits with shale predominating over sandstone. Near and at the top of the group several limestone beds, one of which is oölitic, are present. The proportion of limestone in the upper part gradually increases to the northwest. In central Iowa there is a continuous bed of limestone more than sixty feet thick at the top of the series. In north-central Iowa there is an even greater development of limestone in the upper part of the formation with a corresponding reduction in thickness of the underlying clastic strata.

Thickness

The thickness of the Kinderhook in Iowa has been determined only by the study of deep well logs. The individual exposures are all of limited vertical and lateral extent and the strata are so gently tilted that traverses from contact to contact are not practicable.

At the city of Keokuk where the group is entirely beneath the surface its thickness is given by Norton[21] as 270 feet. In a deep well drilled at Burlington the upper limit of the group was not definitely determined but the full thickness is probably between 300 and 350 feet. A deep well at Mount Pleasant, in Henry county, passed through 360 feet of Kinderhook, according to Norton.[22]

A prospect hole at Marshalltown, in central Iowa, which started at the top of the Kinderhook, encountered the Devonian limestone at 320 feet. In the vicinity of Iowa Falls, in Hardin county, the total thickness, as determined by the study of surface exposures in conjunction with the log of a well, is about 300 feet. There is some evidence of a thinning of the group to the southwest of the outcrop belt. For example, Norton[23] gives its thickness as 125 feet at Pella, in Marion county, and as 160 feet at Des Moines, in Polk county.

Subdivisions

Owing to the lithologic and faunal variations in the Kinderhook beds in passing from southeastern Iowa to the north-central part of the state it is not possible to subdivide the group into formational units of more than local application.

In Lee, Des Moines and Louisa counties no formation names have been applied. The Washington county succession has been subdivided by Bain into the Maple Mill shale at the base, the English River gritstone in the middle and the Wassonville limestone at the top. Still farther northwest in Marshall county,

21 Iowa Geol. Survey, vol. XXI, p. 683; 1912.
22 Idem, p. 647.
23 Idem, pp. 970 and 893.

Beyer used the names LeGrand beds and Marshalltown shales for the upper exposed part of the group.

During the present investigation it was found advisable to subdivide the Kinderhook group of north-central Iowa into six distinct formations which, from the base upward, are designated the Sheffield shale, the Chapin beds, the Mayne Creek formation, the Eagle City beds, the Iowa Falls dolomite and the Alden limestone.

Stratigraphic Relations

The stratigraphic relations of the Kinderhook beds with the underlying Devonian deposits are not well understood since the contact is everywhere concealed except possibly in Muscatine county where dark shales of questionable age rest upon Cedar Valley limestone. However, the evidence points to the presence of a disconformity between the Devonian and Mississippian systems in Iowa. In the southeastern and central parts of the state the relation of basal Kinderhook and Cedar Valley outcrops is such as to indicate that these groups are in contact while in north-central Iowa the Kinderhook is known to rest upon the younger Lime Creek formations of the Devonian.

The formations in contact with the Kinderhook above are of variable age. In southeastern Iowa there appears to be a transition into the Burlington limestone but to the northwest where there is a pinching out of the Burlington, Keokuk, Warsaw and Spergen formations the Kinderhook is succeeded directly by the St. Louis limestone. As a result of the erosion of the overlying Mississippian deposits prior to the advance of the Lower Pennsylvanian seas deposits of Pennsylvanian age rest upon the Kinderhook in the form of occasional outliers in northeastern Washington county while for a considerable distance along the southwestern boundary of the Kinderhook in central and north-central Iowa the main body of the Pennsylvanian overlies the basal Mississippian deposits. At the northwestern extremity of the Mississippian belt the Dakota member of the Cretaceous system rests upon the Kinderhook beds.

Areal Description by Counties

GENERAL STATEMENT

Previous to the present investigation the Kinderhook beds have received careful study only in the southeastern part of the state, especially near the city of Burlington in Des Moines county. The character of the group to the northwest has been discussed in a general way in several county reports, but no detailed examination of the succession of beds has been made.

It is now known that the Kinderhook strata of north-central Iowa, central Iowa and southeastern Iowa are very different both lithologically and faunally. For this reason the areas are described separately.

KINDERHOOK OF SOUTHEASTERN IOWA

Lee County.—Regarding the Kinderhook of Lee county, Keyes[24] has this to say:

"Although this member of the Lower Carboniferous is such an important formation in Des Moines county, immediately to the north, and in northeastern Missouri to the south, it lies almost entirely below the river level in Lee. It has only been recognized in a single place on the Skunk river near the Chicago, Burlington and Kansas City railroad bridge over that stream."

Des Moines County.—The area over which the Kinderhook beds form the surface rock in Des Moines county is confined to the valley of Mississippi river and the lower courses of its larger tributaries in the eastern part of the county.

The most representative and complete section of the Kinderhook in this county as well as in the whole of southeastern Iowa is in the Mississippi river bluff at Burlington. The Prospect Hill exposure is especially favorable for field study. A review of the literature on the Kinderhook of this area is given by Weller[25] in his report on "The Succession of Fossil Faunas in the Kinderhook Beds at Burlington, Iowa." After a discussion of the descriptions of the strata by earlier investigators he adopted the following classification based upon the lithology and fossil content of the beds:

Section of Kinderhook beds at Burlington (After Weller)

		FEET
7.	Soft buff gritty limestone	3-5
6.	White oölitic limestone	2-4

24 Iowa Geol. Survey, vol. III, pp. 339.

25 Iowa Geol. Survey, vol. X, pp. 63-79; 1900.

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*; in some places associated with a thin oölite band	¼-¾
2.	Soft friable argillaceous sandstone, in some places harder and bluish in color, filled with fossils in the upper part, the most abundant of which is *Chonopectus fischeri*	25
1.	Soft blue argillaceous shale (exposed)	60

In the present investigation, Weller's subdivisions have been adopted without modification. A more detailed description of the beds at Prospect Hill than has hitherto been given follows:

Section of Kinderhook beds at Prospect Hill, Burlington

		FEET
7.	Limestone, soft, buff to brownish, dolomitic; with casts of fossils; grading up into the Lower Burlington limestone	5
6.	Limestone, white, oölitic, scaling off obliquely on weathered surfaces	3
5.	Sandstone, soft, fine-grained, drab weathering buff; shaly in upper part; some seams filled with casts of fossil shells; bearing occasional plant remains	6
4.	Limestone, upper one to two feet brownish and dolomitic. Lower layers consisting of dense gray lithographic-like limestone mottled with small patches of brownish dolomite which in some instances follow small fractures. Small calcite geodes occur in the dolomitic areas, and occasional small pockets of sphalerite appear in both the limestone and dolomite	10
3.	Limestone. Lower half coarse-grained and filled with *Chonetes*. Upper half oölitic. Upper surface very undulating, although there is a transition from the oölite into the limestone above. Contact with bed below in places irregular	2/3
2.	Sandstone, fine-grained, soft, drab weathering buff, massive; with occasional thin intercalated layers of shale; upper two feet filled with casts of fossils, most abundant of which is *Chonopectus fischeri*	22½
1.	Shale, bluish, argillaceous, locally calcareous, drab, sparsely fossiliferous, grading into the bed above. The greatest thickness of this bed is in the old clay pit, where nineteen feet is shown. Between the bed of the pit and the level of Mississippi river, about fourteen feet more is concealed. The total thickness of this member at Burlington, as indicated by deep borings, is probably not less than three hundred feet. Exposed	19

Almost continuous exposures of the Kinderhook beds appear in the Mississippi river bluff for more than two miles to the southwest of the above section, but owing to the fact that the dip of the beds is slightly greater than the gradient of the stream, only the uppermost beds are exposed. In the Albert Kirschner quarries at Picnic Point, two miles southwest of Prospect Hill, beds 6 and 7 outcrop in the lower part of the openings. Bed 7 is only three feet in thickness and is represented almost entirely by brownish crinoidal limestone.

The same beds are exposed at the base of the section in the

Kemper quarries one mile south of the last named locality (NW.1/4 sec. 29, T. 69 N., R. 2 W.).

Other outcrops of the Kinderhook occur north of Prospect Hill. In the Main Street cut at North Hill, in Burlington, the succession involves the same beds as at Prospect Hill.

Similar exposures appear along Flint river at Starr Cave (NW.1/4 sec. 19, T. 70 N., R. 2 W.) two miles northwest of Burlington. The section here involves all the beds from the lower sandstone (bed 2) to the lower part of the Upper Burlington limestone.

Fauna of the Kinderhook Beds at Burlington.

Our knowledge of the faunas of the individual beds of the Kinderhook at Burlington has been greatly enhanced through the efforts of Weller[26] to assign the species, which had been described from the group at this locality, to their respective stratigraphic horizons. The following faunal lists are his with occasional changes in nomenclature and with additions necessitated by the writer's studies. The additions are indicated by asterisks.

List of Fossils from bed 1 of the Kinderhook Group at Burlington

SPONGIAE—
Dictophyton sp. undet.

CRINOIDEA—
Crinoid stems

BRACHIOPODA—
Lingula sp. undet.
Orbiculoidea sp. undet.
Schizophoria sp. undet.
Rhipidomella sp. cf. R. burlingtonensis (Hall)
Productella sp. undet.
Productus ovatus Hall
Productus sp. undet.
Eumetria altirostris (White)

PELECYPODA—
Aviculopecten sp. undet.

GASTROPODA—
Platyschisma sp. undet.
Porcellia sp. undet.
Conularia sp. undet.

CEPHALOPODA—
Gomphoceras sp. undet.

CRUSTACEA—
Palaeopalaemon newberryi Whitf. ?

VERTEBRATA—
Coelacanthus welleri Eastman

PLANTS—
Fragments of stems and leaves

List of Fossils from bed 2 of the Kinderhook Group at Burlington

CRINOIDEA—
Joints of crinoid stems

VERMES—
Worm burrows

BRACHIOPODA—
Lingula membranacea Win.
Orbiculoidea capax (White)
Schellwienella inaequalis (Hall)
Chonetes illinoisensis Worthen

26 Idem, pp. 69 to 78.

Chonetes sp. cf. C. geniculatus White
Chonetes sp. undet.
Chonopectus fischeri (N. and P.)
Productus curtirostris Win.
Productus mesicostalis Weller
Productus cooperensis Swallow
Productus ovatus Hall
Productella nummularis (Win.)
Schizophoria sp.
Paryphorhynchus transversum Weller
Rhynchonella sp. undet.
Eumetria altirostris (White)
Composita ? corpulenta (Win.)
Spirifer subrotundus Hall
*Spirifer platynotus Weller
Spirifer biplicatus Hall
Syringothyris extenuatus (Hall)
Reticularia cooperensis (Swallow)

BRYOZOA—
Fenestella sp. undet.

PELECYPODA—
Aviculopecten tenuicostus Win.
Aviculopecten caroli Win.
*Aviculopecten sp.
Pterinopecten cf. P. laetus Hall
*Pernopecten cf. P. cooperensis (Shum.)
Pernopecten ? sp. undet.
Leiopteria spinalata (Win.)
Avicula strigosa (White)
Pteronites whitei (Win.)
Mytilarca occidentalis (W. and W.)
Mytilarca fibristriata (W. and W.)
Goniophora jennae (Win.)
Parallelodon cochlearis (Win.)
Parallelodon modesta (Win.)
Grammysia plena Hall
Grammysia amygdalinus (Win.)
Edmondia burlingtonensis (W. and W.)
Edmondia quadrata (W. and W.)
Edmondia aequimarginalis Win.
Edmondia nitida Win.
Edmondia jejunus (Win.)
Sphenotus rigidus (W. and W.)
Sphenotus bicarinatus (Win.)
Sphenotus iowensis (Win.)
Sphenotus bicostatus Weller
Spathella ventricosa (W. and W.)
*Nucula iowensis W. and W.
Cardiopsis megambonata Win.
Schizodus iowensis Weller
Schizodus burlingtonensis Weller
Cypricardinia sulcifera (Win.)
Glossites elliptica (Win.)
Glossites? burlingtonensis Weller
Promacrus cuneatus Hall
Posidonomya? ambigua Win.

GASTROPODA—
Loxonema shumardana (Win.)
Loxonema oligospira Win.
Loxonema sp. undet.
Murchisonia quadricincta Win.
Strophostylus bivolve (W. and W.)
Sphaerodoma pinguis (Win.)
Naticopsis depressa Win.
Straparollus macromphalus Win.
Straparollus ammon (W. and W.)
Straparollus angularis Weller
Platyschisma barrisi (Win.)
Platyschisma depressa Weller
Phanerotinus paradoxus Win.
Bellerophon bilabiatus W. and W.
Bellerophon vinculatus W. and W.
Bellerophon panneus White?
Bucanopsis deflectus Weller
Patellostium scriptiferus (White)
Porcellia crassinoda W. and W.
Porcellia obliquinoda White
Porcellia rectinoda Win.
Conularia byblis White

SCAPHOPODA—
Dentalium grandaevum Win.

CEPHALOPODA—
Orthoceras whitei Win.
Orthoceras heterocinctum Win.
Orthoceras indianense Hall
Phragmoceras expansum Win.
Cyrtoceras unicorne Win.
Agoniatites opimus (W. and W.)

The strongly Devonian aspect of this assemblage is commented upon by Weller.[27] All the genera of the pelecypods, for example, except two are represented in the Devonian faunas of eastern New York. The cephalopods also have Devonian affinities. The brachiopods, on the other hand, are chiefly Carboniferous types. Weller states that "the strongly Carboniferous element among the brachiopods in the Chonopectus sandstone, is to be considered as a weightier evidence than the holdover pelecypods and cephalopods."

27 Iowa Geol. Survey, vol. X, pp. 73, 74; 1900.

List of Fossils from bed 3 of the Kinderhook Group at Burlington

BRACHIOPODA—
*Schellwienella sp.
*Chonetes gregarius Weller
Chonetes cf. C. geniculata White
Chonopectus fischeri (N. and P.)
*Rhipidomella sp.
*Rhynchonella sp.
*Paryphorhynchus sp.
*Spirifer platynotus Weller
*Spirifer biplicatus Hall?
*Spirifer subrotundus Hall

PELECYPODA—
Aviculopecten iowensis Miller
*Pernopecten sp.
Parallelodon leptogaster (Win.)
*Schizodus sp.

GASTROPODA—
*Bellerophon sp.
*Straparollus sp.
Holopea subconica Win.
Holopella mira Win.

List of Fossils from bed 4 of the Kinderhook Group at Burlington

BRACHIOPODA—
*Chonetes sp.
*Chonetes sp.
Chonopectus fischeri (N. and P.)
Rhynchonella unica Win.
Rhynchopora pustulosa (White)
Paryphorhynchus striaticostatum (M. and W.)
Allorhynchus heteropsis (Win.)
*Allorhynchus sp.
Syringothyris halli Win.

PELECYPODA—
*Allorisma sp.
*Schizodus sp.

List of Fossils from bed 5 of the Kinderhook Group at Burlington

BRYOZOA—
*Ptilopora sp.

BRACHIOPODA—
Leptaena convexa Weller
Schellwienella inaequalis (Hall)
*Chonetes sp.
Productus arcuatus Hall
Productus parvulus Win.
*Productus blairi Miller
Pustula morbilliana (Win.)
Camarophorella lenticularis (W.andW.)
Cranaena ? allei (Win.)
Spirifer biplicoides Weller
*Spirifer platynotus Weller
Brachythyris peculiaris (Shum.)
*Syringothyris sp.
Reticularia cooperensis (Swallow)
Cyrtina acutirostris (Shum.) ?

PELECYPODA—
Pterinopecten nodocostus (W. and W.)
Pernopecten cooperensis (Shum.)
*Lithophaga cf. L. minuta Weller
Parallelodon parvus (W. and W.)
Edmondia nuptialis Win.
Edmondia strigillata Win.
Sphenotus cylindricus (Win.)
Spathella phaselia Win.
Nucula iowensis W. and W.
Palaeoneilo microdonta (Win.)
Palaeoneilo barrisi (W. and W.)
Leda saccata (Win.)
Dexiobia ovata (Hall)
Dexiobia halli Win.
Schizodus trigonalis (Win.)
*Cypricardinia sulcifera (Win.)

GASTROPODA—
Straparollus angularis Weller
Straparollus sp. undet.
Bellerophon sp. undet.
Bucanopsis perelegans (W. and W.)

SCAPHOPODA—
Dentalium grandaevum Win.

VERTEBRATA—
*Fish teeth.

List of Fossils from bed 6 of the Kinderhook Group at Burlington

ANTHOZOA—
Zaphrentis sp. undet.

BRACHIOPODA—
Leptaena convexa Weller
Schellwienella inflata (W. and W.)
*Schellwienella planumbona Weller
*Schellwienella inaequalis (Hall)
*Schellwienella crenulicostata Weller
Chonetes logani N. and P.
*Chonetes burlingtonensis Weller
Chonetes illinoisensis Worthen
*Chonetes sp.
Productus arcuatus Hall
*Productus ovatus Hall
Productella concentrica (Hall)

*Rhipidomella thiemei (White)
*Schizophoria subelliptica (W. and W.)
Cranaena ? allei (Win.)
Spirifer platynotus Weller
*Spirifer biplicoides Weller
*Cliothyridina hirsuta (Hall) ?
Athyris crassicardinalis White

PELECYPODA—
*Pernopecten cooperensis (Shum.)
Pernopecten circulus (Hall)
Conocardium pulchellum W. and W.

GASTROPODA—
Straparollus obtusus (Hall)
Pleurotomaria quinquesulcata Win.
Loxonema sp. undet.
Capulus sp. undet.

CEPHALOPODA—
Orthoceras indianensis Hall
Gyroceras burlingtonensis Owen

CRUSTACEA—
*Griffithides ? sp.

List of Fossils from bed 7 of the Kinderhook Group at Burlington

ANTHOZOA—
*Zaphrentis sp.
*Syringopora sp.
Leptopora typa Win.

CRINOIDEA—
*Several undetermined species

BRYOZOA—
*Cystodictya sp.
*Fenestella sp.
*Ptilopora sp.

BRACHIOPODA—
*Leptaena convexa Weller
Schellwienella inflata (W. and W.) ?
Schellwienella inaequalis (Hall)
*Schellwienella sp.
*Chonetes multicosta Win.
*Chonetes logani N. and P.
*Chonetes illinoisensis Worthen
*Chonetes sp.
Productella concentrica (Hall)
*Productus sampsoni Weller
*Productus sp.
*Rhipidomella thiemei (White)
*Rhynchotetra caput-testudinis (White)
Rhynchopora persinuata (Win.)
*Dielasma burlingtonensis (White) ?
Spiriferina solidirostris White
*Spirifer cf. S. mundulus Rowley
*Spirifer grimesi Hall
*Spirifer forbesi N. and P.
*Spirifer platynotus Weller
*Syringothyris sp.
*Reticularia cooperensis (Swallow)
Nucleospira barrisi White
*Cliothyridina glenparkensis Weller ?

GASTROPODA—
Pleurotomaria mississippiensis W.andW.
*Strophostylus bivolve (W. and W.)
Bellerophon panneus White
Igoceras undata (Win.)
Capulus paralius W. and W.
Capulus vomerium (Win.)

The vertical range of the Kinderhook species at Burlington is indicated in the following table:

Table Showing Range of Species in Kinderhook Beds at Burlington

	Horizons						
	1	2	3	4	5	6	7
SPONGIAE							
Dictophyton sp. undet	x						
ANTHOZOA							
Zaphrentis sp. undet						x	
Zaphrentis sp							x
Syringopora sp							x
Leptopora typa Win							x

Table Showing Range of Species in Kinderhook Beds at Burlington—Continued.

	Horizons						
	1	2	3	4	5	6	7
Bryozoa							
Fenestella sp. undet		x					
Fenestella sp.							x
Ptilopora sp					x		
Ptilopora sp							x
Cystodictya sp							x
Brachiopoda							
Lingula membranacea Win		x					
Lingula sp. undet	x						
Orbiculoidea capax (White)		x					
Orbiculoidea sp. undet	x						
Leptaena convexa Weller					x	x	x
Schellwienella inaequalis (Hall)		x			x	x	x
Schellwienella inflata (W. and W.)						x	x?
Schellwienella planumbona Weller						x	
Schellwienella crenulicostata Weller						x	
Schellwienella sp			x				
Schellwienella sp							x
Chonetes illinoisensis Worthen		x				x	x
Chonetes cf. C. geniculatus White		x	x				
Chonetes gregarius Weller			x				
Chonetes burlingtonensis Weller						x	
Chonetes logani N. and P.						x	x
Chonetes multicosta Win							x
Chonetes sp. undet		x					
Chonetes sp					x		
Chonetes sp							x
Chonetes sp				x			
Chonetes sp				x			
Chonetes sp						x	
Chonopectus fischeri (N. and P.)		x	x	x			
Productella nummularis (Win.)		x					
Productella concentrica (Hall)						x	x
Productella sp. undet	x						
Productus curtirostris Win		x					
Productus cooperensis Swallow		x					
Productus ovatus Hall	x	x				x	
Productus mesicostalis Weller		x					
Productus arcuatus Hall					x	x	
Productus blairi Miller					x		
Productus parvulus Win					x		
Productus sampsoni Weller							x
Productus sp							x
Productus sp	x						
Pustula morbilliana (Win.)					x		
Rhipidomella thiemei (White)						x	x
Rhipidomella cf. R. burlingtonensis Hall	x						
Rhipidomella sp			x				
Schizophoria subelliptica (W. and W.)						x	
Schizophoria sp		x					
Schizophoria sp. undet	x						
Paryphorhynchus transversum Weller		x					

Table Showing Range of Species in Kinderhook Beds at Burlington—Continued.

	Horizons						
	1	2	3	4	5	6	7
Paryphorhynchus striatocostatum (M. and W.)				x			
Paryphorhynchus sp			x				
Rhynchonella unica Win				x			
Rhynchonella sp			x				
Rhynchonella sp. undet		x					
Allorhynchus heteropsis (Win.)				x			
Allorhynchus sp				x			
Rhynchotetra caput-testudinis (White)							x
Rhynchopora persinuata (Win.)							x
Rhynchopora pustulosa (White)				x			
Dielasma burlingtonensis (White) ?							x
Cranaena ? allei (Win.)					x	x	
Cyrtina acutirostris (Shum.) ?					x		
Spiriferina solidirostris White							x
Spirifer platynotus Weller		x	x		x	x	x
Spirifer subrotundus Hall		x	x				
Spirifer biplicatus Hall		x	x?				
Spirifer grimesi Hall							x
Spirifer biplicoides Weller					x	x	
Spirifer forbesi N. and P.							x
Spirifer cf. S. mundulus Rowley							x
Brachythyris peculiaris (Shum.)					x		
Syringothyris halli Win				x			
Syringothyris extenuatus (Hall)		x					
Syringothyris sp					x		
Syringothyris sp							x
Reticularia cooperensis (Swallow)		x			x		x
Eumetria altirostris (White)	x	x					
Nucleospira barrisi White							x
Camarophorella lenticularis (W. and W.)					x		
Athyris crassicardinalis White						x	
Cliothyridina glenparkensis Weller ?							x
Cliothyridina hirsuta (Hall) ?						x	
Composita (?) corpulenta (Win.)		x					
PELECYPODA							
Promacrus cuneatus Hall		x					
Glossites elliptica (Win.)		x					
Glossites ? burlingtonensis Weller		x					
Edmondia burlingtonensis W. and W.		x					
Edmondia quadrata (W. and W.)		x					
Edmondia aequimarginalis Win		x					
Edmondia nitida Win		x					
Edmondia jejunus (Win.)		x					
Edmondia nuptialis Win					x		
Edmondia strigillata Win					x		
Sphenotus cylindricus (Win.)					x		
Sphenotus bicostatus Weller		x					
Sphenotus ventricosa (W. and W.)		x					
Sphenotus rigidus (W. and W.)		x					
Sphenotus bicarinatus (Win.)		x					
Sphenotus iowensis (Win.)		x					
Spathella ventricosa W. and W		x					
Spathella phaselia Win					x		
Grammysia plena Hall		x					
Grammysia amygdalinus (Win.)		x					

Table Showing Range of Species in Kinderhook Beds at Burlington—Continued.

	Horizons						
	1	2	3	4	5	6	7
Cardiopsis megambonata Win		x					
Nucula iowensis W. and W.		x			x		
Palaeoneilo microdonta (Win.)					x		
Palaeoneilo barrisi (W. and W.)					x		
Leda saccata (Win.)					x		
Dexiobia halli Win					x		
Dexiobia ovata (Hall)					x		
Parallelodon cochlearis (Win.)		x					
Parallelodon modesta (Win.)		x					
Parallelodon leptogaster (Win.)			x				
Parallelodon parvus (W. and W.)					x		
Mytilarca occidentalis (W. and W.)		x					
Mytilarca fibristriata (W. and W.)		x					
Conocardium pulchellum W. and W.						x	
Avicula strigosa (White)		x					
Pteronites whitei (Win.)		x					
Leiopteria spinalata (Win.)		x					
Posidonomya ? ambigua Win		x					
Schizodus iowensis Weller		x					
Schizodus burlingtonensis Weller		x					
Schizodus trigonalis (Win.)					x		
Schizodus sp.			x				
Schizodus sp.				x			
Aviculopecten tenuicostus Win		x					
Aviculopecten caroli Win		x					
Aviculopecten iowensis Miller			x				
Aviculopecten sp. undet	x						
Aviculopecten sp.		x					
Pterinopecten cf. P. laetus Hall		x					
Pterinopecten nodocostus (W. and W.)					x		
Pernopecten cf. P. cooperensis (Shum.)		x					
Pernopecten cooperensis (Shum.)					x	x	
Pernopecten circulus (Hall)						x	
Pernopecten ? sp. undet		x					
Pernopecten sp.			x				
Goniophora jennae (Win.)		x					
Lithophaga cf. L. minuta Weller					x		
Allorisma sp.				x			
Cypricardinia sulcifera (Win.)		x			x		
SCAPHOPODA							
Dentalium grandaevum Win		x			x		
GASTROPODA							
Pleurotomaria quinquesulcata Win						x	
Pleurotomaria mississippiensis W. and W.							x
Porcellia crassinoda W. and W.		x					
Porcellia obliquinoda White		x					
Porcellia rectinoda Win		x					
Porcellia sp. undet	x						
Murchisonia quadricincta Win		x					
Bellerophon bilabiatus W. and W.		x					
Bellerophon vinculatus W. and W.		x					

Table Showing Range of Species in Kinderhook Beds at Burlington—**Continued.**

	Horizons						
	1	2	3	4	5	6	7
Bellerophon panneus White ?		x					x
Bellerophon sp.			x				
Bellerophon sp. undet.					x		
Bucanopsis deflectus Weller		x					
Bucanopsis perelegans (W. and W.)					x		
Patellostium scriptiferus (White)		x					
Straparollus macromphalus Win.		x					
Straparollus ammon (W. and W.)		x					
Straparollus angularis Weller		x			x		
Straparollus obtusus (Hall)						x	
Straparollus sp. undet.					x		
Straparollus sp.			x				
Platychisma barrisi (Win.)		x					
Platychisma depressa Weller		x					
Platychisma sp. undet.	x						
Phanerotinus paradoxus Win.		x					
Naticopsis depressa Win.		x					
Loxonema shumardana (Win.)		x					
Loxonema oligospira Win.		x					
Loxonema sp. undet.		x					
Loxonema sp. undet.						x	
Holopea subconica Win.			x				
Holopella mira Win.			x				
Igoceras undata (Win.)							x
Capulus paralius W. and W.							x
Capulus vomerium (Win.)							x
Capulus sp. undet.						x	
Strophostylus bivolve (W. and W.)		x					x
Sphaerodoma pinguis (Win.)		x					
Conularia byblis White		x					
Conularia sp. undet.	x						
CEPHALOPODA							
Orthoceras whitei Win.		x					
Orthoceras heterocinctum Win.		x					
Orthoceras indianense Hall		x				x	
Gomphoceras sp.	x						
Phragmoceras expansum Win.		x					
Cyrtoceras unicorne Win.		x					
Gyroceras burlingtonensis Owen						x	
Agoniatites opimus (W. and W.)		x					
CRUSTACEA							
Griffithides ? sp.						x	
Palaeopalaemon newberryi Whitf. ?	x						
VERTEBRATA							
Coelacanthus welleri Eastman	x						
PLANTS							
Fragments of stems and leaves	x	x		x			

It will be observed that the Upper Kinderhook beds carry a typical Mississippian fauna, the Devonian aspect which characterizes the collections from the lower beds being entirely lost. The appearance of such forms as *Spirifer grimesi* and *Spirifer forbesi* in the topmost bed of the Kinderhook together with the lithologic character of this member at Burlington suggests a transition into the limestone of the Lower Burlington. Such a relationship is indicated also by the field relations of the two formations. Attention is called to the Chouteau affinities of the fossils of beds 6 and 7 of the Kinderhook beds at Burlington.

Louisa County.—In this county the Kinderhook succession is much the same as at Burlington, but some of the individual members of the series are more attenuated.

The best and most complete section exposed in the county is described by J. A. Udden[28] in his report on the geology of the county. This appears "in and near Anderson's Quarry on the east bank of Smith creek, west of the center of the SW. 1/4 of sec. 29, Tp. 73 N., R. 2 W." The succession there as revised by the writer is as follows:

Section at Anderson quarry.

	FEET	INCHES
8. Drift	5	
BURLINGTON.		
7. Limestone, brownish and dolomitic below, but gray and crinoidal above	28	6
KINDERHOOK.		
6. Limestone, yellowish to brownish, dolomitic; with geodic cavities lined with calcite	6	
5. Limestone, light gray, oölitic	3	
4. Sandstone, ash-colored, fine-grained	3	
3. Limestone, irregularly bedded, brownish, dolomitic	3	6
2. Sandstone, ash-gray, fine-grained	9	6
1. Shale, bluish, argillaceous; progressively more calcareous below; with a carbonaceous seam about eight inches thick near the middle. Exposed in the east bank of the creek about forty rods north of the quarry	20	

The fauna of the Kinderhook beds at this locality is listed below:

Fauna of the Kinderhook Beds, Anderson Quarry Section.

	Horizons					
	1	2	3	4	5	6
BRACHIOPODA						
Lingula sp.	x					

28 Iowa Geol. Survey, vol. XI, p. 74; 1901.

Fauna of the Kinderhook Beds, Anderson Quarry Section—Continued.

	Horizons					
	1	2	3	4	5	6
Orthotetes ? sp.		x				
Chonetes geniculatus White		x				
Chonetes sp.		x				
Chonetes sp.		x		x	x	
Chonetes sp.					x	
Chonopectus fischeri (N. and P.)		x				
Productella sp.		x				
Productus cf. P. curtirostris Win.		x				
Productus ovatus Hall		x				
Productus arcuatus Hall				x		
Productus blairi Miller				x		
Productus sp.	x					
Productus sp.				x		
Rhipidomella thiemei (White)				x	x	
Schizophoria sp.		x		x		
Rhynchonella sp.	x	x				
Paryphorhynchus transversum Weller		x				
Spirifer biplicatus Hall		x				
Spirifer biplicoides Weller				x		
Spirifer platynotus Weller					x	
Spirifer subrotundus Hall		x				
Spirifer sp.				x		
Brachythyris burlingtonensis Weller				x		
Reticularia cooperensis (Swallow)				x		
Ambocoelia parva Weller				x		
Nucleospira barrisi White				x		
Composita ? corpulenta (Winchell)		x				
PELECYPODA						
Edmondia cf. E. nuptialis Win.				x		
Edmondia nitida Win.				x		
Sphenotus iowensis (Win.)		x				
Sphenotus sp.				x		
Grammysia plena Hall		x				
Nucula iowensis W. and W.				x		
Leda saccata (Win.)				x		
Parallelodon parvus W and W.				x		
Schizodus trigonalis (Win.)				x		
Pernopecten cooperensis (Shum.)		x		x		
SCAPHOPODA						
Dentalium grandaevum Win.				x		
GASTROPODA						
Bellerophon sp.				x		
Straparollus sp.				x	x	
Strophostylus sp.				x		
Orthonychia sp.				x		
VERTEBRATA						
Fish teeth				x		

In the Anderson quarry section, bed 1 is equivalent to the shale member (bed 1) at Burlington. Bed 2 is the attenuated equivalent of the Chonopectus sandstone (bed 2) and bed 3 is a thin dolomitic facies of bed 4. The thin limestone (bed 3) at Burlington is absent in Louisa county. The oölitic limestone (bed 6) and the overlying buff limestone (bed 7) at Burlington are equivalent to beds 5 and 6 in the above section.

The higher beds of the Kinderhook are again well exposed in the east bank of Smith creek near the bridge in the NW. 1/4 of sec. 31, T. 73 N., R. 2 W. The section given below is slightly modified after Udden.[29]

Section of Kinderhook beds, Smith creek.

		FEET
BURLINGTON.		
9.	Limestone, brownish, crinoidal, bearing *Lobocrinus pyriformis*, a *Pentremites* and *Productus burlingtonensis*	8
8.	Chert	1
7.	Limestone, buff, dolomitic, irregularly bedded; with casts of crinoid stems	5
6.	Limestone, soft, gray weathering yellowish; with fragments of crinoid stems	3
5.	Limestone, gray, crinoidal; with seams of brownish dolomitic limestone; more irregularly bedded and cherty below	10
KINDERHOOK.		
4.	Limestone, brownish, soft, dolomitic, in two ledges, each three feet in thickness	6
3.	Limestone, light gray, oölitic	2½
2.	Sandstone, bluish, fine-grained, with a thin seam of shale near the middle	3½
1.	Limestone, dark gray, fine-grained, imperfectly dolomitized, exposed	1½

The fauna of the Kinderhook beds in this section follows:

Fauna of Kinderhook Beds, in Bank of Smith Creek.

	Horizons			
	1	2	3	4
ANTHOZOA				
Zaphrentis sp.	----	----	x	----
Syringopora sp.	----	----	x	----
BRACHIOPODA				
Leptaena convexa Weller	----	x	----	----
Schellwienella planumbona Weller ?	----	----	x	----
Schellwienella inflata (W. and W.)	----	----	x	----
Schellwienella sp.	----	x	----	----

29 Iowa Geol. Survey, vol. XI, p. 74; 1901.

Fauna of Kinderhook Beds, Smith Creek, Louisa County—Continued

	Horizons			
	1	2	3	4
Streptorhynchus ? sp.	x			
Orthotetes ? sp.	x			
Chonetes logani N. and P.			x	x
Chonetes burlingtonensis Weller				x
Chonetes multicosta Win.				x
Chonetes sp.			x	
Chonetes sp.	x			
Chonetes sp.				x
Productus parvulus Win.		x		
Productus arcuatus Hall				x
Productus sp.				x
Productus sp.		x		
Rhipidomella thiemei (White)			x	
Rhipidomella sp.		x	x	
Schizophoria sp.		x		
Allorhynchus heteropsis (Win.)	x			
Rhynchotetra caput-testudinis (White)				x
Rhynchopora pustulosa (White)	x			
Spiriferina solidirostris (White)				x
Spirifer platynotus Weller		x	x	
Spirifer biplicoides Weller		x		x
Brachythyris sp.		x		
Nucleospira barrisi White		x		
Athyris crassicardinalis White			x	
PELECYPODA				
Cypricardinia sulcifera (Win.)		x		
Worthenia mississippiensis W. and W.		x		
Palaeoneilo barrisi (W. and W.)		x		
Nucula iowensis W. and W.		x		
Edmondia equimarginalis Win.		x		
SCAPHOPODA				
Dentalium grandaevum Win.		x		
GASTROPODA				
Bucanopsis perelegans (W. and W.)		x		
Bellerophon sp.		x		
Murchisonia quadricincta Win.		x		
Straparollus obtusus (Hall)		x	x	
Straparollus sp.		x		
CEPHALOPODA				
Orthoceras indianense Hall		x	x	
Orthoceras sp.		x	x	
TRILOBITA				
Phillipsia ? sp.				x

Several other exposures of the Kinderhook in Louisa county have been described by J. A. Udden.[30] The location and description of these are taken from his report.

Sections in the Bluffs and Creeks North and East of Morning Sun

Section on the first creek in the Mississippi bluffs north of the county line southwest of Oakville, in the SW. ¼ of sec. 35, T. 73 N., R. 2 W. (After Udden.)

		FEET
BURLINGTON.		
11.	Disintegrated crinoidal limestone	6
10.	Chert	1
9.	Disintegrated crinoidal limestone	3
8.	Blue shale	1
7.	Hard white crinoidal limestone with chert in upper layers	8
6.	Beds grading from a disintegrated yellow shaly residue below to a somewhat crumbling crinoidal limestone with much chert above	20
KINDERHOOK.		
5.	Yellow magnesian limestone with irregular bedding above and occasional quartzose concretions	7
4.	Oölitic yellow or brown fossiliferous disintegrated limestone	2
3.	Fine sandstone, like number 1	1½
2.	Compact dark gray limestone, somewhat weathered, showing small cavities and veins filled with calcite	3
1.	Bluish white fine sandstone, weathering yellow, with casts of gastropods and lamellibranchs	8

Section on the Mississippi river bluffs on the second creek north of the county line in the east half of sec. 34, T. 73 N., R. 2 W. (After Udden).

		FEET
BURLINGTON.		
15.	Blue shaly beds, weathering yellow, with some calcareous and cherty bands above	15?
14.	Concealed	?
13.	Chert	1
12.	Brown limestone and chert	2½
11.	Brown limestone, disintegrated	1
10.	Bluish shaly material, with quartz geodes below	2
9.	White crinoidal limestone, with quartz geodes in a shaly seam near base	8
8.	Concealed	?
7.	White crinoidal limestone	4
6.	Concealed	?
5.	Hard white and yellow crinoidal limestone, moderately fine-grained, with layers of chert	10
KINDERHOOK.		
4.	Yellow rather fine-grained dolomitic crinoidal limestone, broken with many joints in upper part	10
3.	Oölitic limestone with *Spirifer marionensis*, *Productella concentrica*, *Spirifer* (undescr. sp.), *Athyris* sp., *Zaphrentis* sp., and *Orthoceras* sp.	3
2.	Yellow or rusty brownish weathered compact limestone, with arenaceous rock above	5
1.	Bluish fine sandstone, weathering yellow, with teeth of *Helodus* and casts of brachiopods in upper part. *Syringothyris extenuatus* occurs near the top of the lowest member; also *Spirifer biplicatus* and *Productus* sp.	9

30 Geology of Louisa County, Iowa Geol. Survey, vol. XI, pp. 72-82; 1901.

Beds 1, 2, 3, and the lower portion of 4 of this section are to be referred to the Kinderhook. All above belong to the Lower Burlington.

Section in a creek one mile southeast of Elrick Junction in the south part of sec. 29, T. 73 N., R. 2 W. (After Udden).

KINDERHOOK.	FEET
5. Yellow limestone, exhibiting oölitic structure below	10
4. Blue evenly bedded argillaceous sandstone	2
3. Fine-grained, concretionary yellow or brown limestone, disintegrated	4
2. Soft fine-grained sandstone, with *Helodus* teeth at base	2½
1. Blue soft sandy material, with wavy yellow stained bands containing *Chonopectus fischeri*, above	6

Section on the east bank of a railroad cut at the edge of the upland, three miles north of Morning Sun (After Udden).

KINDERHOOK.	FEET
5. Disintegrated brownish magnesian limestone with *Athyris incrassatus* and *Chonetes illinoisensis*	3
4. Yellow weathered fine sandstone, with *Edmondia burlingtonensis, Spirifer biplicatus, Chonopectus fischeri, Paryphorhynchus striatocostatum* (var), *Orthotetes inaequalis ?, Chonetes* sp., *Fenestella* sp.	3
3. Fine blue sandstone, with few fossils	10
2. Fine-grained blue sandstone, with casts of *Productus laevicostatus, Productus cooperensis, Athyris corpulenta, Orthotetes inaequalis ?,* and other lamellibranchs in abundance	2
1. Blue shale	1

Kinderhook Sections in Long Creek Basin

"Following Long creek west we find bed rock for the first time near the east line of sec. 13, Tp. 74 N., R. 5 W. From this point the exposures are almost continuous along the south fork for two miles, but have a limited vertical range. The Kinderhook beds gradually disappear under the overlying limestones. The Buffington fork is rocky a mile from its mouth, and has a few scattered exposures farther west. The north or main branch runs through a valley in which the Burlington limestone is frequently exposed in the bluffs or on the small tributaries. But with few exceptions these rocky cliffs are less than twenty feet in height."

Section on a small tributary of Long creek, south of the center of the SE. ¼ of sec. 13, T. 74 N., R. 5 W. (After Udden).

KINDERHOOK.	FEET
4. Brownish gray compact siliceous rock, possibly changed locally from a dolomitic limestone by infiltration	8
3. Not exposed	2
2. Blue soft fine sandstone, with *Orthotetes inaequalis, Chonopectus fischeri, Aviculopecten caroli, Productus levicostus, Rhipidomella*	

	burlingtonensis, Macrodon cochlearis, Orthoceras whitei, Conularia (micronema ?), Edmondia sp.	4
1.	Soft shale (seen farther east)	?

Section in the west bluff of Long creek, south of the center of the NW. ¼ of sec. 13, T. 74 N., R. 5 W. (After Udden).

KINDERHOOK.		FEET
5.	Irregularly bedded, compact brown or gray dolomite; some brachiopods with a few crinoid fragments	10
4.	Rather harder than that below, brown earthy stone	2
3.	Soft rather uniform bluish gray, light colored fine sandstone, with lamellibranchs and teeth of *Helodus* near top	5
2.	Alternating layers of fine loose sandstone	5
1.	Green clayey shale	3

Section on the west bank of Long creek one-fourth mile south of the mouth of Johnny creek, near the center of the south line of sec. 12, T. 74, R. 5 W. (After Udden).

KINDERHOOK.		FEET
5.	Gray compact limestone	8
4.	Concealed	13
3.	Brownish gray gritty rock	3
2.	Blue soft fine sandstone, with casts of *Bellerophon bilabiatus, Straparollus macromphalus, Spirifer subrotundatus, Orthoceras whitei, Glossites elliptica, Straparollus* sp., *Modiomorpha ?* sp., *Bellerophon* (two species)	3
1.	Blue arenaceous soft rock, with shale below	12

Sections on Clifton Creek and Iowa River

"North of Long creek basin the drift rapidly increases in thickness and the bed rock is rarely exposed. It has been observed only in sections 22 and 27, Tp. 75 N., R. V. W., and in and near the bluffs of the Iowa river in sections 16 and 17, Tp. 76 N., R. V. W. At this latter place the blue Kinderhook shale is exposed in the bank of the river, rising some five or six feet above the water for a distance of a few rods. It is covered by the shale and sandstone of the coal measures. Over most of this northern territory the Burlington limestone has been removed and the unprotected Kinderhook beds have been deeply eroded."

Section in a tributary of Clifton creek in the NE. ¼ of the NE. ¼ of sec. 27, T. 75 N., R. 5 W. (After Udden).

		FEET
7.	Crinoidal fossiliferous limestone, with chert seams (exposed farther up in the creek)	10
6.	Concealed	4 ?
5.	Chert of oölitic aspect, and with fragments of fossils	¼
4.	Yellow decayed limestone, with sparse crinoid joints	2
3.	Chert of oölitic appearance, and containing small fragments of fossils	½
2.	Yellow disintegrated limestone, with scattered joints of crinoids, a *Productus,* and various gastropods	½
1.	Bluish gray arenaceous rock, with fish teeth near the top and	

various gastropods; also *Athyris corpulenta, Productus curtirostra, Productella nummularis, Orthoceras inaequalis, Edmondia burlingtonensis, Eumetria altirostris, Porcellia obliquinoda, Grammysia plena, Bellerophon* (undescr ?) and a *Platyschisma* 4

Correlation of the Kinderhook Beds of Louisa County

Only the upper portion of the basal shale is exposed in this county though the lower beds have been penetrated by the drill at several localities. Its total thickness is reported to be as much as 180 feet. The sandstone bed above, which is correlated with the *Chonopectus* sandstone of the Kinderhook beds at Burlington, is very similar in character to the equivalent bed at Burlington and bears essentially the same fossils, though its thickness is less than half as great.

Bed 3 of the Burlington section has not been recognized in any of the Kinderhook exposures of Louisa county. This is not surprising since it has a thickness of only eight inches at Burlington.

Beds 4 and 5 of the Kinderhook at Burlington are present in Louisa county but are more attenuated and less typically developed. For example, the lithographic limestone (bed 4), which is ten feet thick at Burlington, is represented in this area by only three and one-half feet of brownish dolomitic limestone.

The oölitic limestone and the overlying brownish dolomitic limestone of the Louisa county sections are easily identified as beds 6 and 7 of the Burlington section. They have essentially the same development in the two areas.

Muscatine County.—No strata of Kinderhook age are known positively to exist in Muscatine county. However, the Sweetland Creek beds of Udden[31] which were referred by him to the Upper Devonian may possibly be an outlier of the basal Kinderhook as suggested by Weller.[32] This deposit consists of interbedded dark shale, green shale and argillaceous magnesian limestone with a maximum thickness of about forty-eight feet. It is disconformable with Cedar Valley limestone of Devonian age below and with Pennsylvanian sandstone above.

Udden[33] lists the following fossils from the Sweetland Creek beds:

31 Iowa Geol. Survey, vol. IX, pp. 289-303; 1898.
32 Jour. Geol., vol. XVII, pp. 273, 274; 1909.
33 Iowa Geol. Survey, vol. IX, p. 302; 1898.

Lingula cf. melie Hall
Lingula cf. nuda Hall
Lingula subspatulata M. and W. ?
Lingula sp. undet.
Gastropod
Spathiocaris emersoni Clarke
Solenocaris strigata Meek?
Ptyctodus calceolus M. and W.
Rhynchodus cf. excavatus Newb.
Synthetodus
Impressions of plants.

Weller[34] calls attention to the fact that *Ptyctodus calceolus* occurs in beds known to be basal Kinderhook at several localities in Missouri and that a *Spathiocaris* is represented both in the Upper Devonian black shale of southern Illinois and in a basal Kinderhook shale in southwestern Missouri. Further study of the Sweetland Creek beds by Dr. A. O. Thomas and the writer failed to bring to light additional species sufficiently diagnostic to fix the age of the formation more definitely. The problem is the more difficult because there are no known exposures of the basal Kinderhook in southeastern Iowa which can be compared with the Sweetland Creek beds.

Washington County.—The area underlain by the Kinderhook in Washington county is confined to its northeastern and extreme northern parts. The best exposures appear in the valley of English river, though occasional small outcrops occur along the tributaries of this stream and on Goose creek and Whiskey run.

Probably the most complete section of the Kinderhook in this county is the exposure at Maple Mill on the south bank of English river, a short distance south of the center of section 8 of Lime Creek township. This has been described by Bain[35] as follows:

Section of Kinderhook beds at Maple Mill (After Bain).

		FEET
4.	Limestone, ferruginous, arenaceous in places, fine-grained, red, containing numerous casts of fossils, and with thin chert layers two to eight inches thick, also fossiliferous	10
3.	Sandstone, or gritstone, very fine-grained, white to buff, very fossiliferous	18
2.	Limestone, fine-grained, non-fossiliferous	1/6
1.	Shale, argillaceous, dark blue to drab, almost black in places	12

The writer's section of the Kinderhook at Maple Mill differs only in detail from that of Bain.

34 Jour. Geol., vol. XVII, pp. 273, 274; 1909.
35 Geology of Washington County, Iowa Geol. Survey, vol. V, p. 127; 1896.

Revised section of Kinderhook beds at Maple Mill.

		FEET	INCHES
7.	Drift	2	
6.	Limestone, yellowish, dolomitic; speckled with darker patches in lower part; massive; with occasional bands of darker chert	16	
5.	Limestone, brownish, speckled, tough, dolomitic; of a darker color than bed above; in some places showing indications of obscure oölitic texture	2	4
4.	Sandstone, ash-colored, fine-grained, shaly in middle part; grading gradually upward into the bed above	2	
3.	Limestone, brownish to reddish; dense and tough when fresh but weathering to soft thin layers. No recognizable fossils found	1	8
2.	Sandstone, ash-colored, fine-grained, soft, with molds and casts of fossils	13	
1.	Concealed to level of river	13	6

It will be noted that beds 1 and 2 of Bain's section are now concealed and that his bed number 3 is divided into three members (beds 2, 3, and 4) in the writer's section. The shale exposed at the time of Bain's visit was correlated by him with the basal shale (bed 1) of the Kinderhook section at Burlington, although he was not able to secure fossils to substantiate this correlation. This division of the Kinderhook has been designated by Bain the Maple Mill shale from the fact that it is well developed at this locality. He reports[36] that the same shale outcrops along the bank of English river southeast of Kalona (Tp. 77 N., R. 7 W., sec. 16) where it has an exposed thickness of twelve feet.

The sandstone member of Bain's section (bed 3) was named by him, the English River gritstone, and was regarded as the equivalent of the *Chonopectus* sandstone which occupies a similar position above the basal shale at Burlington. The fauna of this member has been studied by Weller.[37] In correlating it with the beds at Burlington he says:

"This fauna of the English River Grit is essentially that of the *Chonopectus* bed at Burlington, but with certain modifications. *Chonopectus fischeri,* although present in the fauna, is not one of the most abundant species; in fact, although most of the species at Maple Mill can be identified with Burlington forms, many of those that are common at Burlington are rare on English river, and vice versa, rare species at Burlington are in several instances more common on English river."

The writer has little to add to the above correlations further

36 Op. cit., p. 133.
37 Jour. Geol., vol. 13, pp. 617 ff.; 1905.

than to suggest that the *Chonopectus* sandstone of Burlington is represented only by the lower thirteen feet of Bain's bed 3, corresponding to bed 2 of the revised section. Following this interpretation, the thin dolomitic limestone member (bed 3) and the sandstone above (bed 4), represent the attenuated representatives of the "Lithographic limestone" (bed 4) and the upper sandstone (bed 5) of the Burlington section. The marked thinning of these beds in Louisa county is in conformity with this view. It must be admitted, however, that the faunas of the uppermost beds are not sufficient to make this correlation certain.

The fauna of bed 2 of the revised section at Maple Mill is as follows:

List of fossils from bed 2, Maple Mill section, Washington county.

VERMES—
- Scalarituba missouriensis Weller

BRACHIOPODA—
- Schellwienella ? sp.
- Chonetes sp.
- Chonopectus fischeri (N. and P.)
- Productella nummularis (Win.)
- Productella concentrica (Hall)
- Productus mesicostalis Weller
- Productus ovatus Hall
- Productus arcuatus Hall
- Productus curtirostris Win.
- Schizophoria sp.
- Paryphorhynchus transversum Weller
- Allorhynchus heteropsis (Win.) ?
- Spirifer biplicatus Hall
- Spirifer maplensis Weller
- Syringothyris extenuatus (Hall)
- Eumetria altirostris (White)
- Composita ? corpulenta (Win.)

PELECYPODA—
- Edmondia jejunis (Win.) ?
- Sphenotus iowensis (Win.)
- Sphenotus sp.
- Grammysia plena Hall
- Grammysia amygdalinus (Win.)
- Palaeoneilo microdonta (Win.)
- Parallelodon cochlearis (Win.)
- Mytilarca occidentalis (W. and W.)
- Pteronites whitei (Win.)
- Leiopteria spinalata (Win.)
- Leiopteria sp.
- Aviculopecten (two species)
- Pernopecten cooperensis (Shum.)
- Goniophora jennae (Win.)

SCAPHOPODA—
- Dentalium grandaevum Win.

GASTROPODA—
- Porcellia obliquinoda White
- Murchisonia sp.
- Bellerophon bilabiatus W. and W.
- Bellerophon vinculatus W. and W.
- Bellerophon sp.
- Euphemus sp.
- Straparollus ammon (W. and W.)
- Straparollus sp.
- Platyschisma barrisi (Win.)
- Naticopsis depressus Win.
- Strophostylus bivolve (W. and W.) ?

CEPHALOPODA—
- Orthoceras whitei Win.
- Orthoceras heterocinctum Win.
- Phragmoceras expansum Win.

TRILOBITA—
- Phillipsia ? sp.

The brownish dolomitic limestone (bed 3) has not yielded fossils sufficiently well preserved to be specifically identified, but a few species have been collected from the fine sandstone of bed 4 above. These are listed below.

List of fossils from bed 4, Maple Mill section, Washington county.

BRACHIOPODA—
- Schellwienella ? sp.
- Chonetes.
- Schizophoria chouteauensis Weller ?
- Spirifer platynotus Weller
- Syringothyris ? sp.
- Reticularia cooperensis (Swallow)
- Nucleospira barrisi White

PELECYPODA—
- Pernopecten cooperensis (Shum.)

The brownish dolomitic limestone capping the section at Maple Mill represented by bed 4 of Bain's section and bed 6 of the revised one is the topmost member of the Kinderhook in Washington county. This member attains its typical development at the old Wassonville mill one and one-half miles west of the above described exposure. Hence the name Wassonville limestone as applied by Bain.[38]

Section at Wassonville Mill.

		FEET	INCHES
15.	Drift	1	
14.	Shale, brownish, dolomitic, much weathered	2	
13.	Limestone, soft, yellowish, dolomitic; showing fine, close stratification on weathered surface; bearing a few silicified fragments of crinoid stems	5	6
12.	Chert, white, nonfossiliferous; in the form of lenses and nodules		3
11.	Limestone, buff, dolomitic, thin-bedded	6	
10.	Band of soft white fossiliferous chert nodules		3
9.	Limestone, massive, yellowish, dolomitic	3	6
8.	Band of soft white fossiliferous chert nodules		3
7.	Limestone, massive, yellowish, dolomitic	7	6
6.	Band of white fossiliferous chert nodules		3
5.	Limestone, soft, massive, yellowish, dolomitic	5	2
4.	Limestone, soft, massive, brownish, dolomitic	2	6
3.	Limestone, tough, brownish, dolomitic, weathering into thin, nodular layers	2	
2.	Sandstone, ash-colored, fine-grained; exposed	4	8
1.	Concealed to level of water in river	5	3

Beds 5 to 15 of the above section are exposed in a quarry back of the mill, while beds 1 to 4 are shown in the river bank just below. The dolomitic limestone layers are nearly barren of identifiable fossils, but certain of the nodular chert bands, especially beds 8 and 10, contain many excellently preserved specimens. The following fossils were collected from the cherts:

List of fossils from beds 8 and 10 of Wassonville Mill section, Washington county.

BRACHIOPODA—
- Schellwienella crenulicostata Weller
- Chonetes logani N. and P.
- Chonetes multicosta Win.
- Productus arcuatus Hall
- Camarotoechia chouteauensis Weller ?
- Spiriferina solidirostris White
- Spirifer platynotus Weller

PELECYPODA—
- Sphenotus cylindricus (Win.) ?
- Leda sp.
- Parallelodon parvus (W. and W.)

38 Iowa Geol. Survey, vol. V, p. 134; 1896.

Aviculopecten sp.
Pelecypods (several undetermined species)

SCAPHOPODA—
Dentalium grandaevum Win.

GASTROPODA—
Bellerophon sp.
Bucanopsis sp.
Straparollus sp.
Gastropods (several undetermined species)

CEPHALOPODA—
Orthoceras sp.

Another excellent exposure of the Wassonville limestone is shown in an abandoned quarry on the opposite side of the river at the head of the big bend (Tp. 77 N., R. 8 W., sec. 6, SE.1/4). The succession of beds at this place is indicated below.

Section of Wassonville limestone at the head of the big bend.

		FEET	INCHES
8.	Drift	3	
7.	Limestone, brownish, dolomitic, soft	9	6
6.	Chert, in the form of a band of nodules		4
5.	Limestone, brownish yellow, dolomitic, massive	7	
4.	Chert, in the form of a band of nodules		3
3.	Limestone, yellowish, massive, dolomitic	5	6
2.	Chert, in the form of a discontinuous band, slightly coarser-grained than that in the beds above		2
1.	Limestone, yellowish to brownish, massive, soft, dolomitic; bearing a few poorly preserved fossils similar to those in the chert just above. Exposed	2	

The Wassonville limestone is again well exposed in an abandoned railway quarry three miles northeast of Wellman. Bain[39] describes this section as follows:

"In the old Burlington, Cedar Rapids and Northern railway quarry (Tp. 77 N., R. 8 W. Sec. 16) the limestone layers are exposed twenty feet thick, with the base twenty feet above the bridge on Smith creek. The stone is of the usual earthy magnesian character, and runs in ledges two to four feet thick, separated by thin layers of chert. The Augusta (Burlington) is reported to occur immediately above the top of the quarry, though it is not now exposed".

The contact relations of the Wassonville limestone with the overlying Burlington limestone are not certainly known, since no section showing the actual contact of the two formations is now exposed in the region. Bain[40] refers to a possible contact section on Smith creek as follows:

"Southeast of Wellman the creek soon cuts through the Augusta into the Kinderhook. In section 19 (Tp. 77 N., R. 8

39 Op. cit., p. 133.
40 Op. cit., p. 133.

W.) the latter was encountered in the base of a quarry on a level with the stream''.

At the time of the writer's visit in the summer of 1915, this section was no longer exposed.

The correlation of the Wassonville limestone with the Kinderhook at Burlington is attended with some difficulty, owing in part to lack of lithologic similarity and in part to faunal differences. Thus, we have at least thirty-five feet of yellowish cherty dolomite at the top of the Kinderhook in this region, while at Burlington the only bed which resembles this lithologically is a zone five feet in thickness at the very top of the section (bed 7). Again, there are many undescribed species of pelecypods and gastropods in the Wassonville limestone which have not been found in the uppermost Kinderhook beds at Burlington. Upon the basis of the brachiopod faunas of the two regions, however, it is possible to say with a reasonable degree of certainty that the Wassonville represents beds 6 and 7, and possibly part of bed 5, of the Burlington section. All of the brachiopods of the Wassonville, with the exception of *Spirifer platynotus,* which ranges from bed 2 to bed 7, at Burlington, are confined to the three uppermost beds at the latter locality.

The marked thinning of the lower members of the Kinderhook is continued from Louisa county into Washington. The extent of the attenuation of the basal shale in this region is not known, but evidently it is considerable, for a deep boring at Sigourney in Keokuk county, which borders Washington on the west, shows this member to be only 198 feet thick as compared to a thickness of 300 feet at Burlington. The sandstone above this (English River gritstone) is only a little more than one-half as thick as at Burlington, and the limestone and sandstone beds directly above are much less than one-half as thick as their probable equivalents in the latter region.

The higher members of the Kinderhook, on the other hand, are distinctly thicker in Washington county than the beds of the same horizon both in Louisa county and at Burlington. It is safe to say that the Wassonville limestone is represented by not more than ten to twelve feet of strata at Burlington. A thickening of the higher limestone beds, which carry a Chouteau fauna, and a thinning of the lower clastic ones is a persistent feature of the Kinderhook as it is traced from southeastern Iowa northwestward to the northern part of the state.

The belt of Kinderhook rocks extending northwest from Washington county does not appear again at the surface, except for a small exposure in Iowa county, until Marshall and Tama counties are reached.

Poweshiek County.—With reference to the Kinderhook of Poweshiek county Stookey[41] says:

"No rocks of this stage appear at the surface in Poweshiek county. All that area where they form the country rock is covered to a depth of from two hundred to four hundred feet with glacial deposits, through which the streams have nowhere cut. All that is positively known of rocks of this age in this county is obtained from the meager records of wells that have been sunk here and there into the rocks.

The Grinnell wells show a body of limestone and shale more than three hundred fifty feet in thickness next below the drift that is regarded as chiefly representing this stage. Wells in the vicinity of Brooklyn penetrate similar deposits. In the northwest quarter of section 12, Bear Creek township, the Talbott and Thompson well shows the following as reported by W. W. Shannon of Brooklyn:

	FEET
Pleistocene deposits	355
Shale	175
Limestone and shale (water)	76

In section 16, Bear Creek township, on the Newkirk farm the well is reported as follows:

	FEET
Yellow and blue clay	350
'Soapstone'	75
Limestone, honeycombed	125

The nearest surface exposure of Kinderhook rocks to the east is at Amana in Iowa county, near the Iowa river. Along the same river in Marshall and Tama counties to the north exposures are found that have been described in detail in the reports by Beyer and Savage. It is not possible to map accurately the limits of this terrane in Poweshiek county, but it is safe to say that the area to the north and east of the divide between the Iowa river basin and that of the North Skunk has as its country rock the Kinderhook deposits."

41 Iowa Geol. Survey, vol. XX, pp. 254, 255.

Iowa County.—The Kinderhook of Iowa county is described by Stookey[42] as follows:

"At Amana in the bank of Price creek is an exposure of limestone, the only one within the limits of the county. The area of exposure is limited to one or two square rods. The rock is brown to buff in color, irregularly and thinly bedded, and cherty. Both the chert and limestone are fossiliferous. *Spirifer biplicatus* and two or three species of *Productus* are among the fossils. This is the only exposure of Kinderhook rocks in Iowa county. The discovery of rocks of this age so far to the eastward is a matter of surprise, and carries the margin of the Kinderhook terrane much farther to the northeastward than was believed to be the case. It is a general law of outcrop in Iowa that the margins of the terranes run in a northwest-southeast direction. It seems a proper inference that the rocks underlying the drift to the west and south belong to the Kinderhook stage.

Everywhere in the central and northwestern parts of the county the glacial deposits overlie a dark shale of considerable thickness, evidently the upper member of the Kinderhook stage. This deposit is referred to by well drillers as 'soapstone', and is dreaded by them as it is barren of water, and often, according to their reports, as much as three hundred feet in thickness. In the southwest part of Benton county the drill strikes the same shale, though its thickness is not so great in that county."

Jasper County.—Referring to the Kinderhook beds in this county, Williams[43] says:

"In Jasper county the area underlain by the Kinderhook rocks cannot be definitely outlined as these materials are deeply buried beneath the glacial deposits. The area outlined as Kinderhook on the map is determined by projecting the line of the strike from outcrops in Marshall county."

KINDERHOOK OF CENTRAL IOWA

General statement.—The area underlain by the Kinderhook in this section of the state comprises roughly the eastern half of Marshall county, the whole of Tama county, with the exception of a small triangular area in the extreme northeast corner which is underlain by the Devonian and the southwestern two-

[42] Iowa Geol. Survey, vol. XX, p. 167.
[43] Iowa Geol. Survey, vol. XV, p. 309.

thirds of Grundy county, excepting a small area of Pennsylvanian in the western part.

The Kinderhook of this area shows a marked variation both lithologically and faunally from the series as it is developed elsewhere in the state, and this has rendered difficult the exact correlation of the beds. Owen,[44] as a result of his study of the formations, referred the beds in question to the Subcarboniferous. Still later Whitney[45] described the deposits in this part of the state and referred them to the Carboniferous upon the basis of their fauna. In his Geology of Iowa, Volume II, page 312; 1870, White describes the exposures near LeGrand and refers the beds to the Kinderhook formation. Wachsmuth and Springer[46] later devoted some space to the strata in this area in connection with their description of the numerous species of crinoids and blastoids from LeGrand, Iowa.

More recent reports on the area are Beyer's Geology of Marshall county[47] and Savage's Geology of Tama county.[48]

The lower beds of the Kinderhook formation are not exposed in central Iowa, though we have some knowledge of their character as a result of Norton's description of the cuttings of a deep well at Marshalltown which was published by Beyer.[49]

The upper portion of the record is as follows:

	FEET
Limestone, light gray, in fine sand, with many angular fragments of limpid quartz at 68 feet	70
Limestone, light yellow, compact, earthy lustre, three samples	45
Limestone, brown, crystalline, cherty at 115 feet	30
Shale, soft, light green, calcareous	175
Limestone ? no samples (Devonian)	145

It will be observed that the beds above the limestone identified as Devonian are composed of 175 feet of shale, overlain by 145 feet of limestone. The shale beds were referred provisionally by Beyer to the basal Kinderhook and the writer has no reason to question this correlation. The overlying limestones belong to the formations designated as the LeGrand beds by Beyer because of their exposure in the quarries near the town

44 Geological Survey Wisconsin, Iowa and Minnesota, pp. 98-102; 1852.
45 Geology of Iowa, vol. I, pt. I, pp. 267, 268; 1858.
46 Geol. Survey Illinois, vol. VIII, pp. 155-208; 1890.
47 Iowa Geol. Survey, vol. VII, pp. 197-262; 1897.
48 Iowa Geol. Survey, vol. XIII, p. 213 ff.; 1903.
49 Iowa Geol. Survey, vol. VII, pp. 211, 212; 1897.

of this name. It is possible also that the Marshalltown shales of Beyer are represented in the upper part of the section.

Marshall County.—The Kinderhook area of Marshall county occupies approximately its eastern half, the western part being underlain by the "Coal Measures."

The most important exposures of the series in this county are in the quarries near LeGrand in the northern part of LeGrand township, though outcrops of lesser importance appear at Rockton in Marion township, and near Marshalltown in Linn township.

LEGRAND BEDS.—A number of years ago several quarries were worked a short distance north and northwest of LeGrand by the LeGrand Quarry Company. The sections are somewhat similar in all of these, but the succession is most complete and can be most satisfactorily studied in the two east quarries. Lower beds are exposed in these than in any other outcrops in the county.

The succession in the east quarry, north of Iowa river, in the extreme northwest corner of section 1 of LeGrand township, is as follows:

Section in the east quarry.

		FEET	INCHES
	Drift		
6.	Limestone, soft, buff, magnesian, much weathered; somewhat nodular; no fossils noted	2	
5.	Limestone, brownish, subcrystalline to crinoidal; some layers in upper half slightly oölitic	12	5
4.	Limestone. gray, magnesian, weathering buff; upper part thin bedded; lower half more massive when fresh but weathering into thin layers; with a rather persistent three inch chert band six and one-half feet below the top; interbedded with a few seams and layers of brownish, crinoidal limestone ranging from one inch to twelve inches in thickness; thin seams of oölitic limestone appear in the lower part of the upper four feet of the bed. With some thin fossiliferous seams	9	8
3.	Limestone, ash-colored to buff, magnesian; subcrystalline; cleaving into thin layers; locally grading in part into brownish, crinoidal limestone; the main crinoid zone; surface of layers in places showing faint ripple marks; with stylolytic seams	5	
2.	Limestone, buff to yellowish, magnesian; with nodular lentils and discontinuous seams of dense gray chert weathering whitish; in upper part are two discontinuous seams of brownish crinoidal limestone which have a maximum thickness of one foot. The uppermost of these bears pebbles and angular fragments of limestone similar in character to that in the layer just below, but no certain evidence of a disconformity at this level is to be found	25	6
1.	Limestone, light gray, oölitic, very fossiliferous. Exposed	7	6

List of fossils from bed 1 of east quarry.

ANTHOZOA—
Zaphrentis sp.
BRACHIOPODA—
Chonetes logani N. and P.
Chonetes sp.
Schellwienella inflata (W. and W.)
Schellwienella planumbona Weller
Schellwienella sp.
Productus sp.
Productella sp.
Productella sp.
Rhipidomella sp.
Dielasma sp.
Camarotoechia sp.
Spirifer platynotus Weller
Spirifer cf. S. platynotus Weller
Spirifer sp.
Syringothyris sp.
Cliothyridina tenuilineata (Rowley)
Composita opposita (W. and W.)
GASTROPODA—
Straparollus obtusus (Hall)
CEPHALOPODA—
Orthoceras sp.

List of fossils from bed 2 of east quarry.

BRACHIOPODA—
Leptaena cf. L. analoga (Phillips)
Chonetes multicosta Win.
Productella sp.
Productus ovatus Hall
Productus arcuatus Hall?
Orthotetes ? sp.
Schuchertella ? sp.
Camarotoechia sp.
Dielasma sp.
Spirifer platynotus Weller
Spirifer sp.
Eumetria sp.
Composita sp.

List of fossils from bed 3 of east quarry.

BRACHIOPODA—
Orthotetes ? sp.
Productella ? sp.
Chonetes multicosta Win.
Leptaena analoga (Phillips)
Camarotoechia sp.
Spirifer legrandensis Weller
Spirifer calvini Weller
Spirifer sp.
Syringothyris ? sp.
Reticularia cf. R. cooperensis (Swallow)
Composita sp.
BRYOZOA—
Chaetetes . ? sp.
Rhombopora sp.
GASTROPODA—
Platyceras sp.

List of fossils from bed 5 of east quarry.

ANTHOZOA—
Zaphrentis sp.
BRACHIOPODA—
Productus sp.
Productus sp.
Orthotetes ? sp.
Rhipidomella sp.
Composita sp.
Spiriferina solidirostris White
Spirifer platynotus Weller
Spirifer sp.
Spirifer sp.
BRYOZOA—
Fenestella sp.
CEPHALOPODA—
Orthoceras sp.

Lower layers were formerly exposed in this section. Thus Beyer[50] reports a thickness of fifteen feet for the oölite bed (bed 1 of above section) and describes an underlying fine-grained bluish sandstone with an exposed thickness of ten feet.

Collections were made in the quarries south of the river from the same horizon as bed 5 of the preceding section. The forms have been identified as follows:

50 Iowa Geol. Survey, vol. VII, p. 214; 1897.

List of fossils from quarries south of Iowa river.

ANTHOZOA—
- Zaphrentis sp.

CRINOIDEA—
- Platycrinus sp.

BRACHIOPODA—
- Orthotetes ? sp.
- Productus sp.
- Rhipidomella cf. R. dubia (Hall)
- Camarotoechia sp.
- Spiriferina solidirostris White
- Spiriferina sp.
- Spiriferina sp.
- Delthyris clarksvillensis (Winchell) ?
- Spirifer platynotus Weller
- Spirifer sp.
- Spirifer sp.
- Spirifer sp.
- Spirifer sp.
- Spirifer sp.
- Spirifer sp.
- Eumetria sp.
- Composita sp.

GASTROPODA—
- Straparollus (two species)

At the point where the Minneapolis and St. Louis railway crosses Timber creek, three and three-fourths miles west of LeGrand, beds corresponding in age to those at the top of the above described east quarry section are well exposed in an abandoned quarry. However, certain of the layers are much more oölitic here.

Timber creek section.

		FEET	INCHES
8.	Drift		
7.	Limestone, compact, gray, magnesian, weathering yellowish, thin bedded, nonfossiliferous; cherty in middle part	6	6
6.	Limestone, brownish, medium-grained, slightly crinoidal, thin bedded; with a median layer of compact gray magnesian limestone three inches thick	2	0
5.	Limestone, brownish, rather coarse-grained, crinoidal, fossiliferous; locally grading laterally into oölite	0	6
4.	Limestone, gray, oölitic, weathering to thin layers	5	0
3.	Limestone, medium-grained, bluish when fresh but weathering brownish	0	6
2.	Limestone, bluish, compact, magnesian, weathering buff; with occasional seams of bluish unaltered limestone; rather massive	7	0
1.	Limestone, bluish when fresh but weathering to a gray color, oölitic	4	0

Collections were made from beds 1, 5, and 6.

List of fossils from bed 1 of Timber creek section.

- Camarotoechia ? sp.
- Rhipidomella sp.
- Eumetria sp.
- Spirifer sp.
- Spirifer sp.

List of fossils from beds 5 and 6 of Timber creek section.

- Camarotoechia sp.
- Rhipidomella sp.
- Streptorhynchus sp.
- Spirifer sp.
- Cliothyridina sp.
- Composita sp.
- Dentalium grandaevum Win.

The latter beds are believed to represent a portion of bed 5 of the east quarry section.

Beyer[51] reports that the topmost beds at LeGrand are again exposed in the old quarries at Rockton near the central part of Marion township. The section there is described by him as follows:

Section of LeGrand beds at Rockton (After Beyer).

		FEET
6.	Loess and soil	1-3
5.	Till, yellow (Iowan)	2-4
4.	Till, reddish brown, sometimes blue below (Kansan)	0-3
3.	Limestone, brown, subcrystalline, rubbly	3-5
2.	Limestone, oölitic, heavy bedded	5
1.	Limestone, gray-brown, beds thinner and slightly argillaceous	2

The strata of the above described sections have been designated the LeGrand beds by Beyer.[52] The limestone above the basal oölite has yielded many species of Echinodermata in the LeGrand area. These have been described by Wachsmuth and Springer, by Miller and Gurley and by Worthen. The list follows:

List of echinoderms described from the LeGrand beds.

CYSTOIDEA—
- Agelacrinus legrandensis Miller and Gurley

BLASTOIDEA—
- Orophocrinus conicus W. and Sp.
- Orophocrinus fusiformis W. and Sp.

CRINOIDEA—
- Rhodocrinus kirbyi W. and Sp.
- Rhodocrinus nanus M. and W.
- Rhodocrinus watersianus W. and Sp.
- Megistocrinus nobilis W. and Sp.
- Batocrinus macbridei W. and Sp.
- Batocrinus poculum Miller and Gurley
- Aorocrinus immaturus W. and Sp.
- Aorocrinus parvibasis W. and Sp.
- Cactocrinus ornatissimus W. and Sp.
- Cactocrinus nodobrachiatus W. and Sp.
- Cactocrinus proboscidialis (Hall)
- Cactocrinus arnoldi W. and Sp.
- Platycrinus symmetricus W. and Sp.
- Platycrinus agassizi W. and Sp.
- Dichocrinus inornatus W. and Sp.
- Dichocrinus delicatus W. and Sp.
- Dichocrinus cinctus Miller and Gurley
- Eutaxocrinus fletcheri Worthen
- Taxocrinus intermedius W. and Sp.
- Goniocrinus sculptilis Miller and Gurley
- Cyathocrinus marshallensis Worthen
- Poteriocrinus genista Miller and Gurley
- Poteriocrinus hammondi Miller and Gurley
- Poteriocrinus legrandensis Miller and Gurley
- Poteriocrinus maccabei Miller and Gurley
- Poteriocrinus maccabei var. decrepitus Miller and Gurley
- Poteriocrinus scopae Miller and Gurley
- Scaphiocrinus elegantulus W. and Sp.
- Scaphiocrinus globosus W. and Sp.
- Scaphiocrinus notatus Millĕr and Gurley
- Graphiocrinus longicirrifer W. and Sp.

ECHINOIDEA—
- Archaeocidaris legrandensis Miller and Gurley

51 Op. cit., p. 216.
52 Idem, p. 221 ff.

MARSHALLTOWN SHALES.—Beyer[53] reports the occurrence of about fifteen feet of argillo-calcareous beds, named by him the Marshalltown shales, above the LeGrand beds in an exposure near the flouring mills at Marshalltown. He describes them as follows:

"They consist of ash blue to deep blue shales interbedded with argillaceous limestones. Chert nodules are present in the upper calcareous layers. After diligent search no trace of organic remains could be found."

At the time of the writer's visit these beds were largely concealed. Only three feet of soft browish dolomitic limestone overlain by three feet of residual soil was exposed.

Tama County.—Savage[54] describes the Kinderhook of Tama county as follows:

"As these rocks are exposed in Tama county they present three different facies. The lowest phase is a yellow, fine-grained sandstone which bears but few fossils and which is seen in but a few of the outcrops in the area. Overlying this sandstone is a stratum of light colored, oölitic limestone which occurs in thick, massive layers. This phase is very fossiliferous throughout and is quite uniformly developed and constantly present wherever in the county the rocks of this horizon are exposed. The upper phase is a brown magnesian limestone which in some layers changes to a yellowish brown, fine-grained sandstone. The layers of this upper phase carry quite a number of fossils, usually in the form of casts or moulds. Near the upper part the magnesian character gives way to thinly bedded limestone which, in the uppermost layers exposed, carries a large quantity of the comminuted fragments of the stems of crinoids."

These beds are the equivalent of the LeGrand beds of Marshall county. A typical exposure of them appears in an old quarry near the east side of section 17, Indian Village township. The following description is after Savage.

Section of Kinderhook beds, section 17, Indian Village township (After Savage).

	FEET	INCHES
14. Yellowish brown loess	2	
13. Brown clay containing numerous crystalline pebbles	6	
12. Bed of grayish brown, impure limestone which breaks up		

53 Op. cit., pp. 214, 215, 226.

54 Iowa Geol. Survey, vol. XIII, p. 213 ff.; 1903.

	into narrow layers and irregular pieces when exposed to the action of the weather. Fossils rare	3	
11.	Band composed largely of nodules of chert		3
10.	Impure limestone, brown in color, with few fossils; species of *Chonetes*, *Rhynchonella*, and *Spirifer* were found	1	
9.	Band of chert nodules		3
8.	Thick, heavy layer of brown magnesian limestone containing casts of *Chonetes* and *Rhynchonella*	2	6
7.	Layer composed mostly of nodules of chert		4
6.	Layer of brown magnesian limestone with casts of *Zaphrentis*, *Chonetes* and *Rhynchonella*		10
5.	Brown limestone with numerous chert nodules intermingled, containing casts of a species of *Productus*		10
4.	Massive layers of brown magnesian limestone in which there is a considerable quantity of sand	4	8
3.	Heavy layer of oölite which weathers into small irregular blocks and bits, containing in abundance *Orthotetes crenistria*, a species of *Rhynchonella*, *Spirifer extenuatus*, *Spirifer biplicatus* and *Straparollus latus*	5	8
2.	Massive beds of oölite in two layers similar to number 3 above and carrying similar fossils, the lower part somewhat talus covered	8	6
1.	Yellowish sandstone with some clay, containing few fossils; not well exposed. To level of road	8	

Numerous crinoids and fish remains are reported to have been found by the quarrymen in the seams separating the layers of magnesian limestone. At the time C. A. White visited this quarry in 1869 a greater thickness of yellow sandstone was exposed below the oölite bed. At present none of the sandstone outcrops.

In another quarry situated near the southwest corner of section 8 of the same township a greater thickness of strata is preserved above the oölite. Savage's description of this exposure is given below:

Exposure in section 8, Indian Village township (After Savage).

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

5.	Magnesian limestone containing some fine-grained yellow sand	1	8
4.	Bed similar to number 5 above	1	6
3.	Layer of massive oölite weathering into small bits and bearing numerous fossils, among which appear *Orthotetes crenistria, Spirifer biplicatus, Spirifer cf. extenuatus,* and *Straparollus latus*	7	
2.	Layer similar to number 3 above in lithological characters and fossils contents	4	6
1.	Layer of light gray oölite similar to numbers 2 and 3 above	3	

At the "Devils Anvil", near the southeast corner of section 7, Indian Village township, Savage measured the following section on the east side of the hill.

Section at "Devils Anvil" (After Savage).

		FEET
9.	Reddish brown clay, containing numerous small pebbles	3
8.	Bed of crinoidal limestone which weathers into thin layers 1 to 4 inches in thickness	7
7.	Layer of crinoidal limestone bearing a band of chert nodules near the middle	2
6.	Bed made up of irregular layers of brown colored magnesian limestone 1 to 4 inches in thickness, and containing numerous nodules of chert 6 to 12 inches in long diameter and 3 to 6 inches in the short direction. Casts of fossils not rare; among them appear species of *Rhynchonella, Zaphrentis, Chonetes* and *Productus*	10
5.	Impure magnesian limestone, brown in color, containing but few fossils, and showing numerous cavities which appear to have been formed by the dissolving action of percolating waters	4
4.	Bed of fine-grained brown colored sandstone in layers 9 to 18 inches in thickness, a part of the layers containing some magnesian limestone, and all of them bearing numerous chert nodules	8
3.	Band of chert nodules on the surface of which appear casts of fossils, among them *Orthotetes* and *Productus*	1/3
2.	Bed of impure sandstone which appears massive in places and at other places weathers into irregular layers 2 to 4 inches in thickness	4
1.	Bed of light gray oölite containing numerous fossil fragments among which are *Orthotetes crenistria, Spirifer biplicatus,* and *Straparollus latus*	6

The oölite bed at the base of the exposure is the same as that of the two preceding sections. The overlying layers have a greater thickness than elsewhere in the county. At the north end of the exposure there are several small bryozoan reefs in the upper four feet of bed 8. These reefs consist of compact gray limestone filled with bryozoans and flanked on the sides by brownish crinoidal limestone.

The reef limestone is structureless but weathers to irregular flakes. The reefs are roughly lenticular in shape and range in size from masses two to three feet long and one foot high to others as much as six feet long and two to three feet high. In some places there is a slight interfingering of the reef material with the limestone on the sides.

The fauna of the reef zone is as follows:

BLASTOIDEA—
Orophocrinus conicus W. and Sp.

BRACHIOPODA—
Leptaena analoga (Phillips)
Camarotoechia sp.
Spirifer calvini Weller
Spirifer legrandensis Weller ?
Reticularia cooperensis (Swallow)

BRYOZOA—
Leioclema wachsmuthi Ulrich
Rhombopora sp.
Streblotrypa sp.
Taeniodictya cf. T. ramulosa var. burlingtonensis Ulrich
Fenestella sp.
Undetermined (several species)

Numerous other exposures of the oölite bed and the overlying layers of magnesian limestone appear along the south bank of Iowa river northeast of LeGrand station and at several points along the bluffs of Sugar creek, a tributary from the north.

Grundy County.—Regarding the Kinderhook of Grundy county, Arey[55] says:

"While there is little superficial demonstration of the fact within the limits of the county, there is no doubt that by far the greater portion of the county is underlain with rock of the Kinderhook series. As has been stated elsewhere already, the only actual rock exposures are on Wolf creek near Beaman and Conrad. At the latter place, an abandoned quarry gives the only opportunity for an examination of rock in place where a section can be secured."

A section of the quarry at Conrad given by Beyer[56] in his Hardin county report is as follows:

Section of Kinderhook beds at Conrad.

		FEET
5.	Drift (modified Kansan probably)	5
4.	Limestone, residual, consists chiefly of cherty concretions imbedded in a matrix of greenish clay streaked and mottled with ferruginous and marly material	3
3.	Limestone, slightly oölitic, composed essentially of a shelly breccia almost identical with No. 1 in the Eagle City section	
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

A number of species were collected from this exposure by the author, viz:

55 Iowa Geol. Survey, vol. XX, p. 77; 1910.
56 Iowa Geol. Survey, vol. X, pp. 270-271.

Zaphrentis sp.
Schellwienella inflata (W. and W.)
Camarotoechia sp.
Rhipidomella thiemei (White) ?
Dielasma ? sp.
Spirifer platynotus Weller
Conocardium sp.
Straparollus obtusus (Hall)
Loxonema ?

Correlation of Kinderhook of Central Iowa

The age of the shales overlying the Devonian limestone in central Iowa is not definitely known but they are believed to belong to the Kinderhook. If they are Kinderhook they undoubtedly belong to the middle or lower or both middle and lower portions of this formation as developed farther south as suggested by the fauna of the overlying LeGrand beds.

The strata now known as the LeGrand beds in Tama and Marshall counties were correlated with the Kinderhook beds at Burlington, Iowa, by White.[57] However, he believed that the middle part of the Burlington Kinderhook was not represented in this part of the state. The oölite bed (bed 6) at Burlington was regarded as the equivalent of the oölite bed near or at the base of the exposures in Tama county, while the underlying sandstone in this county was believed to be the equivalent of the basal shales (bed 1) in the southern section. He noted the similarity of the crinoidal limestones in the upper part of the LeGrand beds to the Burlington limestone in the type section but correlated them nevertheless with the topmost bed of the Kinderhook (bed 7) at Burlington.

Wachsmuth and Springer[58] in their report on the echinoderms from LeGrand agree that the lower part of the series belongs to the Kinderhook but remark that the occurrence of *Cactocrinus proboscidialis,* a characteristic lower Burlington fossil, in the topmost beds renders their correlation with that formation probable.

At the time Beyer examined the beds he submitted a series of fossils, some of which were taken from the uppermost strata, to Professor Calvin, who found them all to be distinctly Kinderhook in character.[59]

Savage discusses the correlation of the beds in his report on the geology of Tama county.[60] He points out the marked differ-

57 Geology of Iowa, vol. I, pp. 195-197; 1870.
58 Geol. Surv. Illinois, vol. VIII, pp. 55.
59 Iowa Geol. Survey, vol. VII, p. 221; 1897.
60 Iowa Geol. Survey, vol. XIII, p. 225 ff.

ence between the faunas of beds 6 and 7 at Burlington and those of the beds correlated with them by White but states that a larger proportion of the fossils of the oölite layers is similar to those found in bed 6 than to those of any other member of the Burlington section.

Numerous collections were made from the LeGrand beds during the writer's field studies. The identification of these has strengthened the correlation of the formation with the uppermost beds of the Kinderhook at Burlington, though the presence of a large number of species, many of which are undescribed, in the northern section, which are absent from the beds at Burlington makes exact correlation difficult. Most of the brachiopods specifically identified from the LeGrand beds, which are common to the two localities, are confined to beds 6 and 7 at Burlington though a few species range down into lower beds and an occasional one occurs in the Lower Burlington of the type section.

The crinoid element of the fauna is remarkable in that none of the species has been found in the Kinderhook elsewhere in Iowa. However, *Cactocrinus proboscidialis* occurs in the Lower Burlington limestone. Wachsmuth and Springer have described another species, *Dichocrinus delicatus,* as common to the Lower Burlington limestone at Burlington and the Kinderhook beds of Marshall county. The exact horizon of the latter is not given but probably it came from the upper part of the LeGrand.

The LeGrand beds are tentatively correlated with the Upper Kinderhook of southeastern Iowa. The uppermost layers at LeGrand very probably represent a transition into the Lower Burlington limestone.

The marked difference in thickness of the LeGrand beds as compared to the Upper Kinderhook at Burlington is worthy of note. If we assume their equivalence we must explain this great discrepancy in thickness as due either to more favorable conditions for the deposition of limestone in the northern area or to the presence of a disconformity between the Kinderhook and Lower Burlington formations in southeastern Iowa. Inasmuch as a study of this contact over wide areas in Des Moines and Louisa counties has revealed no evidence of a break in sedimentation, the theory of original differences in deposition is favored. The continued thickening of the Kinderhook limestones northward from Marshall county as indicated by the exposures in Hardin county also lends weight to this view.

The age of the Marshalltown shales is not definitely known owing to the fact that their contact with the LeGrand beds is not exposed and that no diagnostic fossils have as yet been collected from these strata. If the uppermost limestones of the LeGrand beds are regarded as transition layers between the Kinderhook and Lower Burlington formations then these shales may represent the near shore facies of the basal beds of the Lower Burlington.

KINDERHOOK OF NORTH-CENTRAL IOWA

General statement.—The Kinderhook has a much more widespread distribution in north-central Iowa than in any other part of the state, but the beds are effectually concealed over a large part of the area by a thick mantle of glacial drift. Beginning at the southern part of this province we find that, to the best of our knowledge, the Kinderhook constitutes the surface rock in Hardin county in its extreme southeastern corner, in its central part and in the northern part. It underlies small areas in the north-central part of Hamilton county and in the southwestern part of Butler county; the whole of Franklin county, with the exception of a small area occupied by the Lime Creek beds in the northeast corner; all of Wright county except small areas in the southeastern and southwestern parts; the northern half of Humboldt county; a very narrow linear area in the extreme eastern part of Pocahontas county; all of Kossuth county except the area occupied by the Cretaceous in the western and northwestern parts; the whole of Hancock county barring a small area of Lime Creek in the northeast corner; and the greater part of Winnebago county.

Prior to the present investigation the Kinderhook beds of this part of the state were imperfectly understood and it must be admitted that the exact character and extent of several of the formations is even now not definitely known, owing to the fact that the drift mantle is thick and the outcrops are few and usually small.

The Kinderhook of northern Iowa is somewhat related to that of the central part of the state but possesses little in common with that of southeastern Iowa. The thickness is approximately the same (350 feet), but lithologically and faunally the series is very different. The group is divided into six distinct formations, upon the basis of individual exposures and the log of a well at Iowa Falls.

The Alden limestone
The Iowa Falls dolomite
The Eagle City beds
The Mayne Creek beds
The Chapin beds
The Sheffield beds[60a]

THE SHEFFIELD BEDS.—This basal member of the Kinderhook has a thickness of about sixty feet. The main mass of the formation, representing approximately the lower two-thirds, consists of bluish plastic shale intercalated with which are thin layers of fine-grained sandstone and brownish impure limestone, but the upper third is more calcareous. It is brownish and dolomitic and locally bears a lenticular bed of gray oölitic limestone which, at those localities where it is typically developed, is about six feet in thickness. Fossils are scarce and poorly preserved except in the upper part of the formation, where a few species with Chouteau affinities occur.

It is possible that the lower shaly portion of the Sheffield beds will ultimately be referred to a distinct formation of either Kinderhook or Upper Devonian age. The paucity of recognizable fossils in the lower shales and intercalated sandy layers renders their exact correlation impossible at present. However, the absence of any evidence of a disconformity between these strata and the fossiliferous layers above favors the reference of the entire succession to one formation.

The formation takes its name from the town of Sheffield in northern Franklin county in the vicinity of which it is well exposed.

THE CHAPIN BEDS.—These have a thickness of perhaps twenty to thirty feet and consist of a massive limestone, the lower part of which is altered to dolomite at some localities, followed by fine-grained yellow sandstone. They are best exposed in a small quarry near the town of Chapin in Franklin county. At

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[60a] See footnote 76, page 116.

this locality the beds are very fossiliferous, having yielded about thirty-five species.

THE MAYNE CREEK BEDS.—This formation consists chiefly of soft brownish dolomitic limestone, which at several horizons is arenaceous. It has a thickness of about sixty-eight feet. Occasional chert nodules in the formation yield well preserved fossils. It is best exposed at a locality on Mayne creek in Geneva township of Franklin county.

THE EAGLE CITY BEDS.—This division is made up of alternating beds of brownish dolomite and gray limestone. Some of the limestone beds are oölitic. It is best exposed in the banks of Iowa river at Eagle City in Hardin county and in the lower part of the gorge at Iowa Falls. The limestone horizons contain brachiopods of Upper Kinderhook age. Its thickness is seventy-five feet.

THE IOWA FALLS DOLOMITE.—This member is typically developed in the gorge of Iowa river at Iowa Falls in Hardin county where it has a maximum thickness of not less than fifty feet. Its contact with the underlying formation is very undulating, but this is believed to have resulted from uneven dolomitization rather than from disconformity. The formation is heavily bedded, except at the very top where the layers are comparatively thin. It is brownish in color, and contains but few fossils.

THE ALDEN LIMESTONE.—This is a light gray thin-bedded slightly oölitic limestone which is well exposed at the town of Alden in Hardin county. It has a maximum exposed thickness of about thirty-two feet. The contained fossils are very poorly preserved and the exact age of the formation is open to question. It is referred tentatively to the Kinderhook. The contact of this formation with the underlying dolomite has been observed at only one locality. This is at the old Ivanhoe quarries along Iowa river midway between Alden and Iowa Falls. It is there very irregular, and there is evidence of a distinct disconformity between the two formations.

Hardin County.—The greater part of the surface of Hardin county is underlain by Pennsylvanian strata, but the erosion of these overlying deposits has brought the Kinderhook to the surface over small areas in the southeastern and central parts of the county, and over a broad area in its northern part.

The most important exposures, by far, are along Iowa river between Alden and Eagle City. Indeed, the exposures between these two points furnish the most complete and representative section of the Kinderhook in the northern part of the state.

So far as the writer is aware no strata older than the Eagle City formation are exposed within the limits of Hardin county. Our knowledge of the character and thickness of the lower beds of the Kinderhook in this region has been considerably enhanced by the record of the city well at Iowa Falls. This well is located near the head of Rock Run gorge. The log of the strata passed through as given by Beyer[61] is as follows:

Log of well at Iowa Falls (After Beyer).

		THICKNESS FEET	DEPTH FEET
1.	Drift and weathered material	50	50
2.	Limestone, light gray, compact	15	65
3.	Limestone, brown, dolomitic, subcrystalline	29	94
4.	Limestone, gray-blue, magnesian, cleavage fragments of calcite not uncommon; compact; grading downward into a light colored and less magnesian limestone	16	110
5.	Limestone, gray, semi-oölitic in texture	5	115
6.	Limestone, gray-brown, dolomitic and porous; drillings of a gray compact limestone abundant	11	126
7.	Limestone, brown, dolomitic, with considerable light-colored chert	37	163
8.	Dolomite, gray-brown	7	170
9.	Dolomite, yellowish brown, sugary	7	177
10.	Sandstone, gray-blue, shaly	7	184
11.	Sandstone, white, friable and very fine-grained	10	194
12.	Sandstone, gray, fine-grained and compact; slightly argillaceous and noncalcareous	14	208
13.	Limestone, blue-gray to yellowish gray, compact; slightly argillaceous and exhibits an almost earthy fracture	6	214
14.	Shale, plastic, even-textured, light gray-blue, and slightly calcareous above	62	276
15.	Limestone, hard, compact (penetrated)	2	278

Bed 15 of this section is believed to represent Devonian limestone; bed 14, the Sheffield shale; beds 13 and 12, the Chapin formation; beds 11 to 7, the Mayne Creek formation; and beds 6 to 2, the Eagle City formation.

THE EAGLE CITY BEDS.—The outcrops of this formation in Hardin country are confined to the valley of Iowa river, the

61 Iowa Geol. Survey, vol. X, p. 265.

most complete exposure of the formation being at Eagle City in the extreme southwestern corner of Aetna township. At the east end of the bridge over Iowa river at this place, the following section is shown in an abandoned quarry:

Section of Eagle City formation at Eagle City.

		FEET	INCHES
5.	Drift	5	
4.	Dolomite, thin-bedded at top but more massive below, brownish, soft	25	
3.	Limestone, gray, oölitic, compact	1	4
2.	Dolomite, yellow to brownish, thin-bedded, soft	2	10
1.	Limestone, gray, oölitic	4	

All of these beds are distinctly lower than any observed at Iowa Falls. The fossils collected from bed 1 are as follows:

List of fossils from bed 1 of the bridge section at Eagle City.

BRACHIOPODA—
- Leptaena analoga (Phillips)
- Orthotetes (?) several species
- Schellwienella inflata (W. and W.) ?
- Productus sp.
- Dielasma ? sp.
- Spirifer cf. S. legrandensis Weller
- Reticularia cooperensis (Swallow)
- Eumetria cf. E. verneuiliana (Hall)

BRYOZOA—
- Chaetetes ? sp.
- Rhombopora ? sp.
- Fenestella sp.

GASTROPODA—
- Orthonychia sp.
- Straparollus ? sp.

The following species were collected from bed 3:

List of fossils from bed 3 of the bridge section at Eagle City.

- Productus ovatus Hall
- Orthotetes ? sp.
- Camarotoechia chouteauensis Weller
- Spirifer cf. S. legrandensis Weller

Bed 4 yielded the fossils listed below:

List of fossils from bed 4 of the bridge section at Eagle City.

- Leptaena analoga (Phillips)
- Schellwienella (several species)
- Camarotoechia sp.
- Schizophoria sp.
- Spiriferina subtexta White ?
- Spirifer cf. S. legrandensis Weller
- Spirifer sp.
- Reticularia cooperensis (Swallow)
- Bryozoan sp.

A few rods upstream from the above described quarry, lower beds are exposed in the river bank, viz:

	FEET
Limestone (No. 1 of above section)	2½
Dolomite, soft, yellowish	12
Limestone, dense, lithographic, thinly and irregularly bedded. Exposed above water	1

Regarding the Kinderhook exposures along Iowa river below Eagle City, Beyer[62] has this to say:

"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 at one or two points between, number 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.[63] *Straparollus* casts and a cystophylloid coral were found. 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:

Section of Kinderhook beds south of Gifford (After Beyer).

		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 one hundred 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."

Other exposures of brownish dolomitic limestone of Eagle City age appear at intervals in the banks of Iowa river above Eagle City all the way to Iowa Falls.

Near the east line of the northwest quarter of section 20,

62 Iowa Geol. Survey, vol. X, p. 269-270.

63 In the writer's opinion these beds are probably older than the upper beds at Iowa Falls. They may be correlated tentatively with the Eagle City.

Hardin township, at the mouth of a small creek in the north bank and near the point where the river turns south, twenty-two feet of thinly and irregularly bedded yellowish dolomite outcrops. The rock evidently was once an oölitic limestone, in part at least, as indicated by the fact that small remnants of imperfectly dolomitized gray oölite were observed in the dolomite. No fossils were noted here.

One-half mile above this point in the southeast one-fourth of the southeast quarter of section 18, Hardin township, another good exposure of these beds is afforded in the quarry of the Ellsworth Stone Company.

Section in the quarry of the Ellsworth Stone Company.

	FEET
6. Drift	2— 3
IOWA FALLS DOLOMITE.	
5. Dolomite, soft, brownish, thin-bedded above but massive below. Resting on the irregular surface of the bed below. A two foot zone five feet below the top is rich in simple corals, and bears numerous specimens of *Straparollus obtusus*. The dolomite is granular and slightly vesicular. Probably formed by the alteration of a medium-grained limestone. Thin shaly seams occur in the basal part	20
EAGLE CITY BEDS.	
4. Limestone, gray, oölitic, more compact and in thicker layers than in bluff at Iowa Falls. The upper part is locally dolomitized and discolored yellowish	3— 5
3. Limestone, light gray, lithographic, the upper three and one-half feet interbedded with layers and discontinuous seams of coarser dark gray dolomite	12
2. Dolomite, fine-grained, soft, gray weathering yellowish, rather thinly bedded. With many small pockets and seams of calcite. In some places parts of the bed are filled with masses and streaks of pyrite, which in some instances is associated with the calcite	6
1. Dolomite, dark gray when fresh, ednse, massive. Exposed	7

Beds 1 to 4 of this section are referred to the Eagle City, but probably they represent a higher horizon of that formation than is represented at the type locality described above. Bed 5, on the other hand, belongs to the lower part of the Iowa Falls dolomite. The contact of this formation with the limestone below is undulating in such a way as to suggest a disconformity at this level, but the phenomenon probably is due to uneven dolomitization, in which case it should be classed as a pseudo-disconformity.

Another excellent opportunity for studying the Kinderhook is furnished in the gorge of Iowa river below the dam at Iowa

Falls, two miles above the Ellsworth quarry. The river has cut through an anticlinal flexure here, exposing in the west bank about seventy feet of strata, the lower twenty-five feet of which belongs to the Eagle City. The section is as follows:

Section in gorge at Iowa Falls

	FEET
IOWA FALLS DOLOMITE.	
6. Dolomite, yellowish to brownish, massive below but thin-bedded at the top; slightly vesicular. The lower beds tending to recede in the cliff. Contact with bed below very undulating, as a result of uneven dolomitization	44
EAGLE CITY FORMATION.	
5. Limestone, gray, lithographic, contact with bed above wavy owing to dolomitization along an irregular line; bearing *Camarotoechia subglobosa*	2½
4. Limestone, dark gray, dolomitic, in a single layer with regular contacts	1
3. Limestone, gray, compact, faintly oölitic below but distinctly so above. Flaking off parallel to surface of bluff. This and bed above receding	6
2. Limestone, gray, lithographic, in thin layers but in places assuming a massive appearance. No fossils noted. With layers of darker gray dolomitic limestone interbedded at the top. Weathering whitish	10
1. Limestone, dark gray, dolomitic, dense, brittle; in layers of medium thickness. Exposed	2½

At the dam, bed 5 is seven feet thick and is not dolomitized. Further down stream it thins abruptly and is dolomitized locally.

Bed 3 of the above section contains occasional fossils, several of which are undescribed. A list of those collected is given below:

List of fossils from Eagle City formation at Iowa Falls.

Syringopora ? sp.
Camarotoechia subglobosa Weller ?
Camarotoechia sp.
Eumetria sp.
Conocardium sp.
Schizodus (several species)
Pelecypods (several undetermined species)
Straparollus obtusus (Hall)

THE IOWA FALLS DOLOMITE.—This division of the Kinderhook attains its typical development only in the vicinity of Iowa Falls where it caps the section in the west bank of the gorge of Iowa river at the point where it cuts through the anticline. The character of the formation in this exposure has been considered in the above-described section. In general it consists of yellowish to brownish slightly vesicular beds of dolomite, massive in the lower part, but thin-bedded at the top. The lower beds at many places recede slightly in the cliff.

At a point in the west bank about one hundred yards below the axis of the anticline, this dolomite may be seen in irregular contact with the Eagle City formation. It has here a thickness of forty-four feet, but higher beds undoubtedly have been eroded. The upper six feet is thin-bedded.

A good exposure of this member also appears a short distance upstream in the cliff at the west end of the Washington street bridge. It has an exposed thickness of forty-four feet six inches at this point, the contact with the lower beds being situated two or three feet below the water level. The upper five feet is thin-bedded.

In Wild Cat Glen, on the west side of the river, not far from the last mentioned exposure, the thin-bedded member at the top of the Iowa Falls is eight feet six inches thick, and bears a number of fossils in the form of molds. These are listed below:

List of fossils from Iowa Falls dolomite at Wild Cat Glen.

ANTHOZOA—
- Zaphrentis sp.

BRACHIOPODA—
- Orthotetes ? sp.
- Dielasma sp.
- Camarotoechia cf. C. tuta (Miller)
- Camarotoechia ? sp.
- Spiriferina solidirostris White
- Spirifer sp.
- Ambocoelia sp.
- Centronelloidea rowleyi (Worthen)
- Athyris crassicardinalis White ?

GASTROPODA—
- Orthonychia sp.
- Holopea subconica Win. ?

Approximately one and one-half miles west of the gorge sections, the Iowa Falls dolomite is again well exposed in a high cliff on the south side of Iowa river in the northwest quarter of section 14, Hardin township. The following succession was measured:

Section of Iowa Falls dolomite in Hardin township.

		FEET
4.	Drift	
3.	Dolomite, thin-bedded, brownish	9
2.	Dolomite, brownish, massive, soft, showing concretionary structure	26
1.	Dolomite, soft, brownish, thin-bedded with thin discontinuous bands of chert. Exposed	10

Three hundred yards up stream, in the opposite bank, Des Moines shales and sandstones replace these beds of dolomite. They appear to rest on the irregular surface of bed 1 of the preceding section and to extend down almost to the water level in places. They doubtless fill an old channel cut into the dolomite in pre-Pennsylvanian time.

One-half mile southwest of this point a small exposure of the Iowa Falls dolomite appears at the east end of the railroad bridge, a short distance south of the center of section 15 of Hardin township. It consists of fifteen feet of brownish dolomite in the form of thin even layers in the basal part, massive beds in the middle, and thin, nodular layers at the top. No fossils were found.

Sixty rods above the railroad bridge in the southwest quarter of section 15, the Iowa Falls dolomite may be seen in disconformable relation with the Alden limestone. The contact line is very uneven and undulating. At the south end of the exposure it is at places below the level of the water of the river and at other places is above that level. Toward the north end it rises. The maximum exposed thickness of the dolomite is six feet. It is thin-bedded and nodular in places, and tends to recede in the low bluff. The overlying gray slightly oölitic Alden limestone has a maximum exposed thickness of eighteen feet. Lenticular masses of shale, some of which are of large size, appear here and there along the contact.

Another excellent contact section of the Iowa Falls dolomite with the Alden limestone is shown a short distance upstream in the old Ivanhoe quarries. This exposure is described under the discussion of the Alden limestone.

THE ALDEN LIMESTONE.—This member of the Kinderhook is typically exposed in the south bank of Iowa river just below the wagon bridge at the town of Alden in Alden township. It consists of light gray, slightly oölitic, subcrystalline limestone in thin layers which locally are cross-bedded. Many of the layers are less than one inch in thickness, and layers exceeding three inches are rare. The total thickness of beds exposed in this section is about seventeen feet. Careful search was made for fossils, but no identifiable specimens were found.

A second exposure of the Alden limestone of considerable interest is found in the quarry of the Hale Roberts Stone Company, just northeast of Alden between the wagon road and the Chicago and North Western railway in the southeast quarter of section 18, Alden township. This shows lower layers than are exposed in the river bank at Alden. About thirty-two feet of limestone is exposed, of which the upper half is like that exposed along the river. It is light gray in color, thin-bedded and slightly oölitic. The lower part is a darker gray when fresh and some is slightly bluish. It is in thicker layers and is less oölitic than that above and evidence of cross-bedding is shown at several horizons. Some of the layers near the bottom are as much as a foot in thickness. Occasional fissures, widened by solution, have been filled with clay. One set of these trends nearly north-south and another set nearly east-west. The drift at the top is thin, usually being only a foot or two in thickness.

At the old Ivanhoe quarries in the southeast quarter of section 16 of Alden township, this formation is shown in contact with the Iowa Falls dolomite. The section at that place is as follows:

Section in Ivanhoe quarries.

		FEET
2.	Limestone, light gray, faintly oölitic, some layers slightly crinoidal, especially in the lower part. The upper half weathers to thin layers, but the lower part is more massive and tends to show a darker tint when fresh. Locally slightly mashed and showing slickensided structure along small irregular fractures	18
1.	Dolomite, brownish, cavernous and vesicular; in places concretionary; contact with bed above very irregular and undulating, locally marked by lenses of fine sandstone and shale one foot or more in thickness. Some of these bear small fragments of carbonized wood. Exposed	6

Bed 1 of this section represents the Iowa Falls dolomite. Bed 2 is the Alden limestone which was formerly quarried. No fossils sufficiently well preserved to be identified were found.

In the northwest quarter of section 2, Tipton township, a limestone similar to the Alden in lithologic character outcrops on the west bank of the South Fork of Iowa river just below the wagon bridge. Four feet of slightly mashed gray medium-grained limestone, some layers of which are finely crinoidal, is exposed here. No fossils were found.

Franklin County.—With the exception of a small area in its extreme northeastern part where the Upper Devonian forms the surface rock, the Kinderhook underlies the whole of Franklin county. In the western part of the county it is buried by Wisconsin drift, but to the east, beyond the border of this drift sheet, it is exposed at many localities in the banks of the larger streams.

The Kinderhook of this area comprises the three basal formations: the Sheffield beds, the Chapin beds and the Mayne Creek formation.

THE SHEFFIELD BEDS.—The lower part of this member is well exposed in a clay pit at the brick plant one-half mile south of the town of Sheffield, near the center of section 9, Ross township. The section at this point as described by Williams[64] is as follows:

Section of Sheffield beds in Ross township (After Williams).

		FEET
3.	Shale, buff to yellow, slightly magnesian, containing irregular concretions of lime carbonate and thin bands of limestone at top; nonfossiliferous	3
2.	Shale, yellow, pink to red, plastic	6
1.	Shale, nonfossiliferous, plastic, blue, with some carbonaceous matter and occasional thin seams of selenite	6

A well drilled at the plant encountered firm limestone (Upper Devonian?) about twenty feet below the bottom of the pit. Williams refers the shale in this exposure to the Hackberry shale member of the Upper Devonian, and it is so represented on his geological map of Franklin county. But its correlation with similar bodies of shale exposed in the eastern part of the county and referred to the Kinderhook appears to the writer to be the more reasonable one. Unfortunately the shaly character of the basal Kinderhook in this region has caused its contact relations with the Upper Devonian to be obscured.

The greatest exposed thickness of the Sheffield shale observed in Franklin county is shown about three-fourths mile southeast of the clay pit mentioned above, in the south bank of Bailey creek just east of the road along the west side of section 10, Ross township, and in a road cut above.

Forty-four feet of argillaceous shale, gray when dry but bluish when wet and containing thin bands and flakes of brownish dolomitic limestone in the lower part, is present in the bluff. In the road cut near the top of the bluff this is overlain conformably by twelve feet of soft brownish dolomitic shale which bears the following fossils:

Orthotetes ? sp.
Camarotoechia chouteauensis Weller
Spirifer sp.
Cliothyridina prouti (Swallow)

[64] Geology of Franklin County, Iowa Geol. Survey, vol. XVI, p. 478.

This assemblage of fossils is characteristic of the topmost member of the Sheffeld shale wherever it outcrops in northern Iowa.

The work of Prof. A. O. Thomas has shown the presence of an outlier of the Sheffield formation in sections 7, 8, 17, and 18 of West Fork township which had been mapped previously by Williams as Upper Devonian. The total thickness of the formation in this region, according to Thomas, who has studied certain well records, is sixty feet. Along the north-south road near the northeast corner of section 17, West Fork township, a good opportunity is afforded for studying these beds.

Section of Sheffield beds, section 17, West Fork township.

		FEET
3.	Drift	11
2.	Shale, brownish and dolomitic in upper part, but gray and slightly gritty below. A thin seam of chert eleven feet below the top bears *Cliothyridina prouti, Productus blairi, Camarotoechia chouteauensis,* and a *Spirifer* resembling *Spirifer whitneyi*	16?
1.	Shale, bluish, argillaceous, no fossils noted	22

The fossils of bed 2 are characteristic of the upper fossiliferous part of the Sheffield.

In an abandoned quarry in the southeast quarter of section 7, higher beds of the Sheffield are exposed. The section here is as follows:

Section of Sheffield beds, section 7, West Fork township.

		FEET
3.	Drift	1½
2.	Shale, dolomitic, yellowish, thin-bedded; bearing thin flakes of chert	2
1.	Limestone, gray, in thin layers filled with fragments of brachiopods, crinoids, and other fossils, Locally cross-bedded on a small scale. Many fragments of fossils are silicified and stand in relief on weathered surfaces. Exposed	4

The following fossils were collected from beds 1 and 2:

Productus blairi Miller ?
Camarotoechia sp.
Spirifer sp. (similar to S. whitneyi)
Cliothyridina prouti (Swallow)
Eumetria ? sp.

About twenty rods south of this quarry along the east-west road on the north line of the northeast quarter of section 18, a small outcrop shows several feet of bluish argillaceous shale overlain by one foot of thin-bedded limestone rich in fragments of crinoids. This limestone bed is at a level twenty-seven feet below the quarry described above. The following fossils were collected from it:

Productus sp.	Camarotocchia ? sp.
Camarotocchia sp.	Spirifer sp. (resembles S. whitneyi)

The upper fossiliferous beds of the Sheffield, including the oölitic limestone member, are again well exposed in an abandoned quarry located near the middle of the north line of section 14 of Geneva township. The section is described below.

Section of Sheffield beds, section 14, Geneva township.

		FEET
4.	Soil	1—2
3.	Dolomite, yellowish, soft, thin-bedded, much weathered, earthy, stratification very imperfect	5
2.	Dolomite, yellowish brown, massive when fresh but weathering to thin layers. Lower part filled with silicified fossils	2½
1.	Limestone, gray to pinkish, oölitic, massive when fresh; cut by very even vertical joints with remarkably flat surfaces	6½

On the opposite side of a small valley at this place there is a change in profile at a level about one foot below the bottom of the quarry. A shale bed is believed to underlie the oölite.

List of fossils from above exposure.

Schellwienella sp.	Spirifer sp.
Productus blairi Miller	Spirifer sp. (resembles S. whitneyi)
Productus arcuatus Hall ?	Cliothyridina prouti (Swallow)
Productus sp.	Fish spine.
Camarotoechia sp.	

One mile slightly north of west of the preceding exposure, in the southwest one-fourth of the southeast quarter of section 10, Geneva township, strata of a similar horizon appear in an abandoned quarry situated just east of the bridge over Mayne creek. The sucession of beds here is indicated below:

Section of Sheffield beds in section 10, Geneva township.

		FEET
3.	Soil	1
2.	Shale, brownish, dolomitic, with a band of chert nodules near the middle	11
1.	Dolomite, yellowish brown, in one massive ledge. Soft and vesicular. Exposed	10

Silicified fossils are common. The beds are rent by rather widely spaced vertical joints. Fragments of oölitic limestone were noted in the rubble and doubtless came from a lower bed now concealed. A line of springs appears about ten feet below the base of bed 1.

List of fossils from above exposure.

Chonetes sp.
Streptorhynchus sp.
Productus blairi Miller
Camarotoechia chouteaunsis Weller
Cliothyridina prouti (Swallow)
Spirifer sp. (resembles S. whitneyi)
Fish plate.

THE CHAPIN BEDS.—Following the Sheffield shale conformably appear the Chapin beds. These differ in character from place to place, but consist typically of shale at the base followed above by cross-bedded crinoidal and slightly oölitic limestone which is in turn overlain by brownish soft fine-grained sandstone. The two uppermost beds, however, in places pass laterally into soft brownish dolomitic limestone. All the beds are highly fossiliferous. The thickness of the Chapin is twenty to thirty feet.

The most representative exposure of these beds in Franklin county is at the type section, which is shown in an abandoned quarry one mile west of the town of Chapin in the southwest corner of the southwest quarter of section 29, Ross township. The succession of beds there is as follows:

Section of Chapin beds near Chapin.

		FEET
3.	Drift	2—3
2.	Sandstone, very fine-grained, soft, gray when fresh but weathering yellowish; lower two feet massive, but upper four and one-half feet thin-bedded; filled with casts of fossils	6½
1.	Limestone, gray, subcrystalline, faintly oölitic, with interbedded layers of crinoidal limestone which weather brownish. In rather heavy, even layers when fresh but weathering into thinner layers. Exposed	6½

In a smaller opening only a few rods away in the northeast corner of section 31, number 1 has an exposed thickness of seven feet.

Beds 1 and 2 are highly fossiliferous. The species collected are listed below.

List of fossils from bed 1 of the Chapin beds, near the southwest corner of section 29, Ross township.

ANTHOZOA—
Zaphrentis calceola (W. and W.)
Zaphrentis sp.
Amplexus sp.
Syringopora sp.
Leptopora typa Win.

BLASTOIDEA—
Schizoblastus roemeri (Shum.)

BRACHIOPODA—
- Leptaena analoga (Phillips)
- Chonetes multicosta Win.
- Chonetes logani N. and P.
- Productus arcuatus Hall
- Productus ovatus Hall
- Schizophoria chouteauensis Weller ?
- Rhipidomella tenuicostata Weller ?
- Spiriferina solidirostris White
- Spirifer forbesi N. and P.
- Spirifer legrandensis Weller
- Spirifer platynotus Weller ?
- Spirifer sp.
- Spirifer sp.
- Syringothyris sp.
- Athyris crassicardinalis White ?
- Nucleospira barrisi White.

BRYOZOA—
- Fenestella sp.

GASTROPODA—
- Straparollus obtusus (Hall)

List of fossils from bed 2 of the Chapin beds, near the southwest corner of section 29, Ross township.

ANTHOZOA—
- Zaphrentis sp.
- Leptopora typa Win.

BRACHIOPODA—
- Leptaena analoga (Phillips)
- Chonetes multicosta Win.
- Chonetes sp.
- Productus arcuatus Hall
- Productus ovatus Hall
- Productus sp.
- Schizophoria chouteauensis Weller?
- Camarotoechia sp.
- Dielasma sp.
- Spiriferina cf. S. subtexta White
- Spiriferina solidirostris White
- Spirifer legrandensis Weller
- Spirifer ? sp.
- Spirifer sp.
- Syringothyris cf. S. halli Win.
- Syringothyris sp.
- Cliothyridina sp.
- Nucleospira barrisi White

BRYOZOA—
- Cystodictya sp.
- Fenestella sp.

PELECYPODA—
- Conocardium sp.

THE MAYNE CREEK BEDS.—This formation is typically developed along Mayne creek in Franklin county, hence its name. The type section is located in the north bluff of this creek in the northeast quarter of section 21, Reeve township. A revised description of the succession at this place is given below:

Type section of the Mayne Creek formation.

		FEET
6.	Drift	12
5.	Dolomite, yellowish brown, soft, thin-bedded, with occasional thin lenses of chert	10
4.	Dolomite, yellowish brown, soft, in rather heavy, irregular layers, becoming soft, pulverulent and saccharoidal where weathered; with thin discontinuous seams and nodules of fossiliferous chert which weathers chalky	16
3.	Dolomite, yellowish, compact and tough; more resistant than the bed below	1
2.	Dolomite, very soft, much weathered, brownish, flaking off obliquely; with occasional thin discontinuous seams of chert some of which are fossiliferous	10
1.	Dolomite, compact, brownish, tough, with occasional small nodules of chert. A few imperfect casts and impressions of fossils were noted	4

A number of species of brachiopods, pelecypods and gastropods, several of which are undescribed, were collected from the chert seams of bed 2. These have been identified as follows:

List of fossils from the Mayne Creek formation in the northeast quarter of section 21, Reeve township.

ANTHOZOA—
- Zaphrentis ? sp.

BRYOZOA—
- Cystodictya sp.

BRACHIOPODA—
- Chonetes multicosta Win.
- Orthotetes ? sp.
- Camarotoechia sp.
- Spiriferina solidirostris White
- Spirifer legrandensis Weller ?

PELECYPODA—
- Leda saccata Win.
- Myalina sp.

GASTROPODA—
- Bellerophon sp.
- Bucanopsis sp.
- Meekospira ? sp.
- Orthonychia sp.

CRUSTACEA—
- Phillipsia ? sp.

Two miles northeast of the above described bluff section, near the northwest corner of the northeast quarter of section 23, Reeve township, a part of the Mayne Creek beds is exposed in an abandoned quarry on the property of Mr. Bert Jones. At the present time ten feet of thin-bedded, shelly brownish dolomitic limestone is shown in the quarry face. The upper half contains thin discontinuous bands of chert, and becomes cavernous where long exposed to weathering. Several specimens of a *Productus* and an *Orthotetes?* were collected from the chert. A few small cavities lined with calcite were noted at one point in the middle part of the ledge.

East of the road, near the middle of the west side of section 18, Geneva township, there is a conspicuous outlier of Mayne Creek limestone. About twelve feet of brownish, dolomitic limestone is exposed at the top of the hill. The lower half is massive, cavernous and cherty, and weathers to a brownish pulverulent mass. The upper half is thin-bedded, and contains fossiliferous chert seams. The fossils collected from these seams are:

- Leptaena analoga (Phillips)
- Schizophoria chouteauensis Weller ?
- Reticularia cooperensis (Swallow)
- Composita ? sp.

The Mayne Creek formation appears again in a small abandoned quarry in the north bank of a small creek about fifty yards west of the road in the southeast one-fourth of the southeast quarter of section 9, Reeve township. Ten feet of soft, brownish, thin-bedded dolomite, with occasional bands and lenses of light gray chert are shown. Numerous poorly preserved fossils occur in the chert.

Butler County.—The Kinderhook beds constitute the highest consolidated rock over a small area in the southwestern part of Butler county. The distribution of the formation as indicated in Arey's geological map of the county[65] is only approximately correct. For example, the narrow area of Kinderhook represented in the northwestern part of Madison township and extending into the southwestern part of Pittsford township probably does not exist. Apparently the fact that Williams[66] erroneously referred to the Kinderhook the Owen limestone which outcrops near the middle of the north-south line between section 18, Madison township, Butler county, and section 13, Geneva township, Franklin county, is responsible for the confusion. Again the occurrence of Sheffield shale three-fourths mile north of the town of Aplington in Monroe township as described below necessitates a shifting of the Kinderhook border in that region some distance to the northeast.

The Kinderhook formations represented in Butler county are the Sheffield, the Chapin and the Mayne Creek. The Sheffield covers by far the largest area.

THE SHEFFIELD BEDS.—The basal member of the Kinderhook series of this part of the state outcrops at a number of localities in Washington and Monroe townships.

In the right bank of Beaver creek east of the center of section 31, Washington township, there appears eight feet of bluish, plastic shale with thin intercalated layers of brownish dolomite. It is believed that these beds should be correlated with the lower shaly division of the Sheffield.

Near the middle of the north line of section 18, Washington township, about six feet of soft thin-bedded cherty dolomitic shale outcrops in a roadside gully. Silicified specimens of the following forms were collected at this locality:

Schellwienella ? sp.
Productus blairi Miller
Camarotoechia chouteauensis Weller
Spirifer sp. (resembling S. whitneyi)
Cliothyridina prouti (Swallow)

These species indicate the topmost division of the Sheffield.

Beds carrying the same fauna are exposed in an abandoned quarry in section 28, Washington township, a few rods west of the railway bridge over Beaver creek. Five feet of brownish

65 Iowa Geol. Survey, vol. XX, opposite page 58.
66 Williams, I. A., Iowa Geol. Survey, vol. XVI, p. 487.

arenaceous and dolomitic shale is shown here at the present time.

In Monroe township, this fossiliferous zone of the Sheffield may be studied to good advantage in the gullies along the north-south road in the northwest quarter of section 20, three-fourths of a mile north of the town of Aplington. Seven feet of soft brownish dolomite with a few imperfect casts and impressions of fossils is here overlain by four feet of soft brownish dolomitic shale which bears silicified specimens of the same species as listed above.

Arey[67] reports the occurrence of Lime Creek beds in this vicinity but no trace of such beds could be found by the writer.

THE CHAPIN AND MAYNE CREEK BEDS.—At two points in Washington township these formations appear in contact. The most complete exposure is found in an old quarry near the center of the west half of section 31, between Beaver creek and the Illinois Central railroad. This has been described by Arey[68] and the following description is copied in part from his:

Section in section 31, Washington township.

		FEET	INCHES
5.	Limestone, thin-bedded, yellow to drab, with bands and nodules of chert	3	
4.	Limestone, brown, sugary, dolomitic; with a five inch band of chert in the lower half	1	10
3.	Chert, in the form of a series of lenses		3
2.	Dolomite, massive, yellowish, finely arenaceous, fossiliferous	6	6
1.	Dolomite, brownish, massive, tough; bearing casts and impressions of fossils. Exposed	5	6

Beds 1 and 2 of the above section bear a Chapin fauna and they are referred to that formation. The overlying cherty beds are correlated with the Mayne Creek. Near the southwest corner of the southwest quarter of section 28 there is an east-west ridge just north of Beaver creek. On the south side of this the following composite section is exposed:

		FEET
3.	Dolomite, soft, yellowish, thin-bedded; with occasional small lenses of chert. No identifiable fossils noted	7½
2.	Sandstone, very fine, soft, yellowish, with occasional thin layers of brownish dolomite. A zone in lower part filled with casts of fossils	7
1.	Dolomite, tough, brownish. Fossils scarce	4

67 Iowa Geol. Survey, vol. XX, p. 36.

68 Idem, p. 39.

The fauna of beds 1 and 2 suggests their Chapin age. Bed 3 is referred to the Mayne Creek. The species collected from bed 2 are listed below:

Schizoblastus roemeri Shumard
Fenestella sp.
Productus sp.
Productus sp.
Schellwienella ? sp.
Spirifer legrandensis Weller
Spirifer platynotus Weller ?
Syringothyris sp.
Cliothyridina tenuilineata (Rowley) ?
Conocardium sp.

Another section in which appear beds believed to be of Mayne Creek age is in an old quarry in the southeast one-fourth of the northeast quarter of section 32 of Washington township. Eighteen feet of fine gray massive sandstone with several discontinuous seams of chert is exposed. Fragments of fossils occur in the cherts.

Wright County.—The Kinderhook formation is believed to form the bed rock over the greater part of Wright county though no exposures of rocks of this age are described by Macbride[69] in his report on the geology of Hamilton and Wright counties.

Humboldt County.—The Kinderhook is nearly everywhere covered by glacial drift in Humboldt county. But in the vicinity of the towns of Humboldt and Rutland, oölitic limestones of this age appear at the surface over small areas. The largest of these appears in the east bank of the West Fork of Des Moines river in the southwest part of the town of Humboldt. At an abandoned lime kiln in this area, the limestone has an exposed thickness of twelve feet. The rock is gray in color, and the texture is typically oölitic. In the lower part of the section, the oölite grains are small and the matrix lithographic, but in the upper part the grains are coarser and the texture is more crystalline.

Macbride[70] lists the following gastropods from the oölites of the Humboldt area:

Loxonema yandellana Hall ?
Straparollus macromphalus Winchell
Straparollus obtusus (Hall)
Straparollus planispira Hall ?
Straparollus springvalensis (White)
Bellerophon sublaevis Hall.

The following additional forms have been collected and de-

69 Iowa Geol. Survey, vol. XX, pp. 100-149; 1910.
70 Iowa Geol. Survey, vol. IX, p. 123.

scribed from this locality by Sardeson[71] who remarks that "fossils are readily found in certain strata at Humboldt along the river's bank from Bicknell's Park to the dam . . . ."

Euomphalus luxus White	Myalina ? abstemia Sardeson
Loxonema difficile Sardeson	Cyathophyllum glabrum Keyes

On the east side of the river just below the dam at Humboldt fifteen feet of oölite is exposed in the river bank. The texture of some of the upper layers is very finely oölitic and approaches that of a lithographic limestone, but elsewhere the grains are large except for occasional thin seams. Stratification is very imperfectly developed, and the rock shows many fractures. Slickensided structure is abundantly shown along the fissures.

In the northeast quarter of section 33, Rutland township, just east of the Humboldt cemetery, the oölite is well exposed in a small drainage ditch about four feet in depth. The upper one-third of the outcrop consists of coarse oölite, but in the lower two-thirds the grains are very fine and the rock is dense and rather brittle. Large pisolitic masses ranging from the size of a pea to three or four inches in diameter are common throughout. Many of these consist of a nodule of oölitic limestone coated with concentric layers, but a few show concentric structure throughout. No fossils were noted.

At the town of Rutland the oölite is exposed on the south side of the river both above and below the bridge. On the north side there are good exposures farther west, in the vicinity of the dam. The maximum thickness exposed on this side is ten feet and the rock is rather brittle. The lower half is not well stratified, and weathers to irregular polyhedrons. The oölite grains are small in this part. The upper half is evenly bedded, and the oölite grains are large.

Sardeson regards these beds as identical with those at Humboldt. He lists the following species from this locality:

Cyathophyllum glabrum Keyes	Murchisonia sp. undet.
Macrodon cf. cochlearis Win.	

In the south bank of a small creek southwest of the creamery at Rutland, there is a very interesting section showing the St.

71 Am. Geologist, vol. XXX, p. 300 ff.; 1902.

Louis limestone in contact with the Kinderhook. The succession is as follows:

Section near the creamery at Rutland.

	FEET
4. Drift	2
ST. LOUIS	
3. Limestone, brecciated, dense, gray, imperfectly dolomitized; lower surface irregular and undulating	3
2. Limestone, dense, gray, tough, in the form of one undulating layer which fills irregular depressions in the limestone beneath	½ to 1
KINDERHOOK	
1. Limestone, light gray; stratification very imperfect; finely oölitic except in middle part where there is a thin seam of coarse oölite	2 to 3½

At the mouth of this creek, in the southeast quarter of the northwest quarter of section 29, Rutland township, the contact of the Kinderhook and the St. Louis is again shown. At this point about four feet of the oölite is exposed above the bed of the creek. This is overlain by three feet of gray tough St. Louis dolomite which weathers yellowish. At one point in the exposure this dolomite grades laterally, in part, into unaltered gray brecciated limestone.

About seventy-five yards below this exposure the contact is shown in the river bank. Three feet of Kinderhook oölite is succeeded by a two to three foot layer of yellowish undulating limestone, and this again by four feet of dense gray thin-bedded unaltered limestone which locally is mashed into mounds of breccia. The Kinderhook at this locality also shows considerable fracturing and slight brecciation. Several other exposures between this point and the bridge show similar contact relationships. The gray limestone of the St. Louis is five and one-half feet thick at one point.

The relation of the Humboldt oölite to the Kinderhook formations of Hardin and Franklin counties has not been determined definitely owing to the absence of exposures of underlying formations in Humboldt and adjacent counties. The fauna and the lithologic character of the oölite are of little aid in correlating it with other Kinderhook formations. The fact that it is overlain by the St. Louis limestone at several localities indicates that it represents the topmost member of the Kinderhook group in this part of the state. It may be younger than the

Alden limestone of Hardin county, which has not been found in contact with the St. Louis, but the possibility of greater erosion of the Kinderhook in the Humboldt area than in the Iowa Falls area in pre-St. Louis time must be borne in mind. Inasmuch as the Humboldt oölite bears no resemblance, either lithologically or faunally, to the Iowa Falls or older formations, it is believed to represent either a more öolitic and more fossiliferous facies of the Alden limestone or a younger formation not preserved in Hardin county.

In the southwestern part of Humboldt county a limestone formation which is referred provisionally to the Kinderhook group outcrops at several localities. This was formerly correlated with the St. Louis limestone by Macbride[72] who describes the exposures as follows:

"At various points in Weaver township, as in the northeast quarter of section 9, there are exposures of limestone rock which must be considered here. These are mostly in the form of quarries, originally sink-holes, which have been developed to meet the local demand for rubble stone. From the exposure in section 9, just mentioned, a large amount of rock has been taken. The quality seems to be excellent, and the bedding is such as to make comparatively light the labor of the quarrymen. The rock is a rather coarse-grained, crystalline, encrinital limestone, reminding one of rocks elsewhere referred to the Augusta stage, unlike any seen anywhere in the river exposures. Open sink-holes in this neighborhood show almost everywhere rock of the same character, so that it is probable that all the southwestern part of the county is underlain by similar strata, except where removed by pre-glacial erosion. In the town of Gilmore, for instance, a similar rock in the northeast part of the village comes to the surface of the ground, while a few rods west, the town well goes down sixty feet before encountering rock at all. Nevertheless, we may consider this peculiar encrinital limestone as the surface rock for all that part of Humboldt county lying south of the west fork, except the flood plains immediately adjacent to the stream. The same rock extends far into Pocahontas county, and is there exposed in precisely the same way. Thus in Clinton township, in Pocahontas county, one mile west of Gilmore, and one and one-half miles north, is a sink-hole quarry, which for years has been very extensively worked".

Fossils were collected from this limestone in the outcrops across the county line in Pocahontas county. The age of the

72 Iowa Geol. Survey, vol. IX, p. 132.

formation is discussed in connection with the description of these exposures.

Pocahontas County.—The same limestone formation which outcrops in Weaver township, Humboldt county, forms the bed rock along a narrow belt in the extreme eastern parts of Garfield and Lake townships in Pocahontas county. To the west it passes under Cretaceous deposits. The Pocahontas county extension of this formation was also formerly referred to the St. Louis upon the basis of a few poorly preserved fossils.[73]

In the quarry of the Gilmore Portland Cement Company, one and one-half miles northwest of Gilmore City, the following beds are exposed:

Section in Gilmore Portland Cement Company's quarry.

		FEET
5.	Limestone, light gray, fine-grained, thin-bedded, rather soft. Exposed at the south end of the quarry	4½
4.	Limestone, compact, gray, dense, fine-grained, brittle, very faintly oölitic, massive	10
3.	Limestone, as in bed 2 but filled with cylindrical corals	2½
2.	Limestone, gray, oölitic, compact, brittle	4
1.	Limestone, gray, massive, slightly crinoidal, oölitic. Exposed	6

The beds dip gently in a southeasterly direction in the quarry face, the axis of a low anticline being shown in the northwest end of the quarry.

One-half mile northwest of the preceding section similar beds are shown in two adjoining sink-hole quarries:

Section in sink hole quarries.

		FEET
3.	Limestone, gray, compact, brittle, slightly oölitic	7
2.	Limestone, gray, crinoidal, massive, the matrix oölitic, crinoid fragments less pronounced and oölitic character more characteristic in lower half. Showing tendency towards cross bedding	8
1.	Limestone, gray, compact, fine-grained, slightly oölitic, thin-bedded and somewhat shaly below. Exposed	4½

The following fossils were collected from these exposures:

List of fossils from sink hole quarries two miles northwest of Gilmore City.

ANTHOZOA—
- Zaphrentis sp.
- Monotrypa sp.

BRACHIOPODA—
- Streptorhynchus sp.
- Orthotetes ? sp.
- Productus sp.
- Camarotoechia sp.
- Camarotoechia sp.
- Spiriferina sp.
- Spirifer sp.
- Spirifer ? sp.
- Spirifer sp
- Syringothyris ? sp.
- Eumetria sp.
- Eumetria sp.
- Cliothyridina cf. C. obmaxima (McChesney)
- Composita trinuclea (Hall)

GASTROPODA—
- Orthonychia sp.

73 Iowa Geol. Survey, vol. IX, p. 132, and vol. XV, p. 255.

All of the beds in these exposures belong to a horizon below the coral zone (bed 3) of the cement quarry. The total exposed thickness of the formation, therefore, is not less than thirty-six and one-half feet. A well record at the cement plant is reported to have shown a thickness of forty-one feet of this type of limestone, succeeded below by a brownish dolomitic limestone.

The lack of diagnostic fossils in the fauna listed above, most of the species being undescribed, together with the absence of exposures of associated formations of known age renders the exact correlation of the Gilmore City limestone impossible at present. Lithologically it resembles the Alden limestone of Hardin county more closely than any other formation in north-central Iowa, but unfortunately no identifiable fossils were found in the Alden limestone which could be compared with those collected near Gilmore City. The occurrence of brownish dolomitic limestone below the Gilmore City oölitic limestone as reported in the boring at the cement quarry reminds one of the similar succession in Hardin county where the brownish Iowa Falls dolomite underlies the oölitic Alden limestone. However, exact correlation must await the discovery of better preserved fossil remains in the Alden limestone than have hitherto been found.

The relation of the Gilmore City limestone to the Humboldt oölite could not be determined by field study since no exposure showing them in contact has been found. The inference is that the Humboldt oölite is the younger of the two formations.

Cerro Gordo County.—The Kinderhook series extends into the southwestern part of Cerro Gordo county. Calvin[74] wrote as follows regarding the beds:

"Strata of the Kinderhook stage of the Lower Carboniferous series are exposed along Beaver Dam creek in section 36 of Pleasant Valley township. Where the county line road, on the south side of the section, crosses the creek, the Kinderhook beds are composed of soft, shaly, magnesian limestone; but in Franklin county, a short distance south of the road, beds that occupy a higher position are exposed in the sides of the valley, and these are firm enough to afford quarry stone suitable for bridge piers, foundations, and other rough masonry. An *Athyris* re-

[74] Iowa Geol. Surv., vol. VII, p. 170.

sembling *Athyris proutii* Swallow, a *Productus* related to *P. punctatus,* and *Orthothetes* sp. are the characteristic fossils. The next exposures east of the Kinderhook outcrops are the Devonian beds already noted on Beaver creek. The contact of the Carboniferous with the Devonian was not observed, but the line of overlap lies between the two localities last named."

Kossuth, Hancock and Winnebago Counties.—The Kinderhook apparently extends over this area but it is deeply buried by drift. No exposures are referred to in the literature on these counties. The Cretaceous deposits of western Kossuth county are believed to rest upon the Kinderhook beds.

Correlation of the Kinderhook of North-central Iowa

The Kinderhook of north-central Iowa attains its most typical development in Franklin, Butler and Hardin counties. From a study of individual exposures and the log of a deep well at Iowa Falls in Hardin county the series has been subdivided into six distinct formations as follows:

The Alden limestone
The Iowa Falls dolomite
The Eagle City beds
The Mayne Creek beds
The Chapin beds
The Sheffield beds

The paucity of fossils in the lower shaly strata of the Sheffield beds renders their age uncertain. Further study may indicate their Upper Devonian affinities. The collections obtained from the limestone and dolomitic shale directly above the shales of doubtful age contain a few species of brachiopods and an occasional fish remain. With the exception of a *Spirifer* which resembles *Spirifer whitneyi* of the Upper Devonian the brachiopods are Kinderhook types and are for the most part species characteristic of the Chouteau formation.

The faunas of the Chapin, Mayne Creek, Eagle City and Iowa Falls formations contain many undescribed species but the assemblages are all distinctly Kinderhook in aspect. Occasional species of Burlington brachiopods occur in the higher formations of the series.

The appearance of characteristic Chouteau species in the upper portion of the Sheffield formation and in the Chapin beds is worthy of note. The latter formation has yielded thirty-five species. Twenty of these have been identified specifically. Nearly all of the twenty are characteristic Chouteau forms and twelve of them occur in beds 6 and 7 of the Kinderhook at Burlington.

In this connection, Weller's conclusions regarding the age of the Chouteau fauna in Missouri are of interest.[75]

"From the outline of the faunal history here given, it is evident that the arrangement of the Kinderhook formations into three successive divisions, the Louisiana, Hannibal, and Chouteau, as has usually been done, does not express the proper relationships of the faunas. The Chouteau fauna, in some of its expressions, is without doubt as old as the Louisiana fauna, and it is as impracticable to make one continuous section to contain all of the Kinderhook formations, as it would be to make a standard Devonian section to include the formations of New York and Iowa."

From the above statement it is apparent that while the faunas of the upper Sheffield[76] and Chapin beds have Chouteau affinities and are more closely related to the faunules of beds 6 and 7 at Burlington than to those of the underlying Kinderhook beds, this does not necessarily indicate the exact equivalency of these beds.

The evidence supports the view that the Chouteau fauna appeared earlier in Kinderhook time in the northern area, as it did in central Missouri, than in the Burlington area. The *Chonopectus* fauna of the lower beds in the Burlington area may have existed simultaneously with the Chouteau fauna to the north.

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75 Jour. Geol., vol. 17, pp. 274, 275; 1909.

76 In connection with the term *Sheffield* attention should be called to the fact that in a paper by C. L. Fenton on the Upper Devonian of Iowa in The American Journal of Science, volume xlviii, pages 355-376, 1919, the name Sheffield was applied to the plastic blue shale which underlies the marly fossiliferous zones of the Cerro Gordo sub-stage at Rockford, Juniper Hill, Hackberry Grove, Mason City and elsewhere north and east of Sheffield. Fenton was doubtless under the impression that the shales at Sheffield were identical with those of Devonian age at Mason City and Rockford, being apparently misled by Williams' error in describing and mapping the shales at Sheffield as Upper Devonian in the Franklin county report. (Iowa Geological Survey, volume xvi, pages 477-481, 502 and map opposite page 506.) However, the beds at Sheffield are Kinderhook according to Van Tuyl's evidence and the name as employed by him seems appropriate. Since the name Sheffield for obvious reasons is unavailable for the Upper Devonian shales, the name *Juniper Hill* is here offered for that formation. Juniper Hill, located about one mile northwest of the Rockford Brick and Tile Plant, is in the midst of numerous good exposures of the formation and where its relation to the beds above and below may be readily observed.—A. O. Thomas.

CHAPTER III

THE OSAGE GROUP

Definition of Osage

The term Osage group was proposed by H. S. Williams[1] in 1891 to include the Burlington and Keokuk formations. In later reports several authors have included the Warsaw beds in the Osage also, but Weller[2] now refers the Warsaw to the overlying Meramec group.

Keyes[3] has used the term Augusta series to include the Burlington, Keokuk and Warsaw formations but as Weller[4] has pointed out the term Osage clearly has priority.

Distribution of the Group

Exposures of the Osage group are confined to the southeastern part of Iowa. For the most part they appear in a sinuous northwest-southeast trending belt of irregular width extending from southern Lee county on the south to Keokuk county on the north. It is probable that rocks of this age are present beneath the glacial deposits in southwestern Iowa and south-central Poweshiek counties also. The belt is bounded by the Kinderhook group on the northeast and by the Meramec group on the southwest. As a result of the study of deep well records the group is known to be present beneath Meramec and younger formations in south-central Iowa.

The Osage attains its full development in Iowa in Des Moines, Lee and Van Buren counties only. To the northwest there is a thinning of the group from above downwards probably due in part to nondeposition and in part to post-Osage erosion. In the vicinity of Keokuk both members of the group are present, though the Burlington limestone is below the surface. In south-

1 U. S. Geol. Survey Bull. 80, p. 169.
2 Illinois Geol. Survey, Bull. 41, p. 80; 1920.
3 Iowa Geol. Survey, vol. I, p. 50; 1893.
4 Am. Geologist, vol. XXII, p. 12 ff; 1898.

ern Des Moines county the Burlington and Keokuk formations are fully developed and both are well exposed. Still farther northwest, in Keokuk and Washington counties, the Keokuk is reduced in thickness.

Lithologic Character

The Osage group is composed of interstratified gray to bluish gray crinoidal limestone, gray to brownish dolomitic limestone and ash-colored to bluish shales. The bluish gray crinoidal limestones are characteristic of the Keokuk while the gray ones appear in the Burlington. Shale beds increase in number and thickness towards the top of the group, presumably as a result of a gradual recession of the sea from the area during Osage time.

Thickness

Where both formational members of the Osage are fully developed, it has a thickness of 134 feet. In Washington and Keokuk counties it is probably not much more than one hundred feet thick.

Stratigraphic Relations

The Osage group apparently is conformable with the Kinderhook beds below. It is succeeded by the Meramec beds without a break in the extreme southeastern part of the state but to the northwest, where the St. Louis limestone member of the Meramec overlaps successively older formations, a well marked disconformity exists at the top of the group.

The Burlington Limestone

NOMENCLATURE

The Burlington limestone was so named by Hall[5] because of its typical development in the exposures in and near the city of this name in Des Moines county, Iowa.

AREAL DISTRIBUTION

The distribution of the Burlington limestone as an individual

5 Rept. Geol. Survey, State of Iowa, vol. I, Part i, p. 92; 1858.

unit is not definitely indicated on the geological map of Iowa, since this member is included with the Keokuk in the Osage group, the smallest division which has been mapped. The area over which the Burlington constitutes the surface rock represents only a small part of the area indicated as Osage, owing to the fact that a large proportion of this area is underlain by the Keokuk beds. Previous studies have shown that the exposures of Burlington limestone are confined to a restricted area in the southeastern part of the state, including parts of Van Buren, Lee, Des Moines, Louisa, Washington, and possibly Keokuk counties.

In Van Buren county it forms the surface rock over a small area in the bed of Des Moines river at Bentonsport. It underlies a larger area in the eastern part of Lee county, but its outcrops are confined to a few isolated localities. Thus, there are small exposures in the bed and banks of Lost creek southeast of Denmark; in a number of small quarry openings west of Wever; and in the bed and banks of Skunk river and along its tributaries at and near South Augusta.

It doubtless constitutes the surface rock over the greater part of the eastern half of Des Moines county, but its outcrops are limited, the more important ones being along the ravines about Augusta, in the bluffs of Mississippi river, and numerous other natural exposures, quarries and street cuts in and near the city of Burlington.

The area underlain by the Burlington in Louisa county is confined to its southwestern and southern parts, the more important exposures being located in Morning Sun township.

Northwestward from Louisa county actual exposures of the Burlington have been found by the writer only in Washington county, although there is a strong probability that it underlies the drift over small areas in northeastern Keokuk and southern Iowa counties. In Washington county, it follows a broad, irregular band extending across the central part of the county from southeast to northwest. The most satisfactory exposures are located on and near Crooked creek, northwest of Washington.

LITHOLOGIC CHARACTER

The Burlington limestone succeeds the Kinderhook in vertical succession with no indications of a stratigraphic break. Lithologically, the formation is a unit, but it is desirable to subdivide it into the Lower and Upper Burlington upon the basis of its crinoid fauna, as was pointed out long ago by Niles and Wachsmuth.[6]

The Montrose cherts, which were referred by Keyes[7] to the Upper Burlington, have been demonstrated by the present study to represent the basal member of the Keokuk limestone (see page 142).

The Burlington limestone has long been noted for its profusion of crinoid remains. Probably at no other time in the earth's history have crinoids flourished so prolifically. More than four hundred species of crinoids have been described from this formation alone. At several horizons in the limestone the beds are made up almost completely of the disconnected plates of the calyces and fragments of the stems and arms of crinoids. When they are pure these crinoidal beds are light gray to whitish in color; when impure, they are discolored brownish. Normally they contain occasional discontinuous bands and nodules of chert. Stylotytic seams also are abundantly developed. Alternating with these crinoidal beds and comprising a large part of the formation are beds of fine-grained brownish magnesian, cherty limestone. In the vicinity of Burlington, Iowa, there is a seam of bluish shale averaging about one foot in thickness, in the lower part of the Upper Burlington, but this has not been observed at any other locality in Iowa.

The upper boundary of the Burlington is marked by a fish bed of widespread extent. Regarding this, Wachsmuth and Springer[8] say:

"The close of the Upper Burlington limestone was marked by an extraordinary destruction of fishes whose remains, in the form of teeth and spines, are found in the greatest profusion in a stratum two to ten inches in thickness, which occurs at the very top of the regular limestone beds. It is one of the best stratigraphic landmarks that we know in this formation, as it is found over a wide area in localities over a hundred miles apart and always in the same position relative to the heavy limestone beds."

6 Am. Jour. Science, 2d ser., vol 42, pp. 95-99; 1866.
7 Iowa Geol. Survey, vol. III, p. 341; 1893.
8 Proc. Acad. Nat. Sciences, Philadelphia, 1878, Part II, p. 227.

THICKNESS

The thickness of the Burlington limestone in the type section where it is fully developed is approximately seventy-one feet, of which twenty-seven feet is referred to the Upper Burlington and the remainder to the Lower. In Louisa county the lower member is only one-half as thick as at Burlington, while the upper member is seventeen feet in thickness.

AREAL DESCRIPTION BY COUNTIES

Des Moines and Lee Counties.—The type section of the Burlington limestone is at Burlington, Iowa, where numerous exposures of the formation in and near the city make it possible to work out the complete succession of beds and collect their fossils. The following generalized section will illustrate the character of the formation at this locality:

General section of Burlington limestone at Burlington.

	FEET
UPPER BURLINGTON.	
6. Limestone, brownish to whitish, crinoidal; with occasional chert bands; middle part sometimes magnesian; a thin zone of fish teeth near the top	10-12
5. Shale, bluish, argillaceous, not everywhere present	1¼
4. Limestone, light gray, crinoidal, very fossiliferous	5-8
3. Limestone, brownish, crinoidal	6-8
LOWER BURLINGTON.	
2. Limestone, brownish, fine-grained, magnesian, irregularly bedded; cherty, especially near the base; in places bears a layer of crinoidal limestone near the middle	34-39
1. Limestone, brownish, crinoidal, massive, locally magnesian in part	8-11
KINDERHOOK	

Beds 1 and 2 represent the Lower Burlington. They are well exposed in the old quarry back of the high school, in the quarries at Picnic Point and in the Mississippi river bluff at several points in and near Burlington.

Bed 3 outcrops in the bluff at the Cascade and on the slope below the Miller quarry above the Cascade.

Beds 4 and 6 are excellently exposed in the Miller quarry above the Cascade. Overlying bed 6 at this point, there appears fifteen feet of brownish magnesian limestone, crinoidal in the middle part, which yielded no identifiable fossils but which is referred to the basal Keokuk.

The fossils collected by the writer from the successive horizons of the Burlington limestone are listed below:

List of fossils from bed 1 of the Burlington limestone at Burlington.

CRINOIDEA—
- Platycrinus ornogranulus McChesney ?
- Platycrinus sculptus Hall ?
- Platycrinus sp.
- Cactocrinus multibrachiatus (Hall)
- Cactocrinus proboscidialis (Hall) ?
- Batocrinus subaequalis (McChesney)
- Batocrinus sp.
- Dorycrinus unicornis (O. and Sh.)

BLASTOIDEA—
- Cryptoblastus melo O. and Sh.

BRYOZOA—
- Fenestella serratula Ulr. ?

BRACHIOPODA—
- Dielasma osceolensis Weller
- Rhipidomella burlingtonensis (Hall)
- Spirifer forbesi N. and P.
- Spirifer grimesi Hall
- Spirifer imbrex Hall ?
- Spirifer louisianensis Rowley
- Brachythyris sp.
- Syringothyris ? sp.
- Athyris lamellosa (Leveille)

PELECYPODA—
- Aviculopecten ? sp.

GASTROPODA—
- Orthonychia sp.

TRILOBITA—
- Phillipsia ? sp.

VERTEBRATA—
- Fish teeth

List of fossils from bed 2 of the Burlington limestone at Burlington.

ANTHOZOA—
- Triplophyllum dalei (M.-E. and H.)
- Zaphrentis sp.

CRINOIDEA—
- Platycrinus sp.

BRACHIOPODA—
- Chonetes illinoisensis Worthen
- Pustula alternata (N. and P.)
- Spirifer grimesi Hall
- Brachythyris suborbicularis (Hall)
- Cliothyridina incrassata (Hall)

List of fossils from bed 3 of the Burlington limestone at Burlington.

ANTHOZOA—
- Hadrophyllum glans White
- Triplophyllum dalei (M.-E. and H.) ?
- Monilopora sp.

CRINOIDEA—
- Periechocrinus sp.
- Megistocrinus cf. M. evansi (O. and Sh.)
- Eutrochocrinus christyi (Shum.)
- Uperocrinus pyriformis (Shum.)
- Physetocrinus ventricosus (Hall)
- Strotocrinus regalis (Hall)
- Platycrinus planus O. and Sh. ?
- Platycrinus sp.
- Platycrinus sp.
- Eucladocrinus praenuntius W. and Sp. ?

BLASTOIDEA—
- Orbitremites norwoodi (O. and Sh.)

BRACHIOPODA—
- Chonetes sp.
- Rhipidomella burlingtonensis (Hall)
- Schizophoria swallovi (Hall)
- Spirifer grimesi Hall
- Syringothyris typus Winchell
- Spiriferella plena (Hall)
- Reticularia pseudolineata (Hall)
- Reticularia sp.
- Cliothyridina incrassata (Hall)

List of fossils from bed 4 of the Burlington limestone at Burlington.

ANTHOZOA—
- Zaphrentis calceola (W. and W.)
- Zaphrentis sp.
- Triplophyllum dalei (M.-E. and H.)
- Hadrophyllum glans (White)

CRINOIDEA—
- Platycrinus sp.
- Uperocrinus pyriformis ? (Shum.)

BRYOZOA—
- Fenestella burlingtonensis Ulrich
- Rhombopora gracilis Ulrich
- Cystodictya sp.

BRACHIOPODA—
- Chonetes illinoisensis Worthen
- Productus burlingtonensis Hall
- Productus sp.
- Rhipidomella dubia (Hall)
- Dielasma sp.
- Spirifer grimesi Hall
- Spirifer incertus Hall
- Syringothyris typus Win.
- Athyris lamellosa (Leveille)

GASTROPODA—
- Straparollus sp.
- Lepetopsis capulus (Hall)
- Platyceras sp.
- Orthonychia sp.

TRILOBITA—
- Phillipsia ? sp.

List of fossils from bed 6 of the Burlington limestone at Burlington.

ANTHOZOA—
- Zaphrentis calceola (W. and W.)
- Zaphrentis sp.
- Triplophyllum dalei (M.-E. and H.)
- Amplexus fragilis White and St. John

CRINOIDEA—
- Eretmocrinus calyculoides (Hall)
- Macrocrinus konincki (Shum.)
- Macrocrinus verneuilianus (Shum.)
- Dizygocrinus rotundus (Shum.)
- Dizygocrinus andrewsianus (McChesney)
- Eutrochocrinus christyi (Shum.)
- Eutrochocrinus lovei (W. and Sp.) ?
- Uperocrinus ? sp.
- Aorocrinus parvus (Shum.)
- Dorycrinus quinquelobus (Hall)
- Dorycrinus sp.
- Agaricocrinus ornotrema Hall
- Teleiocrinus umbrosus (Hall)
- Physetocrinus ventricosus (Hall)
- Physetocrinus ? sp.
- Strotocrinus glyptus (Hall) ?
- Platycrinus halli Shum.
- Platycrinus sp.

BLASTOIDEA—
- Pentremites elongatus Shum.
- Orbitremites norwoodi (O. and Sh.)

BRYOZOA—
- Batostomella ? sp.
- Fenestella burlingtonensis Ulrich
- Rhombopora sp.
- Rhombopora sp.
- Rhombopora sp.
- Cystodictya ? sp.
- Cosinium latum Ulrich

BRACHIOPODA—
- Schellwienella ? sp.
- Chonetes illinoisensis Worthen ?
- Chonetes sp.
- Productus burlingtonensis Hall
- Productus sp.
- Pustula alternata (N. and P.)
- Rhipidomella burlingtonensis (Hall)
- Rhipidomella dubia (Hall)
- Rhynchopora sp.
- Dielasma sp.
- Dielasma sp.
- Spirifer grimesi Hall
- Spirifer incertus Hall
- Spirifer sp.
- Spirifer sp.
- Brachythyris suborbicularis (Hall)
- Brachythyris sp.
- Syringothyris typus Win. ?
- Spiriferella plena (Hall)
- Reticularia pseudolineata (Hall)
- Eumetria sp.
- Athyris lamellosa (Leveille)
- Cliothyridina tenuilineata (Rowley) ?
- Cliothyridina obmaxima (McChesney) ?
- Cliothyridina incrassata (Hall)

GASTROPODA—
- Lepetopsis capulus (Hall)
- Orthonychia pabulocrinus (Owen)
- Platyceras obliquum Keyes ?
- Platyceras latum Keyes
- Platyceras paralium W. and W.
- Platyceras sp.

VERTEBRATA—
- Fish teeth

Table Showing Range of Species in Burlington Limestone at Burlington.

	Horizons				
	1	2	3	4	6
ANTHOZOA					
Zaphrentis calceola (W. and W.)	....	....	....	x	x
Zaphrentis sp.	....	....	....	....	x
Zaphrentis sp.	....	....	....	x	....
Zaphrentis sp.	....	x	....	....	....
Triplophyllum dalei (M.-E. and H.)	....	x	x	x	x
Amplexus fragilis White and St. John	....	....	....	....	x
Hadrophyllum glans (White)	....	....	x	x	....
Monilopora sp.	....	....	x	....	....
CRINOIDEA					
Periechocrinus sp.	....	....	x	....	....

Table Showing Range of Species in Burlington Limestone at Burlington—Continued.

	Horizons				
	1	2	3	4	6
Megistocrinus cf. M. evansi (O. and Sh.)			x		
Batocrinus subaequalis (McChesney)	x				
Batocrinus sp.	x				
Eretmocrinus calyculoides (Hall)					x
Macrocrinus konincki (Shum.)					x
Macrocrinus verneuilianus (Shum.)					x
Dizygocrinus rotundus (Shum.)					x
Dizygocrinus andrewsianus (McChesney)					x
Eutrochocrinus christyi (Shum.)			x		x
Eutrochocrinus lovei (W. and Sp.)					x
Aorocrinus parvus (Shum.)					x
Uperocrinus pyriformis (Shum.)			x	x	
Uperocrinus sp.					x
Dorycrinus unicornis (O. and Sh.)	x				
Dorycrinus quinquelobus (Hall)					x
Dorycrinus sp.					x
Agaricocrinus ornotrema Hall					x
Cactocrinus proboscidialis (Hall)	x				
Cactocrinus multibrachiatus (Hall)	x				
Teleiocrinus umbrosus (Hall)					x
Physetocrinus ventricosus (Hall)			x		x
Physetocrinus ? sp.					x
Strotocrinus regalis (Hall)			x		
Strotocrinus glyptus (Hall) ?					x
Platycrinus ornogranulus McChesney	x				
Platycrinus sculptus Hall ?	x				
Platycrinus planus O. and Sh. ?			x		
Platycrinus halli Shum.					x
Platycrinus sp.			x		
Platycrinus sp.			x		
Platycrinus sp.				x	
Platycrinus sp.					x
Platycrinus sp.	x				
Eucladocrinus praenuntius W. and Sp. ?			x		
Eucladocrinus sp.					x
Blastoidea					
Cryptoblastus melo (O. and Sh.)	x				
Orbitremites norwoodi (O. and Sh.)			x		x
Pentremites elongatus Shum.					x
Bryozoa					
Batostomella ? sp.					x
Fenestella serratula Ulrich	x				
Fenestella burlingtonensis Ulrich				x	x
Rhombopora gracilis Ulrich				x	
Rhombopora sp.					x
Rhombopora sp.					x
Rhombopora sp.					x
Cystodictya sp.				x	
Cosinium latum Ulrich					x

Table Showing Range of Species in Burlington Limestone at Burlington—Continued.

	Horizons				
	1	2	3	4	6
BRACHIOPODA					
Schellwienella ? sp.					x
Chonetes illinoisensis Worthen		x		x	x
Chonetes sp.			x		
Chonetes sp.					x
Productus burlingtonensis Hall				x	x
Productus sp.					x
Productus sp.				x	
Pustula alternata (N. and P.)		x			x
Rhipidomella burlingtonensis (Hall)	x		x		x
Rhipidomella dubia (Hall)				x	x
Schizophoria swallovi (Hall)			x		
Rhynchopora sp.					x
Dielasma osceolensis Weller	x				
Dielasma sp.					x
Dielasma sp.					x
Dielasma sp.				x	
Spirifer grimesi Hall	x	x	x	x	x
Spirifer incertus Hall				x	x
Spirifer forbesi N. and P.	x				
Spirifer imbrex Hall	x				
Spirifer louisianensis Rowley	x				
Spirifer sp.					x
Spirifer sp.					x
Brachythyris suborbicularis (Hall)		x			x
Brachythyris sp.	x				
Brachythyris sp.					x
Syringothyris typus Win.			x	x	x?
Syringothyris ? sp.	x				
Spiriferella plena (Hall)			x		x
Reticularia pseudolineata (Hall)			x		x
Eumetria sp.					x
Athyris lamellosa (Leveille)	x			x	x
Cliothyridina tenuilineata (Rowley) ?					x
Cliothyridina obmaxima (McChesney) ?					x
Cliothyridina incrassata (Hall)		x	x		x
PELECYPODA					
Aviculopecten ? sp.	x				
GASTROPODA					
Lepetopsis capulus (Hall)				x	x
Straparollus sp.				x	
Orthonychia pabulocrinus (Owen)					x
Orthonychia sp.				x	
Orthonychia sp.	x				
Platyceras obliquum Keyes					x
Platycreas latum Keyes					x
Platyceras paralium W. and W.					x
Platyceras sp.			x		

Table Showing Range of Species in Burlington Limestone at Burlington—Continued.

	Horizons				
	1	2	3	4	6
Platyceras sp.	....	....	....	....	x
TRILOBITA					
Phillipsia ? sp.	x	....	....	x	....
VERTEBRATA					
Fish teeth	x	....	....	....	x

Wachsmuth and Springer[9] and other investigators have collected and described a large number of other invertebrates, chiefly crinoids, from the Lower and Upper Burlington limestones at this locality in addition to the forms listed above. Unfortunately, neither the time available during the present investigation nor the opportunities for collecting at Burlington rendered it possible for the writer to determine the exact horizon in the section from which each of these came.

In addition to the exposures in the Burlington area, there are other outcrops showing the various phases of the formation in their typical development in outlying districts in Des Moines county. For example, the Lower Burlington is excellently exposed in the Kemper quarries located in the Mississippi river bluff between the city of Burlington and the station of Spring Grove (T. 69 N., R. 2 W., sec. 29, NW. ¼, SW. ¼). The section there is as follows:

Section at Kemper quarries.

		FEET
5.	Limestone, light gray to brown, crinoidal	7½
4.	Limestone, brownish, soft, magnesian, cherty	18
3.	Limestone, light gray or whitish where fresh, but in some places brownish	8½ to 9½
2.	Limestone, buff to brownish, soft, magnesian; with occasional seams of brownish crinoidal limestone; grading into the limestone above	4½ to 5
1.	Limestone, oölitic. Exposed	2

All the beds except numbers 1 and 2, which represent the Kinderhook, are of Lower Burlington age.

9 "The North American Crinoidea Camerata", Mem. Harvard Coll. Mus. Comp. Zool., vol. XXI; 1897.

In the banks of Flint creek in the vicinity of Starr's cave two miles northwest of Burlington, the Lower Burlington is again typically exposed in contact with the Kinderhook below and the lowermost beds of the Upper Burlington above.

The Upper Burlington is very satisfactorily exposed in the quarry of the Burlington Quarry Company located one-half mile north of the Chicago, Burlington, and Quincy railroad shops at West Burlington. The succession of layers at this place is given below:

Section near West Burlington.

		FEET
7.	Drift	13
6.	Limestone, soft, buff, thin-bedded, cherty	3
5.	Limestone, gray to brownish, crinoidal, very cherty in middle part	3½
4.	Limestone, cherty, thin-bedded, gray and crinoidal below, but fine-grained, soft and brownish above	6½
3.	Limestone, gray, crinoidal, with stylolytic seams	6 to 6½
2.	Limestone, gray, crinoidal, finer-grained, with stylolytic seams. Massive when fresh. Upper one and one-half feet brownish, and grading locally into fine-grained nodular limestone. Bearing *Spirifer grimesi, Spiriferella plena, Dizygocrinus rotundus, Pentremites* sp., *Lepetopsis capulus* and other species	9
1.	Limestone, gray, crinoidal, with brownish tint. Locally cherty in upper portion. *Dizygocrinus rotundus, Rhipidomella burlingtonensis, Spirifer grimesi* and *Spiriferella plena*	5½

Beds 1 to 4 represent the Upper Burlington, while beds 5 and 6 are referred to the Keokuk.

In the vicinity of the town of Augusta, nine miles southwest of Burlington, both divisions of the formation are well exposed and afford an opportunity for collecting from all horizons. The most complete section is in the bluff of a creek tributary to Skunk river at South Augusta (NE. ¼, sec. 25, Denmark township).

South Augusta section.

		FEET
UPPER BURLINGTON.		
8.	Limestone, soft, buff, not everywhere present	0-1
7.	Limestone, light gray, crinoidal; with occasional small nodules and thin, irregular, discontinuous seams of chert; some layers very crinoidal; stylolytic	17
6.	Limestone, compact, dense, brownish, nodular, cherty, magnesian; no fossils noted	8
5.	Chert, in the form of a solid band, replacing a layer of crinoidal limestone; some unreplaced crinoid fragments preserved	1
4.	Limestone soft, buff, magnesian	1—1½
3.	Limestone, gray to whitish, crinoidal, cherty, with occasional thin layers of soft buff limestone. The main crinoid zone	7½-8½

LOWER BURLINGTON.

2.	Limestone, fine-grained, soft, bluish gray when fresh but weathering buff; exhibiting numerous concretionary iron stains; with occasional layers of brownish impure cherty crinoidal limestone ranging up to two feet in thickness	12½-13½
1.	Limestone, gray, subcrystalline, very cherty in upper part. Exposed	4

Bed 1 is well exposed also at the mouth of the creek less than one-fourth mile below the bluff, where it causes the rapids in Skunk river.

Bed 3 is excellently exposed farther up the creek on the Frank Crabtree and Menelie properties. This bed outcrops also at the south end of the wagon bridge over Skunk river. Excellent opportunities for collecting crinoids from this bed are afforded at the above localities.

Beds 7 and 8 were formerly quarried in the face of the bluff. They are overlain at one point by twelve feet of cherty limestone of Keokuk age.

The fossils of all the beds from which identifiable specimens were collected are listed below:

List of fossils from bed 1 in the bluff section at South Augusta.

BRYOZOA—
- Fenestella sp.

BRACHIOPODA—
- Productus sp.
- Productus sp.
- Leptaena analoga (Phillips)
- Rhynchonella sp.
- Camarophoria bisinuata (Rowley)
- Schizophoria swallovi (Hall)
- Spiriferina ? sp.
- Spirifer sp.
- Pseudosyrinx ? sp.
- Reticularia sp.
- Composita trinuclea (Hall) ?
- Cliothyridina incrassata (Hall)

List of fossils from bed 1 in the bank of Skunk river at South Augusta.

ANTHOZOA—
- Zaphrentis sp.
- Zaphrentis ? sp.
- Triplophyllum dalei (M.-E. and H.) ?

BRACHIOPODA—
- Chonetes multicosta Win.
- Productus sp.
- Orthotetes ? sp.
- Leptaena analoga (Phillips)
- Rhipidomella dubia (Hall)
- Rhipidomella burlingtonensis (Hall)
- Schizophoria swallovi (Hall)
- Dielasma osceolensis Weller
- Dielasma sp.
- Spiriferina cf. S. subtexta White
- Spirifer grimesi Hall
- Spirifer carinatus Rowley ?
- Spirifer insculptus Rowley
- Spirifer sp.
- Brachythyris suborbicularis (Hall)
- Composita ? sp.
- Cliothyridina parvirostris (M. and W.)

GASTROPODA—
- Straparollus obtusus (Hall)
- Platyceras sp.
- Igoceras sp.

TRILOBITA—
- Griffithides ? sp.

List of fossils from bed 2 in the bluff section at South Augusta.

CRINOIDEA—
- Platycrinus sp.

BRACHIOPODA—
- Schizophoria swallovi (Hall)
- Spirifer grimesi Hall
- Spirifer sp.
- Spiriferella plena (Hall)
- Athyris lamellosa (Leveille)
- Cliothyridina incrassata (Hall)

List of fossils from bed 3 in the bluff section at South Augusta.

ANTHOZOA—
- Triplophyllum dalei (M.-E. and H.)

CRINOIDEA—
- Eutrochocrinus christyi (Shum.) ?

BRACHIOPODA—
- Schizophoria swallovi (Hall)
- Spirifer grimesi Hall
- Spirifer sp.
- Brachythyris suborbicularis (Hall)
- Spiriferella plena (Hall)
- Athyris lamellosa (Leveille)

GASTROPODA—
- Platyceras sp.
- Orthonychia sp.

List of fossils collected from exposures of bed 3 along creek on Crabtree and Menelic properties.

ANTHOZOA—
- Triplophyllum dalei (M.-E. and H.)
- Zaphrentis sp.
- Zaphrentis ? sp.
- Cyathaxonia sp.
- Amplexus sp.

CRINOIDEA—
- Batocrinus grandis W. and Sp.
- Batocrinus cf. B. laura (Hall)
- Macrocrinus konincki (Shum.)
- Eutrochocrinus christyi (Shum.)
- Uperocrinus aequibrachiatus var. asteriscus (M. and W.)
- Uperocrinus pyriformis (Shum.)
- Dorycrinus missouriensis (Shum.)
- Cactocrinus glans (Hall)
- Cactocrinus longus (M. and W.) ?
- Actinocrinus multiradiatus Shum.
- Actinocrinus scitulus M. and W.
- Strotocrinus glyptus Hall
- Platycrinus burlingtonensis O. and Sh.
- Platycrinus discoideus O. and Sh.
- Platycrinus (several species)
- Eucladocrinus pleurovimenus (White)
- Crinoids (several undetermined species)

BLASTOIDEA—
- Pentremites elongatus Shum.
- Orbitremites norwoodi (O. and Sh.)

BRYOZOA—
- Several undetermined species

BRACHIOPODA—
- Productus burlingtonensis Hall
- Pustula alternata (N. and P.)
- Chonetes sp.
- Rhipidomella dubia (Hall)
- Rhipidomella burlingtonensis (Hall)
- Schizophoria swallovi (Hall)
- Spirifer incertus Hall
- Spirifer grimesi Hall
- Spirifer sp.
- Spiriferella plena (Hall)
- Brachythyris suborbicularis (Hall)
- Pseudosyrinx ? sp.
- Athyris lamellosa (Leveille)
- Cliothyridina obmaxima (McChesney)
- Cliothyridina incrassata (Hall)

PELECYPODA—
- Cypricardinia ? sp.

GASTROPODA—
- Lepetopsis capulus (Hall)
- Platyceras (several undetermined species)
- Orthonychia (several undetermined species)

List of fossils collected from exposures of bed 3 at south end of wagon bridge over Skunk river.

ANTHOZOA—
- Triplophyllum dalei (M.-E. and H.)
- Zaphrentis sp.

CRINOIDEA—
- Undetermined (several species)
- Dizygocrinus rotundus (Shum.)
- Physetocrinus ventricosus (Hall) ?
- Uperocrinus pyriformis (Shum.)
- Actinocrinus sp.
- Barycrinus sp.
- Platycrinus (plates of several species)
- Eutrochocrinus christyi (Shum.)

BLASTOIDEA—
- Orbitremites norwoodi (O. and S.)

BRYOZOA—
- Undetermined (several species)
- Cystodictya sp.

BRACHIOPODA—
- Pustula alternata (N. and P.)
- Chonetes multicosta Win.
- Rhipidomella dubia (Hall)
- Rhipidomella burlingtonensis Hall
- Schizophoria swallovi (Hall)
- Spirifer incertus Hall
- Spirifer grimesi Hall
- Brachythyris suborbicularis (Hall)
- Spiriferella plena (Hall)
- Athyris lamellosa (Leveille)
- Cliothyridina incrassata (Hall)

GASTROPODA—
- Igoceras sp.
- Platyceras sp.

List of fossils in bed 7 of the bluff section at South Augusta.

ANTHOZOA—
  Triplophyllum dalei (M.-E. and H.)
BLASTOIDEA—
  Orbitremites norwoodi (O. and S.)
CRINOIDEA—
  Dizygocrinus dodecadactylus (M. and W.)
  Dizygocrinus rotundus (Shum.)
  Uperocrinus pyriformis (Shum.)
  Actinocrinus multiradiatus Shum.
  Platycrinus sp.
BRACHIOPODA—
  Productus burlingtonensis Hall
  Rhipidomella burlingtonensis (Hall)
  Schizophoria swallovi (Hall)
  Spirifer grimesi Hall
  Spirifer incertus Hall
  Spiriferella plena (Hall)
  Cliothyridina incrassata (Hall)
GASTROPODA—
  Platyceras sp.

It will be noted that the faunule obtained from bed 7 of the Upper Burlington limestone in the above section is meager. Much better facilities for collecting from this horizon are afforded by the exposures along the banks of Barb creek, one mile northwest of South Augusta, near the center of section 23, Denmark township. The following species were collected here:

List of fossils from bed 7 of Burlington limestone on Barb creek.

ANTHOZOA—
  Triplophyllum dalei (M.-E. and H.)
  Zaphrentis sp.
  Amplexus sp.
CRINOIDEA—
  Batocrinus laura (Hall)
  Macrocrinus verneuilianus (Shum.)
  Dizygocrinus rotundus (Shum.)
  Dizygocrinus andrewsianus (McChesney)
  Eutrochocrinus christyi (Shum.)
  Uperocrinus hageri (McChesney) ?
  Aorocrinus ? sp.
  Cactocrinus ? sp.
  Platycrinus (plates of several undetermined species)
  Eucladocrinus pleurovimenus (White)
BLASTOIDEA—
  Orbitremites norwoodi (O. and S.)
  Pentremites elongatus Shum.
BRYOZOA—
  Fenestella sp.
BRACHIOPODA—
  Productus burlingtonensis Hall
  Productus (several species)
  Pustula alternata (N. and P.) ?
  Camarotoechia sp.
  Rhipidomella burlingtonensis (Hall)
  Schizophoria swallovi (Hall)
  Spirifer grimesi Hall
  Spirifer incertus Hall
  Brachythyris suborbicularis (Hall)
  Spiriferella plena (Hall)
  Reticularia pseudolineata (Hall)
  Syringothyris ? sp.
  Athyris lamellosa (Leveille)
  Cliothyridina incrassata (Hall)
GASTROPODA—
  Lepetopsis capulus (Hall)
  Platyceras sp.

Near Augusta on the opposite side of Skunk river, there is an excellent exposure of the Upper Burlington, overlain by the Keokuk limestone, in the bed and banks of a small creek one-half mile north of the Augusta bridge in the eastern part of sec. 23, Augusta township. The following section was measured at this locality:

Section of the Upper Burlington limestone at Augusta.

FEET

3. Limestone, coarse-grained, crinoidal; with stylolytic seams; brownish below but light gray above; upper 1 to 1½ feet, fine-

	grained, soft and weathering buff. Some seams in upper part filled with crinoid fragments. Zone of fish teeth 22 inches below top	16 -17
2.	Limestone, soft, buff, cherty, dolomitic; resting on the irregular undulating surface of the bed beneath	1½- 2
1.	Limestone, gray, subcrystalline; with coarser-grained cherty, crinoidal layers in upper and lower parts. Exposed	3

No fossils were collected from bed 2, but beds 1 and 3 yielded numerous species.

List of fossils from bed 1 of section of Upper Burlington limestone at Augusta.

ANTHOZOA—
- Triplophyllum dalei (M.-E. and H.)

CRINOIDEA—
- Platycrinus (plates of several species)

BLASTOIDEA—
- Orbitremites norwoodi (O. and Sh.)

BRYOZOA—
- Evactinopora grandis M. and W. ?
- Rhombopora sp.

BRACHIOPODA—
- Chonetes sp.
- Productus sp.
- Rhipidomella dubia (Hall)
- Rhipidomella burlingtonensis (Hall)
- Schizophoria swallovi (Hall)
- Spirifer grimesi Hall
- Spirifer incertus Hall ?
- Spirifer sp.
- Brachythyris suborbicularis (Hall)
- Spiriferella plena (Hall)
- Syringothyris ? sp.
- Athyris lamellosa (Leveille)
- Cliothyridina incrassata (Hall)
- Cliothyridina parvirostris (M. and W.)

GASTROPODA—
- Lepetopsis capulus (Hall)
- Platyceras sp.

List of fossils from bed 3 of section of Upper Burlington limestone at Augusta.

ANTHOZOA—
- Zaphrentis sp.
- Triplophyllum dalei (M.-E and H.)
- Hadrophyllum glans (White)
- Amplexus sp.

CRINOIDEA—
- Batocrinus laura (Hall)
- Macrocrinus verneuilianus (Shum.)
- Dizygocrinus andrewsianus (McChesney) ?
- Dizygocrinus rotundus (Shum.)
- Eutrochocrinus christyi (Shum.)
- Agaricocrinus sp.
- Actinocrinus multiradiatus Shum.
- Actinocrinus sp.
- Teleiocrinus umbrosus (Hall)
- Platycrinus (plates of several species)
- Eucladocrinus pleurovimenus (White)

BLASTOIDEA—
- Pentremites elongatus Shum.
- Orbitremites norwoodi (O. and Sh.)

BRYOZOA—
- Cystodictya sp.

BRACHIOPODA—
- Chonetes sp.
- Productus viminalis White
- Productus burlingtonensis Hall
- Productus sp.
- Productus sp.
- Pustula alternata (N. and P.)
- Rhipidomella dubia (Hall)
- Rhipidomella burlingtonensis (Hall)
- Schizophoria swallovi (Hall)
- Dielasma sp.
- Camarotoechia sp.
- Spirifer grimesi Hall
- Spirifer incertus Hall
- Spirifer sp.
- Spiriferella plena (Hall)
- Brachythyris suborbicularis (Hall)
- Syringothyris sp.
- Cliothyridina incrassata (Hall)
- Athyris lamellosa (Leveille)

GASTROPODA—
- Lepetopsis capulus (Hall)
- Orthonychia pabulocrinus (Owen)
- Orthonychia quincyense (McChesney)
- Orthonychia sp.
- Platyceras latum Keyes
- Platyceras obliquum Keyes
- Platyceras sp.

TRILOBITA—
- Griffithides ? sp.

VERTEBRATA—
- Fish teeth.

From the exposures at and near South Augusta and at Augusta, the following generalized section of the Burlington has been constructed.

Generalized section of Burlington limestone at and near Augusta.

		FEET
UPPER BURLINGTON.		
8.	Limestone, soft, fine-grained; gray when fresh but weathering buff	0 to 1½
7.	Limestone, brownish below, but light gray above, crinoidal, with stylolytic seams, bearing occasional thin, irregular, discontinous seams of chert	16 to 17
6.	Limestone, brownish, magnesian, subcrystalline to fine-grained, cherty, with occasional seams of crinoidal limestone	8
5.	Chert, in the form of a solid band, replacing a layer of crinoidal limestone; some unreplaced crinoid fragments preserved	1
4.	Limestone, soft, buff, magnesian	1 to 1½
3.	Limestone, gray to whitish, crinoidal, cherty, with occasional thin layers of soft buff limestone. The main crinoid zone	7½ to 8½
LOWER BURLINGTON.		
2.	Limestone, fine-grained, soft, bluish gray when fresh but weathering buff and exhibiting numerous concretionary iron stains; with occasional layers of brownish impure cherty crinoidal limestone ranging up to 2 feet in thickness	12⅔ to 13½
1.	Limestone, gray, subcrystalline, very cherty in upper part. Exposed	4

The range of the more characteristic fossils collected by the writer from the individual beds of the section is indicated on the chart which follows:

Table Showing Range of Fossils in the Burlington Beds at and near Augusta.

	Horizons				
	1	2	3	6	7
ANTHOZOA					
Zaphrentis sp.	x	-------	x	-------	x
Cyathaxonia sp.	-------	-------	x	-------	-------
Hadrophyllum glans (White)	-------	-------	-------	-------	x
Triplophyllum dalei (M.-E. and H.)	x	-------	x	x	x
Amplexus sp.	-------	-------	x	-------	-------
CRINOIDEA					
Batocrinus cf. B. laura (Hall)	-------	-------	x	-------	-------
Batocrinus grandis W. and Sp.	-------	-------	x	-------	-------
Batocrinus laura (Hall)	-------	-------	-------	-------	x
Macrocrinus konincki (Shum.)	-------	-------	x	-------	-------
Macrocrinus verneuilianus (Shum.)	-------	-------	-------	-------	x
Dizygocrinus rotundus (Shum.)	-------	-------	x	-------	x
Dizygocrinus dodecadactylus (M. and W.)	-------	-------	-------	-------	x

Table Showing Range of Fossils in the Burlington Beds at and near Augusta—Continued.

	Horizons				
	1	2	3	6	7
Dizygocrinus andrewsianus (McChesney)					x
Eutrochocrinus christyi (Shum.)			x		x
Aorocrinus ? sp.					x
Uperocrinus pyriformis (Shum.)			x		x
Uperocrinus aequibrachiatus, var. asteriscus (M. and W.)			x		
Uperocrinus hageri (McChesney) ?					x
Dorycrinus missouriensis (Shum.)			x		
Agaricocrinus sp.					x
Actinocrinus scitulus M. and W.			x		
Actinocrinus multiradiatus Shum.			x		x
Actinocrinus sp.					x
Cactocrinus longus (M. and W.) ?			x		
Cactocrinus glans (Hall)			x		
Teleiocrinus umbrosus (Hall)					x
Physetocrinus ventricosus (Hall)			x		
Strotocrinus glyptus (Hall)			x		
Platycrinus discoideus O. and Sh. ?			x		
Platycrinus burlingtonensis O. and Sh.			x		
Eucladocrinus pleurovimenus (White)			x	x	x
Barycrinus sp.			x		
BLASTOIDEA					
Pentremites elongatus Shum.			x		x
Orbitremites norwoodi (O. and S.)			x	x	x
BRYOZOA					
Rhombopora sp.				x	
Evactinopora grandis M. and W. ?				x	
Cystodictya sp.			x		
Cystodictya sp.					x
BRACHIOPODA					
Leptaena analoga (Phillips)	x				
Chonetes multicosta Win.	x		x		
Chonetes sp.				x	x
Productus burlingtonensis Hall			x		x
Productus viminalis White					x
Pustula alternata (N. and P.)			x		x
Rhipidomella dubia (Hall)	x		x	x	x
Rhipidomella burlingtonensis (Hall)	x		x	x	x
Schizophoria swallovi (Hall)	x	x	x	x	x
Camarophoria bisinuata (Rowley)	x				
Camarotoechia sp.					x
Dielasma osceolensis Weller	x				
Dielasma sp.					x
Spiriferina cf. S. subtexta White	x				
Spirifer grimesi Hall	x	x	x	x	x
Spirifer carinatus Rowley	x				
Spirifer insculptus Rowley	x				
Spirifer incertus Hall			x	x	x
Brachythyris suborbicularis (Hall)	x		x	x	x
Reticularia pseudolineata (Hall)					x

Table Showing Range of Fossils in the Burlington Beds at and near Augusta—Continued.

	Horizons				
	1	2	3	6	7
Syringothyris ? sp.					x
Pseudosyrinx ? sp.			x		
Spiriferella plena (Hall)		x	x	x	x
Athyris lamellosa (Leveille)		x	x	x	x
Cliothyridina incrassata (Hall)	x	x	x	x	x
Cliothyridina obmaxima (McChesney)			x		
Cliothyridina parvirostris (M. and W.)	x			x	
Composita trinuclea (Hall)	x				
GASTROPODA					
Lepetopsis capulus (Hall)			x	x	x
Straparollus obtusus (Hall)	x				
Orthonychia pabulocrinus (Owen)					x
Orthonychia quincyense (McChesney)					x
Orthonychia sp.			x		
Platyceras latum Keyes					x
Platyceras obliquum Keyes					x
Platyceras sp.				x	
Platyceras sp.					x
Igoceras sp.		x			
TRILOBITA					
Griffithides ? sp.	x				x

The mingling of Lower and Upper Burlington types of crinoids in bed 3 is worthy of attention. This is of importance in that it suggests the absence of a stratigraphic break between these divisions of the Burlington limestone.

Along Lost creek in Washington township, Lee county, three miles south of Augusta, there are several exposures of the Upper Burlington, both in the banks of the stream and in quarry openings. One such exposure appears in the south bank of the creek just back of the Lost Creek church (NE. ¼, sec. 10). Eight feet of gray to brownish crinoidal limestone is shown. This corresponds in position to bed 7 of the general section at Augusta and to bed 6 of the section at Burlington. The following species were collected at this locality:

List of fossils from exposure of Upper Burlington limestone on Lost creek.

ANTHOZOA—
- Triplophyllum dalei (M.-E. and H.)
- Cyathaxonia sp.

CRINOIDEA—
- Batocrinus laura (Hall) ?
- Eretmocrinus sp.
- Macrocrinus verneuilianus (Shum.)
- Dizygocrinus dodecadactylus (M. and W.)
- Dizygocrinus rotundus (Shum.)
- Actinocrinus sp.
- Platycrinus (fragments of several species)

BLASTOIDEA—
 Orbitremites norwoodi (O. and Sh.)
BRYOZOA—
 Fenestella sp.
 Cosinium latum Ulrich
BRACHIOPODA—
 Chonetes illinoisensis Worthen
 Productus viminalis White
 Productus sp.
 Pustula alternata (N. and P.)
 Rhipidomella dubia (Hall)
 Rhipidomella burlingtonensis (Hall)
 Schizophoria swallovi (Hall)
 Spirifer grimesi Hall
 Spirifer incertus Hall
 Spirifer sp.
 Brachythyris suborbicularis (Hall)
 Spiriferella plena (Hall)
 Cliothyridina incrassata (Hall)
 Athyris lamellosa (Leveille)
GASTROPODA—
 Orthonychia sp.
 Platyceras sp.
 Lepetopsis capulus (Hall)

On the Beebe property near Lost creek, west of Wever, there are several small quarry openings in the Upper Burlington, but the facilities for collecting at this place are not good at the present time. The forms obtained are:

List of fossils from Upper Burlington limestone west of Wever.

ANTHOZOA—
 Zaphrentis sp.
 Triplophyllum dalei (M.-E. and H.)
CRINOIDEA—
 Platycrinus (fragments of several species)
 Strotocrinus sp.
 Dorycrinus cornigerus (Hall)
 Agaricocrinus gracilis (M. and W.)
 Macrocrinus verneuilianus (Shum.)
BLASTOIDEA—
 Orbitremites norwoodi (O. and Sh.)
BRACHIOPODA—
 Productus burlingtonensis Hall ?
 Productus sp.
 Rhipidomella burlingtonensis (Hall)
 Rhipidomella dubia (Hall)
 Schizophoria swallovi (Hall)
 Spirifer grimesi Hall
 Spiriferella plena (Hall)

Van Buren County.—In Van Buren county, only one exposure of the Burlington limestone has been found. This is of the Upper Burlington and appears in the north bank of Des Moines river, just above the water level, one-half mile below the railway station at Bentonsport. It is due to the erosion of a small anticlinal uplift which almost parallels the river at this point. Keokuk limestone is exposed in the bluff higher up. The section is as follows:

Section of Upper Burlington limestone near Bentonsport.

	FEET	INCHES
2. Limestone, gray, subcrystalline	3	10
1. Limestone, light gray, subcrystalline, with occasional thin crinoidal seams. Exposed	2	2

The fossils collected from these beds are listed below:

List of fossils from bed 1 of the Upper Burlington limestone near Bentonsport.

ANTHOZOA—
 Zaphrentis sp.
 Triplophyllum dalei (M.-E. and H.)
BRACHIOPODA—
 Productus viminalis White
 Productus sp.

Productus sp.
Pustula alternata (N. and P.)
Pustula ? sp.
Rhipidomella burlingtonensis (Hall)
Rhynchopora sp.
Spirifer rostellatus Hall
Spirifer grimesi Hall
Spirifer sp.
Spirifer sp.
Athyris lamellosa (Leveille)
Cliothyridina incrassata (Hall)

GASTROPODA—
Platyceras sp.
Orthonychia quincyensis (McChesney)
Orthonychia sp.

List of fossils from bed 2 of the Upper Burlington limestone near Bentonsport.

ANTHOZOA—
Amplexus sp.

BRACHIOPODA—
Chonetes sp.
Productus burlingtonensis Hall ?
Pustula alternata (N. and P.)
Pustula sp.
Rhynchonella sp.
Dielasma sp.
Spiriferina ? sp.
Spirifer grimesi Hall
Spirifer sp.
Brachythyris suborbicularis (Hall)
Syringothyris ? sp.
Reticularia pseudolineata (Hall)

Louisa County.—There are a number of important exposures of the Burlington limestone in Louisa county. These have been described previously by Udden.[10]

In the quarries on Honey creek near the north line of the southwest quarter of section 28, T. 73 N., R. 3 W., a nearly complete section can be worked out. Only the basal portion of the Lower Burlington fails to outcrop.

A generalized section of the Burlington at this locality, and lists of fossils collected by the writer from the successive beds are given below.

General section of Burlington limestone in the quarries on Honey creek.

		FEET
UPPER BURLINGTON.		
7.	Limestone, gray, coarse-grained, crinoidal, cherty; lower and upper parts often dolomitized and represented by brownish soft fine-grained cavernous dolomitic limestone. A six inch layer at the top is in some places rich in fish teeth. With stylolytic seams	10 to 10½
6.	Limestone, gray, subcrystalline, locally crinoidal in part. Tends to be greenish in upper part owing to included greenish specks	6 to 7½
LOWER BURLINGTON.		
5.	Limestone, gray, subcrystalline; some layers crinoidal; filled with irregular nodules	1 to 2½
4.	Limestone, brownish, soft, fine-grained; dolomitic for the most part, but locally crinoidal and little altered in upper part; nodular above but more massive below	7
3.	Chert band	½
2.	Limestone, brownish, crinoidal; grading laterally into fine-grained soft dolomitic limestone except in basal part. With nodules, lenses and bands of gray chert in upper part	9
1.	Limestone, brownish yellow, dolomitic; with a discontinuous seam of brownish crinoidal limestone in lower part; filled with irregular nodular seams of gray chert which weathers whitish. Exposed	3

10 Iowa Geol. Survey, vol. XI, pp. 71-89; 1901.

Beds 1 to 6 are well exposed in the creek bank just below the main quarry. Beds 5 to 7 are typically developed in the main quarry.

There is a suggestion of a disconformity at the base of bed 5 in the bluff section, the contact of this member with bed 4 being undulating. It is probable, however, that there is no stratigraphic break at this horizon, and that the relationship is due to uneven dolomitization, for the lower bed is partly altered at this place.

One-fifth mile upstream from the main quarry and in the opposite bank, there is a fresh quarry opening which shows twelve feet of basal Keokuk limestone overlying bed 7 of the above section.

A table showing the species collected and their range in the Burlington limestone on Honey creek follows:

Table Showing Range of Fossils in the Burlington Limestone, Honey Creek Section, Louisa County.

	Horizons		
	2	6	7
ANTHOZOA			
Hadrophyllum glans (White)		x	
Triplophyllum dalei (M.-E. and H.)		x	x
Zaphrentis sp.		x	
Zaphrentis sp.			x
CRINOIDEA			
Actinocrinus multiradiatus Shum.			x
Actinocrinus sp.			x
Platycrinus cf. P. glyptus Hall			x
Platycrinus sp.			x
Platycrinus sp.	x		
Platycrinus sp.	x		
Uperocrinus pyriformis (Shum.)	x		
Batocrinus laura (Hall)			x
Batocrinus clypeatus (Hall) ?	x		
Macrocrinus konincki (Shum.) ?	x		
Macrocrinus verneuilianus (Shum.)		x	x
Dichocrinus ? sp.		x	
Dorycrinus sp.			x
Strotocrinus regalis (Hall)			x
Strotocrinus glyptus (Hall)			x
Physetocrinus ventricosus (Hall)			x
Teleiocrinus umbrosus (Hall)			x
Dizygocrinus rotundus (Shum.)			x
Eutrochocrinus christyi (Shum.)			x

Table Showing Range of Fossils in the Burlington Limestone, Honey Creek Section, Louisa County—Continued.

	Horizons		
	2	6	7
Aorocrinus parvus (Shum.)	....	....	x
Agaricocrinus sp.	....	....	x
BLASTOIDEA			
Pentremites elongatus Shum.	....	x	x
Pentremites sp.	....	....	x
Metablastus lineatus (Shum.) ?	....	....	x
Orbitremites norwoodi (O. and Sh.)	....	x	x
BRYOZOA			
Fenestella burlingtonensis Ulrich	....	....	x
Fenestella serratula Ulrich	....	....	x
Fenestella sp.	....	....	x
Rhombopora gracilis Ulrich ?	....	....	x
Rhombopora sp.	....	....	x
BRACHIOPODA			
Chonetes sp.	....	....	x
Chonetes sp.	....	x	....
Orthotetes sp.	....	x	....
Pustula sp.	....	....	x
Pustula sp.	....	x	....
Productus burlingtonensis Hall	....	x	....
Rhipidomella burlingtonensis (Hall)	....	x	x
Rhipidomella sp.	....	x	....
Schizophoria swallovi (Hall)	x	x	....
Spirifer incertus Hall	x	....	....
Spirifer grimesi Hall	x	x	x
Spirifer sp.	....	x	....
Brachythyris suborbicularis (Hall)	x	x	x
Spiriferella plena (Hall)	x	x	x
Reticularia pseudolineata (Hall)	....	....	x
Athyris lamellosa (Leveille)	x	x	x
PELECYPODA			
Aviculopecten sp.	....	x	....
Myalina sp.	....	x	....
GASTOPODA			
Orthonychia sp.	x	....	....
Lepetopsis capulus (Hall)	....	....	x
VERTEBRATA			
Fish teeth	....	....	x

The Anderson quarry exposure is of interest in that it shows the contact between the Kinderhook and the Lower Burlington.

The Kinderhook section at this locality has been described on page 63. The Burlington succession is as follows:

Section in Anderson's quarry on the east bank of Smith creek west of the center of the SW. ¼, sec. 29, Tp. 73 N., R. 2 W.

		FEET
7.	Drift	5
UPPER BURLINGTON.		
6.	Limestone, gray, coarse-grained, crinoidal (bed 7 of the Honey creek section)	1½
5.	Limestone, gray, subcrystalline, with crinoidal seams, stylolytic (bed 6 of the Honey creek section)	5½
LOWER BURLINGTON.		
4.	Limestone, gray, subcrystalline, cherty (bed 5 of the Honey creek section)	1½
3.	Mostly concealed. Probably consisting of crinoidal limestone and brownish dolomitic rock. (Beds 3 and 4 and upper part of bed 2 of the Honey creek section)	12
2.	Limestone, soft, dolomitic, brownish; cherty in middle and less dolomitic above	7
1.	Limestone, buff, dolomitic, soft	1

The following species were collected by the writer from bed 5 at this place:

List of fossils from bed 5 of Burlington limestone in Anderson quarry.

ANTHOZOA—
Hadrophyllum glans White
BRYOZOA—
Cystodictya sp.
BRACHIOPODA—
Chonetes illinoisensis Worthen
Chonetes sp.
Productus burlingtonensis Hall
Rhipidomella dubia (Hall)
Rhipidomella burlingtonensis (Hall)
Spirifer grimesi Hall
Spiriferella plena (Hall)
Brachythyris suborbicularis (Hall)

The marked thinning of both divisions of the Burlington in tracing them from Des Moines county northwestward is emphasized by the two preceding sections. Thus the Lower Burlington has decreased in thickness from forty-three feet at Burlington to one-half that amount in Louisa county, while the Upper Burlington has decreased in the same way from twenty-seven to seventeen feet.

The following sections have been copied from Udden's report on the Geology of Louisa County.[11]

"Section in a quarry belonging to James Elrick near the south county line on the left bank of Smith creek (After Udden).

		FEET
12.	Weathered limestone	22
11.	Chert	½
10.	Crinoidal limestone, with fish teeth near top	2
9.	Soft limestone	1

11 Iowa Geol. Survey, vol. XI, pp. 75-81; 1901.

8.	Blue shale, with some chert below	2
7.	Fine-grained, yellowish limestone, with *Productus semireticulatus, Spirifer plenus*, a *Pentremites*; in straight even ledges, with fish teeth above	2
6.	Blue shale	¼
5.	Bluish, rather fine-grained limestone	2
4.	Chert layers, interrupted	1
3.	Coarse-grained, yellowish or white, crinoidal limestone	4½
2.	Bluish white crinoidal limestone, upper ledges very evenly bedded, lower ledges somewhat fine-grained, with *Dielasma rowlei*	8
1.	Softer limestone, with some quartz geodes	1''

Bed 1 and possibly a part of bed 2 doubtless belong to the Lower Burlington, while those above are referred to the Upper Burlington, except beds 11 and 12 which represent the basal Keokuk.

''*Section seen in some quarries on Gospel run, near the north line of sec. 27, Tp. 73 N., R. 3 W. (After Udden).*

		FEET
8.	Chert and disintegrated limestone, with *Eutrochocrinus lovei*	3
7.	Crinoidal limestone, somewhat thin-bedded, with a *Pentremites*	9
6.	Thin-bedded, crinoidal limestone	2
5.	Chert	¾
4.	Yellow irregularly bedded limestone	4
3.	Yellow disintegrated crinoidal limestone	3½
2.	Coarsely aggregated crinoidal limestone, with *Lobocrinus pyriformis*	2
1.	Shaly, disintegrated material	1''

Beds 1 to 5 of this section represent the Lower Burlington, and the higher beds, the Upper Burlington.

''*Sections in a ravine following the west bank of the railroad one and a half miles north of Morning Sun, in the northeast corner of sec. 19, Tp. 73 N., R. 3 W. (After Udden).*

		FEET
4.	Chert layers	5/6
3.	White or yellowish, crinoidal limestone, with teeth of *Orodus, Deltodus and Cladodus*	2½
2.	Greenish white crinoidal limestone, with *Lobocrinus pyriformis, Dizygocrinus rotundus, Dorycrinus quinquelobus, Eutrochocrinus lovei, Pentremites elongatus, Actinocrinus scitulus*	1½
1.	White crinoidal limestone, with *Rhipidomella burlingtonensis*, and *Spirifer plenus*	4''

All of these beds are referable to the Upper Burlington.

''*Section in J. H. Wasson's quarry in the south bank of the south branch of Long creek in the northwest corner of sec. 23, Tp. 74 N., R. 5 W. (After Udden).*

		FEET
6.	Disintegrated limestone, with bands of chert	3
5.	Yellow, disintegrated limestone	3
4.	Blue shale	1
3.	Yellow slightly disintegrated crinoidal limestone, with small hollows filled with calcite crystals (also zinc blende)	4
2.	Yellowish, partly disintegrated limestone, with fish teeth, such as	

	Deltodus spatulatus, Psammodus glyptus, Cladodus sp., *Helodus* sp., and *Orodus* sp.	1½
1.	Crinoidal white limestone in ledges from six to ten inches in thickness with *Eutrochocrinus lovci, Batocrinus laura* var. *sinuosus, Batocrinus laura, Dizygocrinus rotundus*	4½''

Beds 1 and 2 are of Upper Burlington age; beds 3 to 6 are basal Keokuk.

''*Section in Gray's quarry near the north bank of the north branch of Long creek in the NE.¼ of the NW.¼ of sec. 3, Tp. 74 N., R. 5 W. (After Udden).*

		FEET
5.	Yellow disintegrated crinoidal limestone, with fish teeth near the base, and with *Schizophoria swallovi, Eutrochocrinus christyi, Batocrinus laura, Dizygocrinus rotundus,* and teeth of *Deltodus*	5
4.	Encrinital white limestone in heavy ledges, with *Productus semireticulatus, Productus burlingtonensis, Spirifer grimesi*	3
3.	Chert	5/6
2.	Brownish yellow porous, disintegrated limestone	3
1.	Bluish white crinoidal limestone, with occasional crinoids near top	5''

This succession is entirely of Upper Burlington age.

''*Section in F. J. Moore's quarry on the east bank of Long creek in the SW.¼ of the NE.¼ of sec. 33, Tp. 75 N., R. 5 W. (After Udden).*

		FEET
6.	Bands of chert	1
5.	Yellowish shaly material or disintegrated limestone	2
4.	Yellow partly disintegrated limestone, with chert bands and fish teeth in the upper part, containing *Deltodopsis bialveatus, Deltodopsis convexus, Deltodus spatulatus, Cladodus,* fragments of spines	2
3.	Bluish white crinoidal limestone in ledges from six to ten inches in thickness, with *Productus burlingtonensis*	2
2.	Shelly limestone, with many brachiopods and *Igoceras capulus*	1
1.	Crinoidal white limestone	2''

These beds again represent the Upper Burlington.

Washington County.—In Washington county, the Burlington and Keokuk limestones have not been differentiated in previous reports. Thus, Bain[12] in his Geology of Washington County describes them under the title of ''Augusta formation.'' He says:

''The greater number of fossils found belong to the Burlington fauna, though a few Keokuk forms occur. The formation is, however, as a whole, a distinct, well marked, stratigraphic unit for the region studied. It is neither advisable nor possible to divide it into formations which could be separately mapped''.

In the course of the present study, it has been found that the Burlington and Keokuk limestones are recognizable as strati-

12 Iowa Geol. Survey, vol. V, pp 140-143; 1896.

graphic units, although their formational characteristics are not nearly so pronounced as in the counties to the southeast.

The best exposures are on and near Crooked creek, northwest of the town of Washington. The Eckles quarry section is typical (SW. ¼, sec. 2, Tp. 75 N., R. 8 W.).

Eckles quarry section.

		FEET
5.	Drift	12
4.	Limestone, gray, medium-grained, with slight bluish tint, thin-bedded	2½
3.	Shaly parting	½
2.	Limestone, gray, crinoidal, with occasional small lenses of chert and thin layers of brown dolomitic limestone, with stylolytic seams	6
1.	Limestone, gray, crinoidal, with greenish tint above; stylolytic seams. Bears *Cosinium latum* and other Burlington fossils	10

The fauna of the above beds indicates their Upper Burlington age.

The Keokuk Limestone

NOMENCLATURE AND CHARACTER

The Keokuk formation as defined by Hall[13] consists of cherty limestone at the base, the encrinal limestone or "Lower Archimedes Limestone" of Owen directly above, which is well exposed at Keokuk, and the overlying geode bearing shales. Worthen's[14] classification is essentially the same as that of Hall.

In the reports on the geology of Lee and Des Moines counties Keyes[15] designated the basal cherty limestone as the Montrose cherts and referred them to the Upper Burlington. He described the Geode bed as a distinct formation. Gordon[16] likewise referred the Montrose cherts exposed in Van Buren county to the Burlington. He includes the Keokuk limestone, the Geode shales and the Warsaw shales and limestones in the Keokuk stage. In his Geology of Henry County, Savage[17] includes the limestone phase and the Geode shales in the Keokuk.

The present study has demonstrated the Keokuk age of the Montrose cherts. The Geode shales on the other hand are more

13 Geol. of Iowa, vol. I, part I, p. 94; 1858.
14 Idem, p. 193.
15 Iowa Geol. Survey, vol. III, pp. 341 and 445; 1895.
16 Iowa Geol. Survey, vol. IV, p. 206; 1895.
17 Iowa Geol. Survey, vol. XII, p. 254; 1902.

closely related faunally to the Warsaw formation than to the Keokuk. As at present defined, therefore, the Keokuk formation consists of the transition beds known as the Montrose cherts, which are about thirty feet in thickness, and the Keokuk limestone, which is about forty feet in thickness. The lower division consists of alternating layers of gray and bluish cherty limestone. In this division, several Keokuk types of brachiopods appear for the first time. Some of these evidently represent forms intermediate between typical Burlington types and true Keokuk forms. The crinoid fauna of the beds shows similar characteristics, as was pointed out by Wachsmuth and Springer.[18] They say:

"The transition beds are more or less fossiliferous throughout, though the occurrence of the fossils is irregular, and their preservation very variable. They exhibit in an irregular manner the lithologic characters of both formations, while the crinoidal remains which have been obtained from them show such an intermingling and blending of the Burlington and Keokuk species, that it is impossible to say where the one begins and the other ends. The majority of the crinoids found in them can neither be called Burlington nor Keokuk series, and may often be identified as either. They constitute a kind of intermediate type between them, and throw much light upon the growth of the individual and the development of species in the course of time."

This part of the Keokuk formation is well exposed near Augusta, Iowa, and in Cedar Glen, between Hamilton and Warsaw, Illinois. The beds above, constituting the Keokuk limestone of earlier writers, consist of layers of gray to bluish limestone, alternating with beds of shale, which are increasingly prevalent and thicker towards the top. It appears that there was a slow contraction of the sea during Keokuk time, as is indicated by this change in the sediments.

STRATIGRAPHIC RELATIONS

No convincing evidence of a stratigraphic break has been found either at the base or at the top of the Keokuk. Indeed the faunal transition from the Burlington into the Keokuk be-

18 Proc. Acad. Nat. Sci. Philadelphia, Part II, p. 228; 1878.

low and from the Keokuk into the Lower Warsaw (Geode bed) above is such as to preclude the possibility of an important disconformity at either level. However, the presence of rolled shells of *Spirifer grimesi* in the basal bed of the Keokuk suggests a shallowing of the sea in the region at the close of Burlington time.

AREAL DISTRIBUTION

The Keokuk limestone forms the surface rock over a comparatively small area in southeastern Iowa. It has been recognized in Lee, Van Buren, Des Moines, Henry, Louisa, Washington and Keokuk counties. It outcrops also in Hancock county, Illinois, situated directly east of Lee in Iowa, and in Clark county, Missouri, to the south of Lee. In all of the Iowa counties, however, its areal extent is limited. In Van Buren county it comes to the surface only along the valley of Des Moines river in the vicinity of Bonaparte and Bentonsport where it has been exposed by the erosion of a small anticlinal uplift.

Its distribution in Lee county is shown on the geological map of this area prepared by Keyes.[19] The more important areas underlain by the Keokuk are (1) along the valley of Mississippi river and its tributaries at and near the city of Keokuk; (2) in northern Washington township and (3) over the greater part of Denmark township.

It also forms a northwest-southeast belt several miles wide in the southwestern part of Des Moines county,[20] to the north of Lee.

The Keokuk of Henry county[21] comes to the surface only over a small area along the valley of Skunk river in Jackson township and appears to have been exposed by the erosion of a gentle anticline.

The Keokuk and Burlington limestones have not been differentiated on the geological map of Louisa county but all known exposures of the Keokuk are confined to Morning Sun, southern Wapello and southwestern Elliot townships, in the southern part of the county.

The Keokuk of Washington county likewise has not been dif-

19 Iowa Geol. Survey, vol. III, opp. p. 408; 1895.
20 Geological map of Des Moines county, Iowa Geol. Survey, vol. III, opp. p. 492; 1895.
21 Geological map of Henry county, Iowa Geol. Survey, vol. XII, opp. p. 302; 1902.

ferentiated by previous workers in the field nor has there been found an exposure of typical Keokuk in the area during the present investigation. It seems probable, however, that this limestone underlies the drift over a narrow belt extending through the middle of the county in a northwest-southeast direction, bounded on the northeast by the Burlington beds and on the southwest by the St. Louis limestone, which succeeds the Keokuk directly in this part of the state.

In Keokuk county, exposures of the Keokuk limestone occur along Rock creek north of Ollie. But doubtless it forms the surface rock at several other localities, notably along a belt between the St. Louis and Burlington areas in the northeastern part of the county.

AREAL DESCRIPTION BY COUNTIES

Lee County and adjacent parts of Illinois.—The type section of Keokuk limestone is at Keokuk, Iowa. Excellent facilities for studying the formation at that place are afforded in the exposures along Soap creek and in a quarry in the Mississippi river bluff, near the mouth of the creek, where an almost complete succession of the beds is shown (fig. 3).

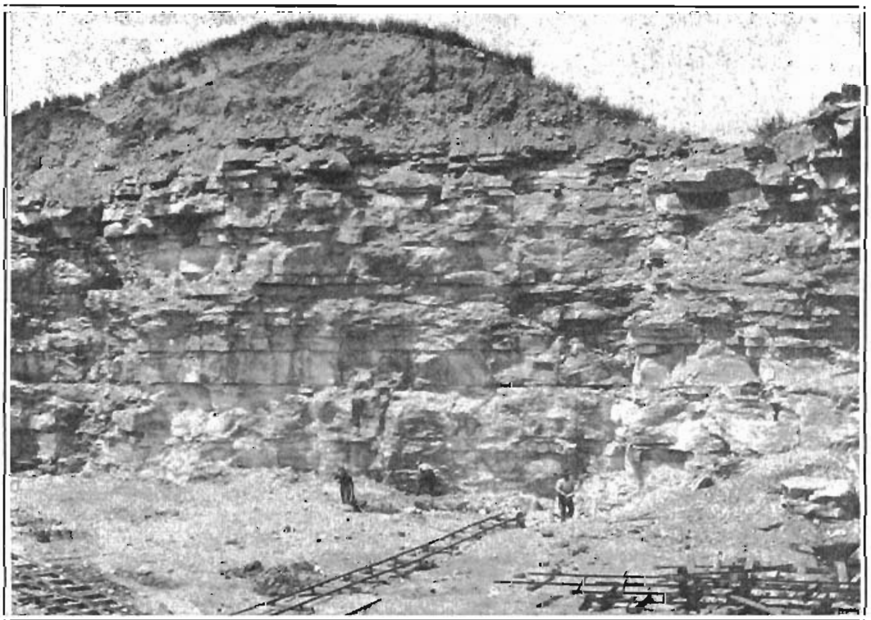

FIG. 3.—Keokuk limestone overlain by glacial drift. Quarry at mouth of Soap creek, Keokuk.

Generalized section of Keokuk limestone along Soap creek and near its mouth, Keokuk.

		FEET
16.	Limestone, gray, subcrystalline	1 1/3—3 1/2
15.	Shale, bluish, argillaceous; locally grading wholly or in part into gray subcrystalline limestone	2 1/2—3 1/2
14.	Limestone, ash-colored, fine-grained, magnesian; locally grading in part into gray more crystalline fossiliferous limestone. The "cottonwood ledge" of quarrymen	1 1/2—2 1/2
13.	Limestone, bluish gray, subcrystalline; *Composita globosa* abundant	1 1/2—2 1/2
12.	Limestone, bluish gray, thin-bedded, cherty; with shaly seams	1 5/6—2 1/2
11.	Limestone, massive, bluish, subcrystalline; with layers and seams of gray fine-grained magnesian limestone and calcareous shale. Fish teeth locally abundant at base	4 1/2—6
10.	Limestone, bluish, subcrystalline, *Spirifer keokuk* abundant	0 —1 1/2
9.	Shale, bluish, argillaceous, very fossiliferous; locally with seams of gray subcrystalline limestone	1 —1 1/2
8.	Limestone, gray, compact, most of the layers thin and lenticular; with thin intercalated shaly seams. Fish teeth in topmost layer	2 3/4—3
7.	Limestone, gray, subcrystalline, the "gray ledge" or "eighteen inch ledge" of quarrymen. Bearing a few fish teeth	1 —2 1/2
6.	Limestone, light gray, massive, cherty; locally grading into shale in part. A shaly parting at the base is rich in crinoids. The "white ledge" of quarrymen	3 —4
5.	Limestone, gray, impure, massive, fine-grained, magnesian, cherty; locally with occasional seams of gray, subcrystalline limestone; bearing a few large calcite geodes many of which contain millerite: the "millerite ledge" of quarrymen	5 —6
4.	Limestone, light gray, impure, soft; bearing occasional crinoids	5/6—1
3.	Limestone, bluish, medium grained; bearing a few fish teeth	3/4—1 1/3
2.	Limestone, grayish, medium-grained	2 —3
1.	Limestone, grayish, medium-grained, cherty; fish teeth locally abundant. Exposed	6

The fossils of the successive beds are listed below:

List of fossils from bed 1 of the Keokuk limestone at Keokuk.

ANTHOZOA—
- Triplophyllum dalei (M.-E. and H.)
- Palaeacis obtusus (M. and W.)

BRYOZOA—
- Fenestella triserialis Ulrich ?
- Fenestella species II ?
- Fenestella limitaris Ulrich ?
- Fenestella serratula Ulrich
- Fenestella tenax Ulrich
- Polypora burlingtonensis Ulrich ?
- Cystodictya lineata Ulrich
- Worthenopora spinosa Ulrich
- Glyptopora sp.

BRACHIOPODA—
- Orthotetes keokuk (Hall)
- Productus cf. P. gallatinensis Girty
- Productus setigerus Hall
- Avonia sp.
- Pustula alternata (N. and P.)
- Pustula biseriata (Hall)
- Tetracamera subtrigona (M. and W.)
- Spirifer cf. S. keokuk Hall
- Spirifer tenuicostatus Hall
- Brachythyris suborbicularis (Hall)
- Syringothyris subcuspidatus (Hall) ?
- Spiriferella neglecta (Hall)
- Reticularia pseudolineata (Hall)
- Athyris lamellosa (Leveille) ?
- Composita trinuclea (Hall)

PELECYPODA—
- Aviculopecten sp.
- Cypricardinia ? sp.

GASTROPODA—
- Platyceras equilateralis Hall
- Orthonychia pabulocrinus (Owen)

VERTEBRATA—
- Fish teeth (Sandalodus, etc.)

The following additional species are listed from this bed by C. H. Gordon:[22]

Eutrochocrinus planodiscus (Hall)
Platyceras fissurella Hall

List of fossils from bed 2 of Keokuk limestone at Keokuk.

ANTHOZOA—
Triplophyllum dalei (M.-E. and H.)
VERMES—
Enchostoma sp.
CRINOIDEA—
Actinocrinus sp.
BRYOZOA—
Fenestella multispinosa Ulrich ?
BRACHIOPODA—
Productus viminalis White ?
Productus setigerus Hall ?
Productus sp.
Pustula biseriata (Hall) ?
Rhipidomella dubia (Hall)
Tetracamera subcuneata (Hall)
Rhynchopora beecheri (Greger)
Dielasma sp.
Spirifer cf. S. keokuk Hall
Spirifer logani Hall ?
Spirifer tenuicostatus Hall
Brachythyris suborbicularis (Hall)
Syringothyris sp.
Spiriferella neglecta (Hall)
Reticularia pseudolineata (Hall)
Eumetria sp.
PELECYPODA—
Myalina keokuk Worthen
GASTROPODA—
Platyceras equilateralis Hall ?
VERTEBRATA—
Fish teeth

List of fossils from bed 3 of Keokuk limestone at Keokuk.

ANTHOZOA—
Triplophyllum dalei (M.-E. and H.)
BRACHIOPODA—
Orthotetes keokuk (Hall)
Productus setigerus Hall ?
Pustula biseriata (Hall)
Rhipidomella dubia (Hall)
Spirifer cf. S. keokuk Hall
Brachythyris suborbicularis (Hall)
Brachythyris sp.
Syringothyris sp.
Reticularia pseudolineata (Hall)
Cliothyridina parvirostris (M. and W.)

List of fossils from bed 4 of Keokuk limestone at Keokuk.

ANTHOZOA—
Triplophyllum dalei (M.-E. and H.)
Amplexus sp.
CRINOIDEA—
Actinocrinus pernodosus Hall ?
Actinocrinus lowei Hall ?
Agaricocrinus americanus var. tuberosus Hall
BRYOZOA—
Fenestella multispinosa Ulrich ?
BRACHIOPODA—
Productus sp.
Pustula alternata (N. and P.)
Spiriferella neglecta (Hall)
Brachythyris suborbicularis (Hall)
Reticularia pseudolineata (Hall)
Cliothyridina sp.
GASTROPODA—
Platyceras equilateralis Hall ?

Gordon[23] reports three species of crinoids from this bed which were not found by the writer, namely:

Agaricocrinus americanus (Roemer)
Macrocrinus lagunculus (Hall)
Platycrinus saffordi Hall

22 Am. Jour. Sci., 3d ser., vol. 40, p. 296, 1890.
23 Op. cit., p. 296.

List of fossils from bed 5 of Keokuk limestone at Keokuk.

ANTHOZOA—
- Triplophyllum dalei (M.-E. and H.)

CRINOIDEA—
- Eucladocrinus sp.
- Barycrinus sp.

BRYOZOA—
- Fenestella compressa Ulrich ?
- Fenestella serratula Ulrich
- Fenestella tenax Ulrich
- Fenestella sp.
- Archimedes owenanus Hall
- Polypora halliana Prout ?
- Rhombopora dichotoma Ulrich ?
- Cystodictya lineata Ulrich
- Glyptopora sp.

BRACHIOPODA—
- Orthotetes keokuk (Hall)
- Productus setigerus Hall
- Productus sp.
- Avonia sp.
- Pustula alternata (N. and P.)
- Pustula biseriata (Hall)
- Pustula sp.
- Spirifer cf. S. keokuk Hall
- Brachythyris suborbicularis (Hall)
- Spiriferella neglecta (Hall)
- Reticularia pseudolineata (Hall)
- Composita trinuclea (Hall)

List of fossils from bed 6 of Keokuk limestone at Keokuk.

ANTHOZOA—
- Zaphrentis sp.
- Amplexus sp.
- Triplophyllum dalei (M.-E. and H.)
- Hadrophyllum (species undescribed)
- Palaeacis obtusus (M. and W.)

CRINOIDEA—
- Agaricocrinus americanus var. tuberosus Hall
- Agaricocrinus sp.
- Agaricocrinus sp.
- Actinocrinus lowei Hall
- Actinocrinus pernodosus Hall
- Uperocrinus nashvillae (Hall)
- Platycrinus saffordi Hall ?
- Platycrinus sp.
- Platycrinus sp.
- Barycrinus spurius (Hall)
- Barycrinus stellatus (Hall)

BRYOZOA—
- Fenestella serratula Ulrich
- Fenestella tenax Ulrich
- Fenestella compressa Ulrich
- Fenestella species III
- Fenestella species II
- Polypora halliana Prout
- Polypora varsoviensis Prout
- Polypora species II
- Cystodictya lineata Ulrich
- Worthenopora spiuosa Ulrich

BRACHIOPODA—
- Orthotetes keokuk (Hall)
- Productus setigerus Hall
- Productus cf. P. gallatinensis Girty
- Productus ovatus Hall
- Productus sp.
- Pustula biseriata (Hall)
- Pustula alternata (N. and P.)
- Pustula ? sp.
- Avonia (species undescribed)
- Rhipidomella dubia (Hall)
- Dielasma sp.
- Spirifer cf. S. keokuk Hall
- Spirifer rostellatus Hall
- Spirifer tenuicostatus Hall
- Spirifer subaequalis Hall ?
- Syringothyris (?) sp.
- Spiriferella neglecta (Hall)
- Reticularia pseudolineata (Hall)
- Cliothyridina obmaxima (McChesney)
- Composita trinuclea (Hall)

PELECYPODA—
- Conocardium sp.
- Myalina keokuk Worthen

GASTROPODA—
- Platyceras equilateralis Hall

Gordon[24] found the following crinoids in this bed:

- Actinocrinus sp.
- Agaricocrinus americanus (Roemer)
- Barycrinus magister (Hall)

List of fossils from bed 8 of Keokuk limestone at Keokuk.

ANTHOZOA—
- Zaphrentis varsoviensis Worthen
- Zaphrentis sp.
- Triplophyllum dalei (M.-E. and H.)
- Amplexus sp.
- Palaeacis obtusus (M. and W.)

CRINOIDEA—
- Dorycrinus sp.
- Agaricocrinus americanus var. tuberosus Hall

BRYOZOA—
- Fistulipora spergenensis Rominger ?

24 Op. cit., p. 296.

Stenopora sp.
Fenestella serratula Ulrich
Fenestella multispinosa Ulrich
Fenestella triserialis Ulrich
Fenestella compressa Ulrich ?
Fenestella species I
Fenestella species II ?
Hemitrypa perstriata Ulrich ?
Polypora simulatrix Ulrich
Polypora species I
Polypora sp.
Archimedes cf. A. negligens Ulrich
Pinnatopora sp.
Rhombopora attenuata Ulrich ?

BRACHIOPODA—
Orthotetes keokuk (Hall)
Productus cf. P. gallatinensis Girty ?
Productus setigerus Hall
Productus ovatus Hall
Productus sp.
Productus sp.
Productus sp.
Pustula biseriata (Hall)
Pustula alternata (N. and P.)
Pustula (species undescribed)
Avonia sp.
Rhipidomella dubia (Hall)
Dielasma sinuata Weller
Dielasma sp.
Spiriferina ? sp.
Spiriferina ? sp.
Spirifer keokuk Hall
Spirifer tenuicostatus Hall
Spirifer rostellatus Hall
Brachythyris suborbicularis (Hall)
Syringothyris sp.
Spiriferella neglecta (Hall)
Reticularia pseudolineata (Hall)
Cliothyridina parvirostris (M. & W.) ?
Composita pentagona Weller
Composita trinuclea (Hall)
Composita sp.

PELECYPODA—
Lithophagus illinoisensis Worthen

TRILOBITA—
Griffithides (?) sp.

VERTEBRATA—
Fish teeth

List of fossils from bed 9 of Keokuk limestone at Keokuk.

ANTHOZOA—
Zaphrentis varsoviensis Worthen
Triplophyllum dalei (M.-E. and H.)
Amplexus sp.
Monilopora beecheri Grabau

CRINOIDEA—
Batocrinus ? sp.
Dorycrinus mississippiensis Roemer
Dorycrinus sp.
Agaricocrinus americanus var. tuberosus Hall
Barycrinus tumidus (Hall)
Barycrinus stellatus (Hall)

BRYOZOA—
Fistulipora sp.
Leioclema punctatum (Hall)
Fenestella serratula Ulrich
Fenestella tenax Ulrich
Fenestella multispinosa Ulrich
Fenestella triserialis Ulrich ?
Fenestella compressa Ulrich ?
Fenestella rudis Ulrich
Fenestella sp.
Fenestella sp.
Hemitrypa proutana Ulrich
Hemitrypa perstriata Ulrich ?
Polypora varsoviensis Prout
Polypora retrorsa Ulrich
Polypora maccoyana Ulrich
Polypora simulatrix Ulrich
Polypora sp.
Ptilopora valida Ulrich
Rhombopora attenuata Ulrich
Acanthoclema confluens Ulrich
Taeniodictya ramulosa Ulrich
Cystodictya sp.
Cystodictya sp.
Glyptopora keyserlingi (Prout)
Cyclopora (several species)
Proutella discoidea (Prout) ?
Worthenopora spinosa Ulrich

BRACHIOPODA—
Productus setigerus Hall
Pustula alternata (N. and P.)
Spiriferina sp.
Spirifer tenuicostatus Hall
Spirifer cf. S. pellaensis Weller
Spirifer keokuk Hall
Syringothyris sp.
Spiriferella neglecta (Hall)
Reticularia setigera (Hall)
Cliothyridina parvirostris (M. and W.)
Composita trinuclea (Hall)

PELECYPODA—
Aviculopecten sp.
Aviculopecten sp.
Lithophagus illinoisensis Worthen
Cypricardinia sp.

GASTROPODA—
Platyceras sp.

VERTEBRATA—
Pleuracanthus

List of fossils from bed 10 of the Keokuk limestone at Keokuk.

ANTHOZOA—
Triplophyllum dalei (M.-E. and H.)

BRYOZOA—
Fenestella serratula Ulrich ?

BRACHIOPODA—
- Orthotetes keokuk (Hall)
- Productus setigerus Hall
- Pustula alternata (N. and P.)
- Pustula biseriata (Hall)
- Rhipidomella dubia (Hall)
- Dielasma sinuata Weller
- Spirifer keokuk Hall
- Spirifer tenuicostatus Hall
- Syringothyris textus (Hall)
- Spiriferella neglecta (Hall)
- Reticularia pseudolineata (Hall)
- Eumetria verneuiliana (Hall)
- Composita globosa Weller

PELECYPODA—
- Myalina keokuk Worthen

List of fossils from bed 11 of Keokuk limestone at Keokuk.

ANTHOZOA—
- Triplophyllum dalei (M.-E. and H.)

BRYOZOA—
- Stenopora sp.

BRACHIOPODA—
- Orthotetes keokuk (Hall)
- Productella sp.
- Productus setigerus Hall ?
- Productus sp.
- Productus sp.
- Productus sp.
- Pustula alternata (N. and P.)
- Rhipidomella dubia (Hall)
- Dielasma sp.
- Spirifer keokuk Hall
- Pseudosyrinx keokuk Weller ?
- Spiriferella neglecta (Hall)
- Reticularia pseudolineata (Hall)

GASTROPODA—
- Platyceras sp.
- Orthonychia sp.
- Orthonychia sp.
- Conularia cf. C. missouriensis Swallow

TRILOBITA—
- Griffithides ? sp.

VERTEBRATA—
- Fish teeth

List of fossils from bed 12 of Keokuk limestone at Keokuk.

ANTHOZOA—
- Triplophyllum dalei (M.-E. and H.)

BRYOZOA—
- Stenopora sp.
- Stenopora sp.
- Archimedes sp.
- Fenestella tenax Ulrich
- Ptilopora sp.
- Rhombopora sp.

BRACHIOPODA—
- Pustula alternata (N. and P.)
- Spirifer cf. S. keokuk Hall
- Cliothyridina obmaxima (McChesney)

List of fossils from bed 13 of Keokuk limestone at Keokuk.

ANTHOZOA—
- Triplophyllum dalei (M.-E. and H.)
- Zaphrentis cf. Z. spinulosa (M.-E. and H.)
- Zaphrentis sp.
- Monilopora beecheri Grabau

CRINOIDEA—
- Agaricocrinus americanus var. tuberosus Hall
- Actinocrinus pernodosus Hall
- Dorycrinus sp.

BRYOZOA—
- Fistulipora spergenensis Rom. ?
- Fenestella serratula Ulrich ?
- Fenestella species II ?
- Fenestella sp.
- Fenestella species III
- Polypora striata Cumings
- Polypora varsoviensis Prout
- Rhombopora varians Ulrich ?

BRACHIOPODA—
- Productus sp.
- Productus sp.
- Pustula alternata (N. and P.)
- Rhipidomella dubia (Hall)
- Spirifer keokuk Hall
- Brachythyris subcardiformis (Hall)
- Composita globosa Weller

TRILOBITA—
- Griffithides ? sp.

VERTEBRATA—
- Cochliodus nobilis N. and W.

List of fossils from bed 14 of Keokuk limestone at Keokuk.

ANTHOZOA—
- Triplophyllum dalei (M.-E. and H.)
- Monilopora beecheri Grabau

CRINOIDEA—
- Barycrinus sp.

BRYOZOA—
- Fenestella sp.
- Cystodictya lineata Ulrich

BRACHIOPODA—
- Pustula biseriata (Hall)

Productus setigerus Hall
Rhynchonella sp.
Dielasma sp.
Spirifer cf. S. keokuk Hall
Spiriferella neglecta (Hall)
Reticularia pseudolineata (Hall)
Cliothyridina parvirostrisa (M. and W.)
Cliothyridina obmaxima (McChesney)
PELECYPODA—
Lithophagus illinoisensis Worthen ?
Aviculopecten sp.

Several additional species are reported from this bed by Gordon[25], viz:

Uperocrinus nashvillae (Hall)
Dizygocrinus biturbinatus (Hall)
Dorycrinus mississippiensis Roemer
Agaricocrinus wortheni Hall
Agaricocrinus americanus (Roemer) var.
Barycrinus tumidus (Hall)
Archimedes owenanus Hall

List of fossils from bed 15 of Keokuk limestone at Keokuk.

ANTHOZOA—
Triplophyllum dalei (M.-E. and H.)
BRYOZOA—
Stenopora sp.
BRACHIOPODA—
Pustula alternata (N. and P.)
Rhipidomella dubia (Hall)
Spirifer cf. S. keokuk Hall
Brachythyris suborbicularis (Hall)
Brachythyris subcardiformis (Hall)
Composita globosa Weller

List of fossils from bed 16 of Keokuk limestone at Keokuk.

ANTHOZOA—
Triplophyllum dalei (M.-E. and H.)
Monilopora beecheri Grabau
BRYOZOA—
Batostomella sp.
Stenopora sp.
Stenopora sp.
Archimedes owenanus Hall
Polypora varsoviensis Prout
Hemitrypa sp.
Fenestella serratula Ulrich
Fenestella compressa Ulrich
Fenestella triserialis Ulrich
Fenestella compressa var. nododorsalis Ulrich
Fenestella multispinosa Ulrich ?
Fenestella species II
Pinnatopora sp.
Rhombopora sp.
Cystodictya lineata Ulrich
Worthenopora spinosa Ulrich
BRACHIOPODA—
Orthotetes keokuk (Hall)
Chonetes sp.
Productus setigerus Hall
Productus ovatus Hall ?
Productus cf. P. gallatinensis Girty
Productus sp.
Pustula biseriata (Hall)
Rhipidomella dubia (Hall)
Tetracamera subtrigona (M. and W.)
Dielasma sp.
Spirifer cf. S. keokuk Hall
Spirifer tenuicostatus Hall
Brachythyris subcardiformis (Hall)
Syringothyris textus (Hall) ?
Reticularia sp.
Cliothyridina (?) sp.
Composita trinuclea (Hall)
PELECYPODA—
Myalina keokuk Worthen
Aviculopecten sp.
Aviculopecten sp.
GASTROPODA—
Platyceras equilateralis Hall (?)
Ptychomphalus (?) sp.
TRILOBITA—
Griffithides (?) sp.
VERTEBRATA—
Fish teeth

The vertical range of all the more characteristic species listed above is shown in the following table:

25 Am. Jour. Sci.; 3d ser., vol. 40, p. 296.

Table Showing Range of Species in the Keokuk Limestone at Keokuk.

	Horizons															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
ANTHOZOA																
Hadrophyllum sp.						x										
Triplophyllum dalei (M.-E. and H.)	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x
Zaphrentis varsoviensis Worthen								x	x							
Zaphrentis cf. Z. spinulosa (M.-E. and H.)													x			
Zaphrentis sp.						x		x								
Amplexus sp.				x		x		x	x							
Palaeacis obtusus (M. and W.)	x					x		x								
Monilopora beecheri Grabau									x				x	x		x
VERMES																
Enchostoma sp.		x														
CRINOIDEA																
Platycrinus saffordi Hall				x		x?										
Platycrinus sp.						x										
Eucladocrinus sp.					x											
Actinocrinus pernodosus Hall				x?		x							x			
Actinocrinus lowei Hall				x?		x										
Actinocrinus sp.						x										
Actinocrinus sp.		x														
Batocrinus sp.									x							
Macrocrinus lagunculus (Hall)				x												
Uperocrinus nashvillae (Hall)						x								x		
Agaricocrinus americanus (Roemer)				x		x								x		
Agaricocrinus americanus var. tuberosus Hall				x		x		x	x				x			
Agaricocrinus wortheni Hall														x		
Agaricocrinus sp.						x										
Dorycrinus mississippiensis Roemer									x					x		
Dorycrinus sp.								x	x				x			
Dizygocrinus biturbinatus (Hall)														x		
Eutrochocrinus planodiscus (Hall)	x															
Barycrinus spurius (Hall)						x										
Barycrinus magister (Hall)						x										
Barycrinus tumidus (Hall)									x					x		
Barycrinus stellatus (Hall)						x			x							
Barycrinus sp.					x											
BRYOZOA																
Fistulipora spergenensis Rominger								x?					x?			
Fistulipora sp.									x							
Stenopora sp.								x			x	x			x	x
Batostomella sp.																x
Leioclema punctatum (Hall)									x							
Fenestella triserialis Ulrich	x?							x	x?							x
Fenestella limitaris Ulrich	x?															
Fenestella serratula Ulrich	x				x	x		x	x	x?			x?			x
Fenestella tenax Ulrich	x				x	x			x			x				
Fenestella multispinosa Ulrich		x?		x				x	x							x?
Fenestella compressa Ulrich					x?	x		x?	x?							x
Fenestella rudis Ulrich									x							
Fenestella compressa var. nododorsalis Ulrich																x
Fenestella species II	x?					x		x?					x?			x
Fenestella species III						x							x			
Fenestella species I								x								
Hemitrypa proutana Ulrich									x							
Hemitrypa perstriata Ulrich								x?	x?							

Table Showing Range of Species in the Keokuk Limestone at Keokuk—Continued.

	Horizons															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Archimedes owenanus Hall					x									x		x
Archimedes cf. A. negligens Ulrich								x								
Polypora burlingtonensis Ulrich	x?															
Polypora halliana Prout					x	x										
Polypora varsoviensis Prout						x			x				x			x
Polypora simulatrix Ulrich								x	x							
Polypora retrorsa Ulrich									x							
Polypora maccoyana Ulrich									x							
Polypora striata Cumings													x			
Polypora species II						x										
Polypora species I								x								
Pinnatopora sp								x								x
Ptilopora valida Ulrich									x							
Rhombopora attenuata Ulrich								x?	x							
Rhombopora dichotoma Ulrich					x											
Rhombopora varians Ulrich													x?			
Acanthoclema confluens Ulrich									x							
Taeniodictya ramulosa Ulrich									x							
Cystodictya lineata Ulrich	x				x	x								x		x
Cystodictya sp									x							
Glyptopora keyserlingi (Prout)									x							
Glyptopora sp	x				x											
Proutella discoidea (Prout)									x?							
Worthenopora spinosa Ulrich	x					x			x							x
BRACHIOPODA																
Orthotetes keokuk (Hall)	x		x		x	x		x		x	x					x
Chonetes sp																x
Productus setigerus Hall	x	x?	x		x	x		x	x	x	x?			x		x
Productus ovatus Hall						x		x								x
Productus cf. P. gallatinensis Girty	x					x		x								x
Productus viminalis White		x?														
Pustula biseriata (Hall)	x	x	x		x	x		x		x				x		x
Pustula alternata (N. and P.)	x	x		x	x	x		x	x	x	x	x	x		x	
Pustula sp					x			x								
Avonia sp	x				x	x		x								
Rhipidomella dubia (Hall)		x	x			x		x		x	x		x		x	x
Tetracamera subcuneata (Hall)		x														
Tetracamera subtrigona (M. and W.)	x															x
Rhynchopora beecheri (Greger)		x														
Dielasma sinuata Weller								x		x						
Dielasma sp		x				x		x			x			x		x
Spiriferina sp								x?	x							
Spirifer keokuk Hall								x	x	x	x		x			
Spirifer cf. S. keokuk Hall	x	x	x		x	x						x		x	x	x
Spirifer cf. S. pellaensis Weller									x							
Spirifer tenuicostatus Hall	x	x				x		x	x	x						x
Spirifer logani Hall		x?														
Spirifer rostellatus Hall						x		x								
Spirifer subaequalis Hall						x										
Brachythyris suborbicularis (Hall)	x	x	x	x	x			x							x	
Brachythyris subcardiformis (Hall)													x		x	x
Syringothyris subcuspidatus (Hall)	x?															
Syringothyris textus (Hall)										x						x?
Pseudosyrinx keokuk Weller											x?					

Table Showing Range of Species in the Keokuk Limestone at Keokuk—Continued.

	Horizons															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Spiriferella neglecta (Hall)	x	x	----	x	x	x	----	x	x	x	x	----	----	x	----	----
Reticularia pseudolineata (Hall)	x	x	x	x	x	x	----	x	----	x	x	----	----	x	----	----
Reticularia setigera (Hall)	----	----	----	----	----	----	----	----	x	----	----	----	----	----	----	----
Eumetria verneuiliana (Hall)	----	----	----	----	----	----	----	----	----	x	----	----	----	----	----	----
Eumetria sp.	----	x	----	----	----	----	----	----	----	----	----	----	----	----	----	----
Athyris lamellosa (Leveille)	x?	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
Cliothyridina parvirostris (M. and W.)	----	----	x	----	----	----	----	x	x	----	----	----	----	x	----	----
Cliothyridina obmaxima (McChesney)	----	----	----	----	----	x	----	----	----	----	----	x	----	x	----	----
Composita trinuclea (Hall)	x	----	----	----	x	x	----	x	x	----	----	----	----	----	----	x
Composita pentagona Weller	----	----	----	----	----	----	----	x	----	----	----	----	----	----	----	----
Composita globosa Weller	----	----	----	----	----	----	----	----	----	x	----	----	x	----	x	----
PELECYPODA																
Conocardium sp.	----	----	----	----	----	x	----	----	----	----	----	----	----	----	----	----
Myalina keokuk Worthen	----	x	----	----	----	x	----	----	----	x	----	----	----	----	----	x
Aviculopecten sp.	x	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
Aviculopecten sp.	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	x
Aviculopecten sp.	----	----	----	----	----	----	----	----	x	----	----	----	----	----	----	----
Lithophagus illinoisensis Worthen	----	----	----	----	----	----	----	x	x	----	----	----	----	x?	----	----
Cypricardinia ? sp.	x	----	----	----	----	----	----	----	x	----	----	----	----	----	----	----
GASTROPODA																
Ptychomphalus ? sp.	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	x
Orthonychia pabulocrinus (Owen)	x	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
Orthonychia sp.	----	----	----	----	----	----	----	----	----	----	x	----	----	----	----	----
Platyceras fissurella Hall	x	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
Platyceras equilateralis Hall	x	x?	----	x?	----	x	----	----	----	----	----	----	----	----	----	x?
Conularia cf. C. missouriensis Swallow	----	----	----	----	----	----	----	----	----	----	x	----	----	----	----	----
TRILOBITA																
Griffithides ? sp.	----	----	----	----	----	----	----	x	----	----	x	----	x	----	----	x
VERTEBRATA																
Pleuracanthus sp.	----	----	----	----	----	----	----	----	x	----	----	----	----	----	----	----
Cochliodus nobilis (N. and W.)	----	----	----	----	----	----	----	----	----	----	----	----	x	----	----	----

The lower portion of the Keokuk, comprising the beds called in earlier reports the Montrose cherts, is not exposed at Keokuk at the present time, but was formerly opened to observation in the excavation beneath the bed of Mississippi river for the Keokuk dam.

Section of Montrose cherts in excavation below bed of Mississippi river at Keokuk.

		Thickness Feet	Thickness Inches	Approximate percentage of chert
13.	Limestone, dark gray; impregnated with small irregular patches of chert and chalcedony, and containing small, imperfect calcareous geodes		8	50
12.	Limestone, ash-colored, impure; very fine-grained. Chert correspondingly fine-grained, and occurring as discontinuous seams most of which run parallel to the bedding	3	8	30
11.	Chert, white, gray and bluish, dense; with discontinuous bands and irregular pockets of dark gray crinoidal limestone. A few geodic cavities in the chert are lined with drusy quartz studded with rhombs of calcite	1	3	75
10.	Limestone, dark gray, crinoidal, fine-grained; locally almost entirely replaced by dark gray chert	1	9	50–75
9.	Limestone, impure, very fine-grained, ash-colored; with pockets and patches of bluish to whitish chert	5		33
8.	Limestone, dark gray, crinoidal, cherty		9	33
7.	Limestone, dark gray; bearing small crinoid stems; with whitish chert band in middle	2		50
6.	Limestone, very fine-grained, ash-colored; bearing irregular patches of whitish chert	1	2	25
5.	Chert, in the form of a layer about 7 inches thick which locally grades into gray crinoidal limestone		7	25
4.	Limestone, fine-grained; with seams and nodules of bluish and whitish chert	1	5	25
3.	Limestone, gray; bearing whitish fossiliferous chert as large irregular patches and irregular discontinuous bands	3		50
2.	Limestone, fine-grained; with nodules of white and dark colored chert	1		30
1.	Limestone, dark gray, crinoidal, lighter colored and purer downward; in layers 6 to 22 inches thick, bearing fossiliferous chert in the form of bands, lenses and nodules	8		30

The basal cherty beds of the Keokuk may be studied to good advantage at the present time along Cedar Glen, a small creek on the Illinois side of Mississippi river, about midway between the towns of Hamilton and Warsaw. The section of the Keokuk, which is nearly complete at this place, is as follows:

Section of Keokuk limestone at Cedar Glen, Illinois

		Feet	Inches
17.	Drift, yellowish, sandy, of variable thickness.		
16.	Limestone, grayish, coarse-grained, cherty. *Spirifer keokuk* common. Bed 10 of Keokuk section	2	4
15.	Limestone, grayish, cherty; in thin irregular layers separated by shaly partings	2	4

		Feet	Inches
14.	Limestone, grayish, subcrystalline; cherty in lower part. *Orthotetes keokuk* abundant. Bed 7 of the Keokuk section	1	6
13.	Limestone, light gray, in places cherty; weathering to an irregular chipstone; the "White ledge" of the Keokuk section. Lower part somewhat shaly	2	6
12.	Limestone, grayish; upper and lower parts subcrystalline, and weathering to thin irregular chips; middle part consisting of ash-colored magnesian limestone in heavier layers. The "Millerite ledge" of the Keokuk section	5	8
11.	Limestone, bluish gray, coarse-grained, *Palaeacis obtusus* and fish teeth common	1	8
10.	Limestone, grayish with slight bluish tint, coarse-grained, highly fossiliferous. Bed 2 of Keokuk section	2	
9.	Limestone, consisting of cherty gray subcrystalline limestone, with thin cherty seams of bluish gray coarse-grained limestone. Bed 1 of Keokuk section	5	
8.	Limestone, fine-grained, ash-colored, magnesian; with very irregular chert patches, and with interbedded seams of bluish gray coarse-grained cherty limestone. Upper part somewhat shaly	4	
7.	Limestone, bluish gray, coarse-grained, cherty	4	5
6.	Limestone, fine-grained, cherty, ash-colored, magnesian. Chert in form of very irregular patches. No fossils noted	6	1
5.	Limestone, grayish, medium to coarse-grained, cherty; locally in massive layers but for the most part split into thin layers of chert bands	8	
4.	Limestone, gray, fine-grained, cherty, magnesian; with discontinuous layers of cherty gray coarse-grained non-magnesian limestone. Locally the coarse-grained limestone predominates. Grading into the bed below through a layer of fossiliferous limestone about 8 inches to 1 foot thick. This is bluish and coarse-grained above, but is gradually a finer and lighter gray cherty crinoidal limestone below	9	6
3.	Limestone, light gray to whitish, crinoidal, with occasional bands or lenses of whitish chert; massive where fresh; weathered surfaces flaking off obliquely	2–4	
2.	Limestone, light gray, subcrystalline; some layers crinoidal; bearing irregular chert nodules many of which exhibit concretionary structure in the form of alternating bands of lighter and darker colored material. Chert much shattered where weathered, as in other layers. Bed receding slightly; tending to scale off obliquely to weathered surface	4	
1.	Limestone, light gray, crinoidal, with occasional large whitish chert nodules; massive where fresh, but scaling off obliquely to weathered surface. Exposed	2	6

Collections were made from the lower members of the section. The forms identified from each bed are as follows:

List of fossils from bed 1 of Keokuk limestone at Cedar Glen, Illinois.

ANTHOZOA—
- Triplophyllum dalei (M.-E. and H.)

BRYOZOA—
- Cystodictya sp.

BRACHIOPODA—
- Pustula alternata (N. and P.)
- Spirifer tenuicostatus Hall
- Spirifer logani Hall
- Spirifer sp. ?
- Brachythyris suborbicularis (Hall)
- Reticularia pseudolineata (Hall)
- Athyris lamellosa (Leveille)
- Cliothyridina obmaxima (McChesney)

GASTROPODA—
- Platyceras sp.

List of fossils from bed 2 of Keokuk limestone at Cedar Glen, Illinois.

ANTHOZOA—
Cyathaxonia ? sp.
Triplophyllum dalei (M.-E. and H.)
Zaphrentis sp.
BRYOZOA—
Cystodictya sp.
BRACHIOPODA—
Productus sp.
Productus sp.
Tetracamera subtrigona (M. and W.)
Dielasma sp.
Spirifer logani Hall
Spirifer cf. S. grimesi Hall
Reticularia pseudolineata (Hall)
Cliothyridina obmaxima (McChesney)
GASTROPODA—
Orthonychia ? sp.

List of fossils from bed 3 of Keokuk limestone at Cedar Glen, Illinois.

BRYOZOA—
Cystodictya sp.
BRACHIOPODA—
Chonetes sp.
Productus sp.
Pustula alternata (N. and P.)
Dielasma sp.
Delthyris similis Weller ?
Spirifer tenuicostatus Hall
Reticularia pseudolineata (Hall)
Cliothyridina incrassata (Hall)

List of fossils from bed 4 of Keokuk limestone at Cedar Glen, Illinois.

ANTHOZOA—
Triplophyllum dalei (M.-E. and H.)
Amplexus sp.
BRYOZOA—
Stenopora ? sp.
Fenestella multispinosa Ulrich
Fenestella serratula Ulrich
Fenestella sp.
Fenestella sp.
Taeniodictya ramulosa Ulrich ?
Cystodictya sp.
BRACHIOPODA—
Orthotetes keokuk (Hall)
Chonetes sp.
Productus sp.
Productus sp.
Avonia sp.
Pustula alternata (N. and P.)
Pustula sp.
Tetracamera subtrigona (M. and W.)
Dielasma sp.
Delthyris sp.
Spirifer tenuicostatus Hall
Spirifer cf. S. keokuk Hall
Spirifer cf. S. grimesi Hall
Spirifer sp.
Brachythyris suborbicularis (Hall)
Spiriferella neglecta (Hall) ?
Reticularia pseudolineata (Hall)
Cliothyridina sp.
Composita trinuclea (Hall)
GASTROPODA—
Orthonychia sp.

List of fossils from bed 5 of Keokuk limestone at Cedar Glen, Illinois.

ANTHOZOA—
Cyathaxonia ? sp.
Triplophyllum dalei (M.-E. and H.)
Amplexus sp.
Palaeacis obtusus (M. and W.)
CRINOIDEA—
Platycrinus ? sp.
BRYOZOA—
Fenestella serratula Ulrich
Rhombopora varians Ulrich
Cystodictya sp.
BRACHIOPODA—
Orthotetes keokuk (Hall)
Productus sp.
Pustula alternata (N. and P.)
Rhipidomella dubia (Hall)
Tetracamera subcuneata (Hall)
Tetracamera subtrigona (M. and W.)
Dielasma sp.
Delthyris sp.
Delthyris sp.
Spirifer logani Hall
Spirifer cf. S. grimesi Hall
Spirifer keokuk Hall
Spirifer tenuicostatus Hall
Reticularia pseudolineata (Hall)
Eumetria verneuiliana (Hall)
Athyris lamellosa (Leveille)
Cliothyridina obmaxima (McChesney)
Composita trinuclea (Hall)
PELECYPODA—
Conocardium sp.
Myalina keokuk Worthen
GASTROPODA—
Orthonychia ? sp.
TRILOBITA—
Griffithides ? sp.
VERTEBRATA—
Fish teeth

List of fossils from bed 7 of Keokuk limestone at Cedar Glen, Illinois.

ANTHOZOA—
- Triplophyllum dalei (M.-E. and H.)
- Amplexus sp.
- Palaeacis obtusus (M. and W.)

BRYOZOA—
- Meekopora sp.
- Fenestella multispinosa Ulrich ?
- Fenestella sp.
- Hemitrypa sp.
- Cystodictya sp.
- Cyclopora ? sp.

BRACHIOPODA—
- Orthotetes keokuk (Hall)
- Chonetes sp.
- Productus sp.
- Productus sp.
- Pustula alternata (N. and P.)
- Rhipidomella dubia (Hall)
- Schizophoria sp.
- Tetracamera subcuneata (Hall)
- Tetracamera subtrigona (M. and W.)
- Delthyris sp.
- Spirifer tenuicostatus Hall
- Spirifer rostellatus Hall
- Spirifer cf. S. keokuk Hall
- Spirifer logani Hall
- Brachythyris suborbicularis (Hall)
- Syringothyris sp.
- Spiriferella neglecta (Hall)
- Reticularia pseudolineata (Hall)
- Cliothyridina obmaxima (McChesney)
- Composita trinuclea (Hall)

PELECYPODA—
- Cypricardinia ? sp.

GASTROPODA—
- Orthonychia ? sp.

VERTEBRATA—
- Fish teeth

List of fossils from bed 8 of Keokuk limestone at Cedar Glen, Illinois.

ANTHOZOA—
- Triplophyllum dalei (M.-E. and H.)

BRYOZOA—
- Meekopora ? sp.
- Leioclema punctatum (Hall)
- Polypora retrorsa Ulrich ?
- Cystodictya sp.
- Cystodictya sp.
- Cyclopora ? sp.

BRACHIOPODA—
- Avonia sp.
- Productus sp.
- Tetracamera subcuneata (Hall)
- Cranaena sulcata Weller
- Delthyris sp.
- Spirifer ? sp.
- Reticularia pseudolineata (Hall)
- Athyris lamellosa (Leveille)
- Composita trinuclea (Hall)

List of fossils from bed 9 of Keokuk limestone at Cedar Glen, Illinois.

ANTHOZOA—
- Triplophyllum dalei (M.-E. and H.)
- Palaeacis obtusus (M. and W.)

BRACHIOPODA—
- Orthotetes keokuk (Hall)
- Productus sp.
- Productus sp.
- Avonia sp.
- Rhipidomella dubia (Hall)
- Tetracamera subtrigona (M. and W.)
- Dielasma ? sp.
- Spiriferella neglecta (Hall)
- Reticularia pseudolineata (Hall)

VERTEBRATA—
- Fish teeth

A fairly complete section of the Keokuk limestone appears near Nauvoo, Illinois, opposite Montrose, Iowa. The following section is exposed in the banks of a small creek and in a quarry near its mouth a short distance south of the city limits of Nauvoo.

Section of Keokuk limestone near Nauvoo, Illinois.

	FEET	INCHES
14. Thin layers of gray cherty limestone and bluish shale interbedded; weathering buff. Exposed only in quarry	2	
13. Limestone, gray, thin-bedded, fine-grained and cherty in bank of creek, but more massive, bluish and coarser-grained in quarry	4	
12. Limestone, bluish, medium-grained, tough; locally pass-		

	ing into shale. *Fenestella* sp.; *Pustula* sp.; *Orthotetes keokuk; Rhipidomella dubia; Dielasma ?* sp.; *Spirifer keokuk; Reticularia pseudolineata; Phillipsia ?* sp.	12–15	
11.	Shale, with thin layers of gray to bluish fossiliferous limestone	1 1/2–2	
10.	Limestone, bluish gray, medium-grained; massive when fresh but weathering to thin irregular layers. Contact with bed above very uneven and undulating	1–4 1/2	
9.	Shaly parting with thin seams of limestone		10
8.	Limestone, gray, fine-grained to medium-grained, brittle; weathering to thin irregular layers. *Triplophyllum dalei; Fenestella* sp.; *Hemitrypa* sp.; *Cystodictya* sp.; *Productus* sp.; *Productus setigerus; Pustula alternata; Orthotetes keokuk; Brachythyris suborbicularis; Phillipsia ?* sp.	3	
7.	Shaly parting with seams and lentils of cherty limestone		10
6.	Limestone, gray, dense, brittle, thinly and irregularly bedded, cherty. Some layers passing laterally into gray calcareous shale locally. *Cystodictya* sp.; *Orthotetes keokuk; Dielasma* sp.; *Spirifer tenuicostatus; Brachythyris suborbicularis; Reticularia pseudolineata; Hemitrypa* sp.; *Spirifer* cf. *S. keokuk*	2	2
5.	Limestone, bluish gray. Fossils scarce. Flakes off obliquely on weathered surface. *Palaeacis obtusus; Spirifer keokuk*	1	9
4.	Limestone, like No. 1. A bluish layer 3 to 4 inches thick in middle part is rich in fish teeth. *Palaeacis obtusus; Orthotetes keokuk; Pustula alternata; Dielasma* sp.; *Platyceras* sp.	7	
3.	Limestone, bluish gray, medium-grained, weathering to thin flakes. *Pustula alternata; Orthotetes keokuk; Rhipidomella dubia; Spirifer tenuicostatus; Spirifer* cf. *S. keokuk*	1	10
2.	Shaly parting		10
1.	Limestone, gray, fine-grained, irregularly stratified; with thin layers of medium-grained bluish gray cherty limestone. *Fenestella* sp.; *Productus* sp.; *Pustula* sp.; *Orthotetes keokuk; Girtyella indianensis; Reticularia pseudolineata*	7	

The uppermost part of the exposure is very fossiliferous. Collections were made from beds 9, 10, 11, 13 and 14. The following lists were prepared from these:

List of fossils from bed 9 of the Keokuk limestone at Nauvoo, Illinois.

ANTHOZOA—
- Zaphrentis varsoviensis Worthen
- Triplophyllum dalei (M.-E. and H.)
- Amplexus sp.
- Monilopora beecheri Grabau

CRINOIDEA—
- Actinocrinus lowei Hall ?
- Dorycrinus sp.

BRYOZOA—
- Leioclema punctatum (Hall)
- Fenestella serratula Ulrich
- Rhombopora varians Ulrich
- Phractopora trifolia (Rominger)

BRACHIOPODA—
- Spirifer sp.
- Reticularia pseudolineata (Hall)

GASTROPODA—
- Ptychospira sp.
- Platyceras sp.

List of fossils from bed 10 of Keokuk limestone at Nauvoo, Illinois.

ANTHOZOA—
- Triplophyllum dalei (M.-E. and H.)
- Amplexus sp.
- Monilopora beecheri Grabau
- Palaeacis obtusus (M. and W.)

BRYOZOA—
- Cyclopora sp.
- Fistulipora sp.
- Bactropora simplex Ulrich
- Fenestella sp.
- Polypora sp.
- Archimedes negligens Ulrich
- Hemitrypa sp.
- Leioclema punctatum (Hall)
- Cystodictya sp.
- Phractopora trifolia (Rominger)

BRACHIOPODA—
- Orthotetes keokuk (Hall)
- Productus sp.
- Pustula alternata (N. and P.)
- Rhipidomella dubia (Hall)
- Spirifer tenuicostatus Hall
- Brachythyris suborbicularis (Hall)
- Reticularia pseudolineata (Hall)
- Cliothyridina parvirostris (M. and W.)
- Cliothyridina obmaxima (McChesney)

List of fossils from bed 11 of Keokuk limestone at Nauvoo, Illinois.

ANTHOZOA—
- Triplophyllum dalei (M.-E. and H.)
- Monilopora beecheri Grabau
- Amplexus sp.
- Zaphrentis varsoviensis Worthen
- Palaeacis obtusus (M. and W.)

CRINOIDEA—
- Parichthyocrinus meeki (Hall)

BRYOZOA—
- Leioclema punctatum (Hall)
- Fenestella serratula Ulrich
- Fenestella multispinosa Ulrich
- Hemitrypa pateriformis Ulrich
- Archimedes negligens Ulrich
- Polypora simulatrix Ulrich
- Polypora maccoyana Ulrich
- Polypora halliana Prout
- Bactropora simplex Ulrich
- Rhombopora attenuata Ulrich
- Rhombopora varians Ulrich
- Streblotrypa major Ulrich
- Cystodictya sp.
- Phractopora trifolia Ulrich
- Worthenopora spinosa Ulrich
- Worthenopora sp.

BRACHIOPODA—
- Productus sp.
- Orthotetes keokuk (Hall)
- Pustula alternata (N. and P.)
- Camarotoechia mutata (Hall)
- Rhipidomella dubia (Hall)
- Spiriferina sp.
- Spirifer keokuk Hall
- Spirifer tenuicostatus Hall
- Reticularia pseudolineata (Hall)
- Composita trinuclea (Hall)
- Cliothyridina parvirostris (M. and W.)

TRILOBITA—
- Griffithides ? sp.

List of fossils from bed 13 of Keokuk limestone at Nauvoo, Illinois.

BRYOZOA—
- Stenopora sp.
- Chaetetes ? sp.
- Taeniodictya ramulosa Ulrich
- Worthenopora spinosa Ulrich
- Archimedes sp.
- Rhombopora attenuata Ulrich

BRACHIOPODA—
- Chonetes illinoisensis Worthen
- Pustula alternata (N. and P.)
- Productus mesialis Hall
- Productus sp.
- Spiriferina sp.
- Spirifer keokuk Hall
- Syringothyris sp.
- Spiriferella neglecta (Hall)
- Eumetria verneuiliana (Hall)

List of fossils from bed 14 of the Keokuk limestone at Nauvoo, Illinois.

ANTHOZOA—
- Monilopora beecheri Grabau

CRINOIDEA—
- Dorycrinus sp.
- Barycrinus sp.

BRYOZOA—
- Stenopora sp.
- Leioclema gracillimum Ulrich
- Worthenopora spinosa Ulrich
- Cystodictya sp.
- Phractopora trifolia (Rominger)
- Rhombopora varians Ulrich
- Rhombopora ? asperula Ulrich
- Rhombopora attenuata Ulrich
- Streblotrypa major Ulrich
- Taeniodictya ramulosa Ulrich
- Glyptopora keyserlingi (Prout)
- Fenestella cingulata Ulrich
- Fenestella serratula Ulrich
- Fenestella rudis Ulrich
- Polypora biseriata Ulrich
- Polypora retrorsa Ulrich
- Hemitrypa sp
- Ptilopora sp.
- Archimedes negligens Ulrich

BRACHIOPODA—
- Productus sp.
- Rhipidomella dubia (Hall)
- Camarotoechia mutata Hall
- Spiriferina sp.
- Spirifer keokuk Hall

Near Niota, Illinois, opposite Fort Madison, Iowa, there are other good exposures of the Keokuk limestone. The following section was measured two miles southwest of Niota in the banks of a small creek tributary to Mississippi river.

Section of Keokuk limestone near Niota, Illinois.

		Feet	Inches
29.	Drift		
28.	Shale, bluish, calcareous, checking into irregular blocks and chips. Geodes scarce, some stained with bitumen. Flakes of fossiliferous limestone in lower part	13	
27.	Shale, highly calcareous, grayish blue in color, bearing a few hollow geodes most of whose shells are stained with bitumen	1	6
26.	Shale, argillo-calcareous, bluish, no geodes noted	3	4
25.	Limestone, light gray, fine-grained, weathering to thin shelly layers, bearing *Archimedes owenanus*, *Spirifer keokuk*, *Lithophagus illinoisensis*, and numerous crinoid stems	2	
24.	Shale, bluish, argillaceous	4	
23.	Limestone, dark gray, crystalline, very fossiliferous. Some of the fossils identified are: *Spirifer keokuk*, *Productus* sp., *Orthotetes keokuk*, *Zaphrentis* sp., *Spirifer* sp., and fish teeth	1	2
22.	Shale, bluish	1	6
21.	Limestone, gray, crystalline	2	6
20.	Limestone, shaly, thinly laminated	1	10
19.	Limestone, gray, dense, crystalline, fossiliferous, bearing a few nodules of chert	3	
18.	Shale, bearing fossiliferous flakes of limestone	1	
17.	Limestone, impure, fine-grained, cherty, bearing bands of coarsely crystalline limestone	3	8
16.	Limestone, grayish, fine-grained, dense, no fossils recognized	2	8
15.	Limestone, gray, crystalline, bearing *Spirifer keokuk*, *Girtyella turgida* and other fossils	1	2
14.	Limestone, ash-colored, very fine-grained, weathering to thin irregular layers	1	6
13.	Limestone, gray, crinoidal, *Orthotetes keokuk* abundant	1	8
12.	Limestone, shaly	1	4
11.	Limestone, coarse-grained and crinoidal in upper part but fine-grained and shaly below; bearing two inch chert band near the top. Some of the fossils collected from this layer are: *Orthotetes keokuk*, *Spirifer keokuk*, *Spirifer logani*, *Reticularia pseudolineata*, *Tetracamera subtrigona*, *Productus* sp.	2	6
10.	Chert, bluish, dense, fossiliferous	8	8
9.	Limestone, grayish blue, crystalline, bearing disseminated crystals of pyrite and a few chert nodules		8
8.	Shale, bluish, calcareous	2	6
7.	Limestone, crystalline, cherty, bearing rounded geodic masses of calcite with incomplete chalcedonic shells	2	5
6.	Shale, bluish, argillaceous	2	
5.	Shale, bluish, calcareous, with bands of cherty fossiliferous limestone	2	
4	Limestone, gray, crystalline; with intercalated shale band; bearing *Spirifer logani*, *Reticularia pseudolineata* and *Spirifer keokuk*	3	6
3.	Shaly parting		4
2.	Shale, calcareous, bearing irregular seams and nodules of chert	7	
1.	Limestone, light gray, fine-grained, cherty; bearing *Orthotetes keokuk* and other Keokuk species. Exposed	3	

Beds 1 to 25 inclusive constitute the Keokuk limestone; beds

26 to 28, on the other hand, represent the Geode bed or Lower Warsaw.

In Denmark township, Lee county, Iowa, the Keokuk limestone is well exposed in a bluff two and one-half miles northwest of the town of Denmark.

Section of Keokuk limestone northwest of Denmark.

		FEET	INCHES
19.	Massive, gray limestone bearing numerous broad shells of *Orthotetes keokuk*	1	5
18.	Limestone layers with thin intercalated shale bands	2	
17.	Shale, calcareous below but more argillaceous above	3	6
16.	Limestone, gray and buff	1	4
15.	Limestone, cherty, stratification very irregular or lacking; checking into irregular blocks and weathering buff; *Spirifer keokuk* common	2	4
14.	Shaly parting		4
13.	Limestone, gray and blue, very fossiliferous. The following forms were noted: *Conularia* sp., *Spirifer keokuk, Orthotetes keokuk, Cliothyridina* sp., *Reticularia pseudolineata* and *Tetracamera subtrigona*	1	6
12.	Limestone, argillaceous, buff, non-fossiliferous, stratification obscure, disintegrating into angular blocks	2	4
11.	Shaly parting		6
10.	Limestone, dense, gray, cherty above	1	4
9.	Shale, highly calcareous, massive, unfossiliferous; checking irregularly and containing irregular bands of chert and a few imperfect geodes	5	6
8.	Limestone, in the form of a dense gray layer		8
7.	Shaly parting	1	2
6.	Limestone, massive, weathering to thin spalls	1	5
5.	Shale, argillaceous, thinly laminated	1	3
4.	Limestone, massive, crinoidal, cherty below	2	
3.	Shale, calcareous; showing no bedding; bands of cherty limestone intercalated	6	5
2.	Limestone, coarse-grained, crinoidal, bearing nodular chert below. *Pustula alternata, Productus setigerus* and *Reticularia pseudolineata*	1	4
1.	Shale, passing laterally into limestone		

In a bluff at South Augusta (NE. ¼ sec. 25, Denmark township) the basal beds of the Keokuk are exposed in contact with the Upper Burlington limestone.

Section of Keokuk limestone at South Augusta.

		FEET
4.	Residual soil filled with angular chert fragments. To brow of hill	3
3.	Limestone, thin-bedded, gray, subcrystalline, very cherty; a solid layer of chert twenty inches thick at base at one point. Bed 3 of Augusta section	3½
2.	Limestone, gray, coarse-grained, crinoidal, very cherty, especially in lower part. Bed 2 of Augusta section	6
1.	Limestone, coarse-grained, crinoidal, gray below but bluish gray above, bearing worn shells of *Spirifer grimesi.* Bed 1 of Augusta section	1½ to 2

List of fossils from bed 1 of Keokuk limestone at South Augusta.

ANTHOZOA—
- Zaphrentis sp.

BRACHIOPODA—
- Spirifer grimesi Hall
- Spirifer tenuicostatus Hall
- Brachythyris suborbicularis (Hall)
- Reticularia pseudolineata (Hall)
- Cliothyridina incrassata (Hall)

TRILOBITA—
- Griffithides ? sp.

List of fossils from bed 2 of Keokuk limestone at South Augusta.

BRACHIOPODA—
- Spirifer grimesi Hall
- Spirifer sp.
- Reticularia pseudolineata (Hall)

VERTEBRATA—
- Fish teeth

List of fossils from bed 3 of Keokuk limestone at South Augusta.

CRINOIDEA—
- Batocrinus sp.

BRYOZOA—
- Fenestella sp.
- Taeniodictya ramulosa Ulrich
- Proutella ? sp.

BRACHIOPODA—
- Productus ovatus Hall
- Avonia sp.
- Dielasma sp.
- Tetracamera subtrigona (M. and W.)
- Spiriferina sp.
- Spirifer tenuicostatus Hall
- Spirifer rostellatus Hall
- Spiriferella neglecta (Hall)
- Syringothyris sp.
- Reticularia pseudolineata (Hall)
- Athyris lamellosa (Leveille)
- Cliothyridina incrassata (Hall)
- Composita trinuclea (Hall)

PELECYPODA—
- Conocardium sp.

TRILOBITA—
- Griffithides ? sp.

Des Moines County.—The Des Moines county exposures of the Keokuk limestone are confined chiefly to the area about Augusta in the southern part of the county. However, the basal beds of this formation have been recognized at localities farther north.

One of the most complete sections in the county occurs along the banks of a small creek one-half mile north of the Augusta wagon bridge in the eastern part of section 23, Augusta township. The succession of beds there is as follows:

Section of Keokuk limestone near Augusta.

		FEET	INCHES
13.	Drift	2	
12.	Limestone, bluish gray, impure. Exposed	1	
11.	Concealed, probably soft shaly limestone; loose blocks on surface highly fossiliferous	3	
10.	Limestone, bluish gray, medium-grained, dense	2	2
9.	Limestone, consisting of thin layers of bluish gray coarse-grained limestone alternating with layers of thin-bedded gray fine-grained cherty limestone which weathers buff	7	6
8.	Limestone, bluish gray, medium-grained, bearing *Orthotetes keokuk* and *Pustula alternata*	7	11
7.	Limestone, gray, subcrystalline, thinly and irregularly bedded, cherty	1	6
6.	Limestone, bluish gray, medium grained, *Orthotetes keokuk* and *Palaeacis obtusus* abundant		6
5.	Limestone, dark gray to bluish gray, thinly and irregularly bedded, cherty	2	
4.	Limestone, bluish gray, medium-grained to crinoidal; for the		

	most part massive but in places divided into thin layers by chert bands	1	6
3.	Limestone, gray, subcrystalline, thin-bedded, cherty; with a massive layer of crinoidal limestone in upper part	10	
2.	Limestone, light gray, coarse-grained, crinoidal, with occasional chert nodules or bands	6	3
1.	Limestone, coarse-grained, crinoidal, gray below but bluish above; the topmost layer, which is 8 inches thick, bears water-worn specimens of *Spirifer grimesi*	1	6

The Keokuk limestone is underlain at this point by twenty-one feet of crinoidal limestone of Upper Burlington age. This has been described in a previous chapter. The fossils of the successive beds of the Keokuk limestone near Augusta are listed below.

List of fossils from bed 1 of Keokuk limestone near Augusta.

ANTHOZOA—
- Triplophyllum dalei (M.-E. and H.)
- Cyathaxonia sp.
- Amplexus sp.

BRYOZOA—
- Fenestella sp.
- Cystodictya sp.

BRACHIOPODA—
- Orthotetes sp.
- Pustula alternata (N. and P.)
- Tetracamera subtrigona (Hall)
- Spirifer grimesi Hall
- Spirifer tenuicostatus Hall
- Reticularia pseudolincata (Hall)
- Brachythyris suborbicularis (Hall)
- Athyris lamellosa (Leveille)
- Cliothyridina incrassata (Hall)
- Cliothyridina parvirostris (M. and W.)

PELECYPODA—
- Conocardium sp.

GASTROPODA—
- Platyceras sp.
- Orthonychia sp.

VERTEBRATA—
- Fish teeth

List of fossils from bed 2 of Keokuk limestone near Augusta.

CRINOIDEA—
- Actinocrinus sp.

BRYOZOA—
- Fenestella sp.

BRACHIOPODA—
- Productus sp.
- Pustula alternata (N. and P.)
- Spirifer incertus Hall
- Spirifer grimesi Hall
- Brachythyris suborbicularis (Hall)
- Reticularia pseudolineata (Hall)
- Cliothyridina incrassata (Hall)

GASTROPODA—
- Orthonychia sp.
- Orthonychia sp.

TRILOBITA—
- Griffithides ? sp.

List of fossils from bed 3 of Keokuk limestone near Augusta.

BRYOZOA—
- Fenestella sp.
- Proutella sp.

BRACHIOPODA—
- Tetracamera subtrigona (M. and W.)
- Productus ovatus Hall
- Productus sp.
- Pustula sp.
- Dielasma sp.
- Spirifer tenuicostatus Hall
- Spirifer rostellatus Hall
- Reticularia pseudolineata (Hall)
- Spiriferina sp.
- Athyris lamellosa (Leveille)
- Cliothyridina obmaxima (McChesney)
- Cliothyridina parvirostris (M. and W.)

GASTROPODA—
- Orthonychia ? sp.

List of fossils from bed 5 of Keokuk limestone near Augusta.

ANTHOZOA—
- Triplophyllum dalei (M.-E. and H.)

BRACHIOPODA—
- Productus ovatus Hall

Productus sp.
Avonia sp.
Chonetes sp.
Delthyris ? sp.
Spirifer logani Hall
Spirifer sp. ?
Brachythyris suborbicularis (Hall)
Reticularia pseudolineata (Hall)
Composita trinuclea (Hall)
PELECYPODA—
Cypricardinia sp.

List of fossils from bed 6 of Keokuk limestone near Augusta.

ANTHOZOA—
Palaeacis obtusus (M. and W.)
Triplophyllum dalei (M.-E. and H.)
BRACHIOPODA—
Pustula alternata (N. and P.)
Tetracamera subtrigona (M. and W.)
Spiriferina sp.
Spirifer sp.
Brachythyris suborbicularis (Hall)
Reticularia pseudolineata (Hall)
Syringothyris sp.
Cliothyridina obmaxima (McChesney)
GASTROPODA—
Platyceras sp.
VERTEBRATA—
Fish teeth

List of fossils from bed 7 of Keokuk limestone near Augusta.

ANTHOZOA—
Zaphrentis sp.
CRINOIDEA—
Dorycrinus (spine)
Platycrinus sp.
BRYOZOA—
Cystodictya sp.
Worthenopora spinosa Ulrich ?
BRACHIOPODA—
Pustula alternata (N. and P.)
Dielasma sp.
Tetracamera subtrigona (M. and W.)
Spiriferina sp.
Reticularia pseudolineata (Hall)
Athyris lamellosa (Leveille)
Cliothyridina incrassata (Hall) ?
Cliothyridina obmaxima (McChesney)
GASTROPODA—
Platyceras sp.
Orthonychia sp.
TRILOBITA—
Griffithides ? sp.

List of fossils from bed 9 of Keokuk limestone near Augusta.

CRINOIDEA—
Actinocrinus lowei Hall
BRACHIOPODA—
Tetracamera subtrigona (M. and W.)
Spirifer logani Hall
Spiriferella neglecta (Hall) ?
Cliothyridina incrassata (Hall)
GASTROPODA—
Platyceras sp.

List of fossils from bed 10 of Keokuk limestone near Augusta.

BRYOZOA—
Phractopora trifolia (Rominger)
BRACHIOPODA—
Spirifer keokuk Hall
Spirifer logani Hall
Reticularia pseudolineata (Hall)

List of fossils from bed 11 of Keokuk limestone near Augusta.

ANTHOZOA—
Zaphrentis varsoviensis Worthen ?
Triplophyllum dalei (M.-E. and H.)
Amplexus sp.
Monilopora beecheri Grabau
CRINOIDEA—
Actinocrinus sp.
Platycrinus sp.
Synbathocrinus sp.
BRYOZOA—
Cyclopora ? sp.
Leioclema gracillimum Ulrich
Leioclema punctatum (Hall)
Phractopora trifolia (Rominger)
Taeniodictya ramulosa Ulrich
Glyptopora keyserlingi (Prout)
Rhombopora varians Ulrich
Rhombopora attenuata Ulrich
Rhombopora transversalis Ulrich
Cystodictya pustulosa Ulrich
Fenestella serratula Ulrich
Fenestella multispinosa Ulrich ?
Streblotrypa radialis Ulrich
BRACHIOPODA—
Orthotetes ? sp.
Productus wortheni Hall ?
Pustula sp.
Tetracamera subtrigona (M. and W.)

Tetracamera subcuneata (Hall)
Rhipidomella dubia (Hall)
Spiriferina ? sp.
Spirifer tenuicostatus Hall ?
Spirifer logani Hall
Spirifer cf. S. keokuk Hall
Spirifer rostellatus Hall
Spiriferella neglecta (Hall)
Brachythyris suborbicularis (Hall)
Reticularia pseudolineata (Hall)
Syringothyris sp.
Cliothyridina incrassata (Hall)
PELECYPODA—
Conocardium sp.
GASTROPODA—
Platyceras sp.

The following faunal table includes the more characteristic species of the collections made at both South Augusta and Augusta.

Table Showing Range of Fossils in the Keokuk Beds at Augusta and South Augusta.

	Horizons									
	1	2	3	5	6	7	8	9	10	11
ANTHOZOA										
Zaphrentis varsoviensis Worthen ?										x
Triplophyllum dalei (M.-E. and H.)	x			x	x					x
Cyathaxonia sp.	x									
Palaeacis obtusus (M. and W.)					x					
Monilopora beecheri Grabau										x
Amplexus sp.	x									x
CRINOIDEA										
Batocrinus sp.			x							
Dorycrinus (spine)						x				
Actinocrinus lowei Hall								x		
Actinocrinus sp.										x
Actinocrinus sp.		x								
Synbathocrinus sp.										x
BRYOZOA										
Leioclema gracillimum Ulrich										x
Leioclema punctatum (Hall)										x
Taeniodictya ramulosa Ulrich			x							x
Cystodictya pustulosa Ulrich										x
Cystodictya sp.						x				
Cystodictya sp.	x									
Phractopora trifolia (Rominger)									x	x
Glyptopora keyserlingi (Prout)										x
Rhombopora attenuata Ulrich										x
Rhombopora varians Ulrich										x
Rhombopora transversalis Ulrich										x
Streblotrypa radialis Ulrich										x
Fenestella serratula Ulrich										x
Fenestella multispinosa Ulrich										x
Proutella sp.			x							
Worthenopora spinosa Ulrich ?						x				
BRACHIOPODA										
Orthotetes keokuk (Hall)							x			
Orthotetes sp.	x									

Table Showing Range of Fossils in the Keokuk Beds at Augusta and South Augusta. Continued.

	Horizons									
	1	2	3	5	6	7	8	9	10	11
Chonetes sp.				x						
Productus ovatus Hall			x	x						
Productus wortheni Hall ?										x
Pustula alternata (N. and P.)	x	x			x	x	x			
Pustula sp.										x
Avonia sp.			x	x						
Rhipidomella dubia (Hall)										x
Tetracamera subtrigona (M. and W.)	x		x		x	x		x		x
Tetracamera subcuneata (Hall)										x
Dielasma sp.			x			x				
Spiriferina sp.			x		x	x				
Spirifer grimesi Hall	x	x								
Spirifer incertus Hall		x								
Spirifer tenuicostatus Hall	x		x							x
Spirifer rostellatus Hall			x							x
Spirifer logani Hall				x				x	x	x
Spirifer keokuk Hall									x	
Spirifer cf. S. keokuk Hall										x
Brachythyris suborbicularis (Hall)	x	x		x	x					x
Spiriferella neglecta (Hall)			x					x?		x
Reticularia pseudolineata (Hall)	x	x	x	x	x	x			x	x
Syringothyris sp.										x
Athyris lamellosa (Leveille)	x		x			x				
Cliothyridina incrassata (Hall)	x	x	x			x?		x		x
Cliothyridina obmaxima (McChesney)			x		x	x				
Cliothyridina parvirostris (M. and W.)	x		x							
Composita trinuclea (Hall)			x	x						
PELECYPODA										
Conocardium sp.	x		x							x
Cypricardinia sp.				x						
GASTROPODA										
Platyceras sp.						x		x		x
Platyceras sp.	x									
Orthonychia sp.						x				
Orthonychia sp.	x									
Orthonychia sp.		x								
Orthonychia sp.		x								
TRILOBITA										
Griffithides ? sp.	x	x	x			x				

Approximately two miles northeast of Augusta the Keokuk limestone is again well exposed in the south bank of Long creek on the Harry Hillgardner property. The following beds are exposed at this place:

Section in the south bank of Long creek.

		FEET	INCHES
12.	Drift, to brow of hill		
11.	Limestone, as in bed 7. Interbedded with layers of soft shale	5	
10.	Limestone, bluish gray, slightly crinoidal. *Orthotetes keokuk, Spirifer keokuk, Reticularia pseudolineata, R. dubia, Pustula* sp.	2	
9.	Limestone as in bed 7. *Spirifer tenuicostatus*	4	6
8.	Limestone, gray, medium-grained; in thin layers separated by shaly seams	2	8
7.	Limestone, gray to drab, soft, magnesian; flaking off obliquely to surface. No fossils noted	5	6
6.	Limestone, gray, medium-grained; with seams of fine-grained soft limestone	3	6
5.	Shaly seam		6
4.	Limestone, gray, fine-grained, soft, cherty; with layers and seams of gray to bluish coarser-grained slightly crinoidal fossiliferous limestone. A thin bluish crinoidal layer at the top bears many fish teeth. *Palaeacis obtusus, Zaphrentis varsoviensis, Fenestella* sp.	5	6
3.	Limestone, bluish gray, cherty, slightly crinoidal. *Triplophyllum dalei, Brachythyris suborbicularis, Pustula alternata, Rhipidomella dubia, Conocardium* sp. *Reticularia pseudolineata, Spirifer tenuicostatus* and fragments of fish teeth		10
2.	Shaly seam	3	
1.	Limestone, drab, fine-grained, magnesian, with segregations of calcite. To water in creek	4	6

Thirty rods north of this exposure there is a bluff section on the opposite bank of the creek. Bed 10 is overlain at this point by eighteen feet of bluish shale, calcareous in the lower part, which is referred to the Lower Warsaw. This member is in turn followed above by five feet of Spergen dolomitic limestone.

In the region about Burlington only the basal beds of the Keokuk are preserved. Thus, in the Miller quarry above the Cascade the following beds are seen in contact with the upper Burlington limestone.

Section of Keokuk limestone in Miller quarry.

		FEET	INCHES
3.	Limestone, brownish, magnesian, very cherty	7½	
2.	Limestone, brownish, crinoidal	1	5
1.	Limestone, yellowish, magnesian, cherty, especially near the base	5	3

No identifiable fossils were found in any of the layers but their position above the Upper Burlington suggests their Keokuk age.

Van Buren County.—The exposures of the Keokuk limestone in Van Buren county are confined to a narrow belt along Des Moines river where the overlying formations have been eroded as a result of the uplift of an anticline which nearly parallels the river. A general section of the Keokuk limestone as exposed at and near the town of Bentonsport is as follows:

Generalized section of the Keokuk limestone at Bentonsport and vicinity.

		FEET	INCHES
20.	Limestone, bluish gray, coarse-grained; in one massive ledge	3	
19.	Shale, bluish, argillaceous, highly fossiliferous; with discontinuous seams and flakes of gray impure, cherty limestone	1	6
18.	Limestone, gray, medium-grained	1	6
17.	Shale, bluish, argillaceous, slightly fossiliferous		2–12
16.	Limestone, bluish, rather coarse-grained; separated from the bed below by a shaly parting 5 to 10 inches thick	2	6
15.	Limestone, gray, subcrystalline, with irregular nodules of chert; massive when fresh but weathering into thin layers; locally shaly in lower part	2	
14.	Limestone, bluish, coarse-grained, cherty; for the most part in one massive ledge	2	
13.	Limestone, light gray to whitish, medium-grained, slightly crinoidal; grading locally into gray subcrystalline limestone which weathers to yellowish shaly layers	2	6
12.	Limestone, consisting of alternating layers of rather coarse-grained bluish limestone and gray subcrystalline limestone which weathers shaly	6	5
11.	Limestone, bluish gray, rather coarse-grained; with shaly partings between the layers in lower part	3	6
10.	Limestone, grayish, subcrystalline; with seams of coarser-grained bluish cherty limestone in lower part	4	9
9.	Shale, bluish, calcareous, weathering drab and yellowish, unfossiliferous	6	6
8.	Limestone, bluish gray, subcrystalline, with a shaly parting four inches thick near the middle	3	10
7.	Limestone, fine-grained, impure, ash-colored, dolomitic; shaly towards the top; weathering buff; with a few cherty seams	3	9
6.	Limestone, gray, subcrystalline, cherty	1	9
5.	Limestone, bluish gray and medium-grained in lower part, but fine-grained and ash-colored above	5	5
4.	Limestone, gray, fine-grained, structureless, cherty; locally passing into gray subcrystalline fossiliferous limestone	3	
3.	Limestone, bluish gray, medium-grained to coarse-grained, slightly crinoidal; upper one-half locally bearing fish teeth and pygidia of trilobites; middle part rich in crinoids	3	
2.	Limestone, grayish, subcrystalline, very cherty; locally grading into coarse-grained bluish gray crinoidal limestone	2	
1.	Limestone, bluish gray, cherty	1	3

Beds 1 to 4 represent the basal portion of the formation and are well exposed on Lexington creek, nearly one mile above its mouth, in section 7, Bonaparte township. Beds 5 to 20, on the other hand, are exposed in the north bluff of Des Moines river about one-fourth mile below the station at Bentonsport. Bed 20 is overlain here by highly fossiliferous shales and shaly limestones of the Lower Warsaw (Geode bed). These are described in a later chapter devoted to this formation.

The fossils of the individual beds of the Keokuk limestone in this area are listed below.

List of fossils from bed 1 of Keokuk limestone in Bentonsport area.

CRINOIDEA—
- Dorycrinus sp.

BRYOZOA—
- Leioclema punctatum (Hall)

BRACHIOPODA—
- Productus setigerus Hall
- Productus sp.
- Pustula biseriata (Hall)
- Tetracamera subtrigona (M. and W.)
- Dielasma sp.
- Dielasma sp.
- Spiriferina sp.
- Spirifer grimesi Hall
- Spirifer logani Hall
- Spirifer rostellatus Hall
- Spirifer tenuicostatus Hall
- Spirifer cf. S. keokuk Hall
- Spiriferella neglecta (Hall)
- Composita trinuclea (Hall)

GASTROPODA—
- Platyceras sp.
- Platyceras sp.

TRILOBITA—
- Griffithides ? sp.

List of fossils from bed 2 of Keokuk limestone in Bentonsport area.

BRACHIOPODA—
- Avonia sp.
- Dielasma ? sp.
- Dielasma sp.
- Tetracamera subtrigona (M. and W.)
- Spirifer sp.
- Reticularia pseudolineata (Hall)

GASTROPODA—
- Orthonychia sp.

List of fossils from bed 3 of Keokuk limestone in Bentonsport area.

ANTHOZOA—
- Cyathaxonia sp.
- Amplexus sp.
- Zaphrentis varsoviensis Worthen (?)
- Zaphrentis sp.
- Triplophyllum dalei (M.-E. and H.)
- Palaeacis obtusus (M. and W.)

CRINOIDEA—
- Actinocrinus sp.
- Dorycrinus sp.

EHINOIDEA—
- Archaeocidaris sp.

BRYOZOA—
- Stenopora sp.
- Cyclopora ? sp.

BRACHIOPODA—
- Orthotetes keokuk (Hall)
- Productus setigerus Hall
- Productus sp.
- Pustula alternata (N. and P.)
- Pustula ? sp.
- Rhipidomella dubia (Hall)
- Tetracamera subcuneata (Hall)
- Tetracamera subtrigona (M. and W.)
- Dielasma sp.
- Spiriferina sp.
- Spirifer tenuicostatus Hall
- Spirifer logani Hall
- Spirifer cf. S. keokuk Hall
- Syringothyris sp.
- Syringothyris sp.
- Spiriferella neglecta (Hall)
- Reticularia pseudolineata (Hall)
- Cliothyridina parvirostris (M. & W.) ?

PELECYPODA—
- Myalina keokuk Worthen

GASTROPODA—
- Platyceras equilateralis Hall
- Platyceras fissurella Hall ?
- Platyceras sp.

TRILOBITA—
- Griffithides ? sp.

VERTEBRATA—
- Fish teeth

List of fossils from bed 4 of Keokuk limestone in Bentonsport area.

BRYOZOA—
- Stenopora sp.
- Fenestella serratula Ulrich
- Fenestella sp.
- Fenestella sp.

BRACHIOPODA—
- Orthotetes keokuk (Hall)
- Chonetes shumardanus De Koninck
- Productus sp.
- Avonia sp.
- Pustula alternata (N. and P.)
- Pustula sp.
- Camarophoria bisinuata (Rowley)
- Camarotoechia mutata (Hall)
- Dielasma sp.
- Dielasma sp.

Spiriferina sp.
Delthyris ? sp.
Spirifer rostellatus Hall
Spirifer cf. S. keokuk Hall
Pseudosyrinx keokuk Weller
Reticularia pseudolineata (Hall)
Cliothyridina obmaxima (McChesney)

PELECYPODA—
Aviculopecten cf. A. oblongus (M. and W.)
Allorisma sp.

GASTROPODA—
Platyceras sp.

CEPHALOPODA—
Orthoceras sp.

List of fossils from bed 6 of Keokuk limestone in Bentonsport area.

ANTHOZOA—
Cyathaxonia sp.
Triplophyllum dalei (M.-E. and H.)
Palaeacis obtusus (M. and W.)

CRINOIDEA—
Platycrinus sp.
Agaricocrinus sp.

BRYOZOA—
Cystodictya sp.

BRACHIOPODA—
Schuchertella ? sp.
Productus sp.
Productus sp.
Pustula alternata (N. and P.)
Rhipidomella dubia (Hall)
Tetracamera subtrigona (M. and W.)
Spirifer tenuicostatus Hall
Spirifer rostellatus Hall
Spirifer keokuk Hall
Spirifer logani Hall
Brachythyris suborbicularis (Hall)
Spiriferella neglecta (Hall)
Reticularia pseudolineata (Hall)
Cliothyridina obmaxima (McChesney)

PELECYPODA—
Lithophagus illinoisensis Worthen ?
Cypricardinia ? sp.

GASTROPODA—
Platyceras sp.
Platyceras sp.
Orthonychia sp.
Orthonychia sp.

List of fossils from bed 7 of Keokuk limestone in Bentonsport area.

ANTHOZOA—
Triplophyllum dalei (M.-E. and H.)

CRINOIDEA—
Dorycrinus mississippiensis Roemer
Eutrochocrinus planodiscus Hall

BRACHIOPODA—
Pustula alternata (N. and P.)
Pustula sp.
Pustula sp.
Tetracamera subtrigona (M. and W.)
Spirifer tenuicostatus Hall
Spirifer keokuk Hall
Spirifer rostellatus Hall
Reticularia pseudolineata (Hall)
Cliothyridina obmaxima (McChesney)

GASTROPODA—
Straparollus sp.
Platyceras sp.

List of fossils from bed 8 of Keokuk limestone in Bentonsport area.

ANTHOZOA—
Triplophyllum dalei (M.-E. and H.)
Zaphrentis varsoviensis Worthen
Zaphrentis sp.
Amplexus sp.
Palaeacis obtusus (M. and W.)

CRINOIDEA—
Dorycrinus sp.
Actinocrinus ? sp.

BRYOZOA—
Meekopora sp.
Cystodictya sp.

BRACHIOPODA—
Orthotetes ? sp.
Schuchertella ? sp.
Productus wortheni Hall ?
Productus mesialis Hall
Productus sp.
Pustula alternata (N. and P.)
Pustula sp.
Rhipidomella dubia (Hall)
Tetracamera subtrigona (M. and W.)
Dielasma sp.
Spirifer tenuicostatus Hall
Spirifer logani Hall
Spirifer keokuk Hall
Spirifer cf. S. keokuk Hall
Spirifer sp.
Brachythyris suborbicularis (Hall)
Syringothyris subcuspidatus (Hall)
Reticularia pseudolineata (Hall)
Eumetria verneuiliana (Hall)
Cliothyridina incrassata (Hall) ?
Cliothyridina sp.

GASTROPODA—
Platyceras sp.
Platyceras sp.

TRILOBITA—
Griffithides ? sp.

VERTEBRATA—
Fish teeth

List of fossils from bed 10 of Keokuk limestone in Bentonsport area.

ANTHOZOA—
- Amplexus sp.

BRYOZOA—
- Rhombopora varians Ulrich
- Cyclopora sp.
- Worthenopora spinosa Ulrich

BRACHIOPODA—
- Schuchertella ? sp.
- Orthotetes keokuk (Hall)
- Productus setigerus Hall
- Productus ovatus Hall
- Productus sp.
- Productus sp.
- Pustula alternata (N. and P.)
- Pustula sp.
- Pustula sp.
- Rhipidomella dubia (Hall)
- Tetracamera subtrigona (M. and W.)
- Cranaena sulcata Weller ?
- Dielasma sinuata Weller
- Dielasma sp.
- Spirifer tenuicostatus Hall
- Spirifer rostellatus Hall
- Spirifer sp.
- Spirifer sp.
- Spirifer sp.
- Spirifer sp.
- Brachythyris suborbicularis (Hall)
- Syringothyris ? sp.
- Spiriferella neglecta (Hall)
- Reticularia pseudolineata (Hall)
- Eumetria verneuiliana (Hall) ?
- Cliothyridina parvirostris (M. and W.)
- Composita ? sp.

PELECYPODA—
- Aviculopecten sp.
- Aviculopecten sp.

GASTROPODA—
- Orthonychia sp.

List of fossils from bed 11 of Keokuk limestone in Bentonsport area.

ANTHOZOA—
- Palaeacis obtusus (M. and W.)

CRINOIDEA—
- Dorycrinus sp.

BRYOZOA—
- Stenopora sp.
- Hemitrypa sp.
- Cystodictya sp.

BRACHIOPODA—
- Schuchertella sp.
- Productus setigerus Hall
- Productus wortheni Hall ?
- Productus ovatus Hall
- Productus sp.
- Avonia sp.
- Avonia sp.
- Pustula biseriata (Hall)
- Pustula alternata (N. and P.)
- Rhipidomella dubia (Hall)
- Tetracamera subtrigona (M. and W.)
- Rhynchopora sp.
- Dielasma sp.
- Dielasma sp.
- Spiriferina ? sp.
- Spirifer keokuk Hall
- Spirifer sp.
- Spirifer sp.
- Spirifer sp.
- Spirifer sp.
- Brachythyris suborbicularis (Hall)
- Reticularia pseudolineata (Hall)
- Eumetria verneuiliana (Hall)

GASTROPODA—
- Orthonychia sp.

VERTEBRATA—
- Fish teeth

List of fossils from bed 12 of Keokuk limestone in Bentonsport area.

ANTHOZOA—
- Zaphrentis illinoisensis Worthen ?
- Triplophyllum dalei (M.-E. and H.)
- Amplexus sp.

BRYOZOA—
- Stenopora sp.
- Fenestella serratula Ulrich
- Fenestella cingulata Ulrich ?
- Fenestella sp.
- Hemitrypa sp.
- Cystodictya sp.
- Worthenopora spinosa Ulrich
- Cyclopora ? sp.

BRACHIOPODA—
- Schuchertella ? sp.
- Schuchertella ? sp.
- Productus setigerus Hall
- Productus cf. P. setigerus Hall
- Productus sp.
- Productus sp.
- Pustula alternata (N. and P.)
- Pustula biseriata (Hall)
- Pustula sp.
- Rhipidomella dubia (Hall)
- Tetracamera sp.
- Dielasma sp.
- Spirifer rostellatus Hall
- Spirifer sp.
- Brachythyris suborbicularis (Hall)
- Spiriferella neglecta (Hall)
- Reticularia pseudolineata (Hall)
- Eumetria sp.
- Cliothyridina parvirostris (M. and W.)

List of fossils from bed 13 of Keokuk limestone in Bentonsport area.

ANTHOZOA—
- Amplexus ? sp.

CRINOIDEA—
- Agaricocrinus sp.
- Platycrinus ? sp.

BRYOZOA—
- Meekopora ? sp.
- Leioclema punctatum (Hall)
- Fenestella serratula Ulrich
- Fenestella (several species)
- Cystodictya (several species)
- Worthenopora spinosa Ulrich

BRACHIOPODA—
- Schuchertella ? sp.
- Productus setigerus Hall ?
- Productus sp.
- Avonia sp.
- Pustula biseriata (Hall)
- Pustula sp.
- Pustula ? sp.
- Camarotoechia mutata (Hall)
- Cranaena sulcata Weller ?
- Dielasma sp.
- Dielasma sp.
- Delthyris ? sp.
- Spirifer rostellatus Hall
- Spirifer tenuicostatus Hall
- Spirifer sp.
- Brachythyris suborbicularis (Hall)
- Spiriferella neglecta (Hall)
- Reticularia pseudolineata (Hall)
- Composita trinuclea (Hall)
- Cliothyridina parvirostris (M. and W.)

PELECYPODA—
- Schizodus sp.

TRILOBITA—
- Griffithides ? sp.

List of fossils from bed 14 of Keokuk limestone in Bentonsport area.

BRYOZOA—
- Stenopora sp.
- Fenestella serratula Ulrich
- Cystodictya sp.

BRACHIOPODA—
- Productus setigerus Hall
- Productus sp.
- Pustula sp.
- Rhipidomella dubia (Hall) ?
- Dielasma ? sp.
- Spirifer tenuicostatus Hall
- Spirifer sp.
- Reticularia pseudolineata (Hall)
- Cliothyridina parvirostris (M. and W.)

GASTROPODA—
- Orthonychia sp.
- Platyceras sp.

TRILOBITA—
- Griffithides ? sp.

VERTEBRATA—
- Fish teeth

List of fossils from bed 15 of Keokuk limestone in Bentonsport area.

ANTHOZOA—
- Monilopora beecheri Grabau
- Palaeacis obtusus (M. and W.)

BRACHIOPODA—
- Schuchertella sp.
- Productus setigerus Hall
- Productus ovatus Hall
- Productus sp.
- Productus sp.
- Productus sp.
- Productus sp.
- Rhipidomella dubia (Hall)
- Camarotoechia mutata (Hall)
- Rhynchopora beecheri Greger
- Spirifer tenuicostatus Hall
- Spirifer keokuk Hall
- Reticularia pseudolineata (Hall)

PELECYPODA—
- Myalina keokuk Worthen
- Lithophagus illinoisensis Worthen ?

TRILOBITA—
- Griffithides ? sp.

List of fossils from bed 16 of Keokuk limestone in Bentonsport area.

ANTHOZOA—
- Palaeacis obtusus (M. and W.)
- Triplophyllum dalei (M.-E. and H.)

BRYOZOA—
- Stenopora ? sp.
- Fenestella serratula Ulrich

BRACHIOPODA—
- Orthotetes keokuk (Hall)
- Productus sp.
- Rhipidomella dubia (Hall)
- Dielasma sp.
- Spirifer cf. S. keokuk Hall
- Spirifer tenuicostatus Hall
- Composita trinuclea (Hall)

GASTROPODA—
- Orthonychia sp.

List of fossils from bed 18 of Keokuk limestone in Bentonsport area.

ANTHOZOA—
- Palaeacis obtusus (M. and W.)
- Zaphrentis varsoviensis Worthen ?
- Triplophyllum dalei (M.-E. and H.)
- Monilopora beecheri Grabau

BRYOZOA—
- Meekopora sp.
- Stenopora sp.
- Leioclema punctatum (Hall)
- Fenestella serratula Ulrich
- Hemitrypa sp.
- Cystodictya sp.
- Cyclopora ? sp.
- Cyclopora ? sp.
- Worthenopora spinosa Ulrich

BRACHIOPODA—
- Chonetes illinoisensis
- Schuchertella sp.
- Orthotetes keokuk (Hall)
- Productus setigerus Hall
- Productus ovatus Hall
- Productus cf. P. altonensis Weller
- Productus sp.
- Productus sp.
- Pustula alternata (N. and P.)
- Pustula biseriata (Hall)
- Rhipidomella dubia (Hall)
- Camarotoechia mutata (Hall)
- Spirifer tenuicostatus Hall
- Spirifer keokuk Hall
- Spirifer sp.
- Spirifer sp.
- Reticularia pseudolineata (Hall)
- Eumetria verneuiliana (Hall)
- Eumetria ? sp.
- Composita trinuclea (Hall) ?

PELECYPODA—
- Conocardium sp.
- Myalina keokuk Worthen

TRILOBITA—
- Griffithides ? sp.

List of fossils from bed 20 of Keokuk limestone in Bentonsport area.

ANTHOZOA—
- Zaphrentis varsoviensis Worthen
- Triplophyllum dalei (M.-E. and H.)

BRYOZOA—
- Stenopora sp.
- Taeniodictya ramulosa Ulrich

BRACHIOPODA—
- Orthotetes keokuk (Hall)
- Productus setigerus Hall
- Pustula alternata (N. and P.)
- Pustula biseriata (Hall)
- Rhipidomella dubia (Hall)
- Camarotoechia mutata (Hall)
- Rhynchopora beecheri Greger
- Dielasma ? sp.
- Dielasma ? sp.
- Girtyella indianensis (Girty)
- Spirifer keokuk Hall
- Spirifer cf. S. keokuk Hall
- Spirifer tenuicostatus Hall
- Reticularia pseudolineata (Hall)
- Composita trinuclea (Hall)

GASTROPODA—
- Orthonychia sp.

Henry County.—The only exposures of the Keokuk limestone of importance in Henry county appear along a creek emptying into Skunk river from the south, a short distance west of Webster's mill in the western part of section 4 of Jackson township. This section has been described previously by Savage[26] in his Geology of Henry County. Fifty-two feet of Keokuk limestone overlain by impure limestones and shales of the Lower Warsaw (Geode bed) is exposed along this creek. The section is given below.

Section of Keokuk limestone near Webster's mill.

		FEET	INCHES
19.	Limestone, bluish gray, medium-grained, upper part gray, very cherty; filled with bryozoans		8
18.	Limestone, as above, with fish teeth		3
17.	Shale, soft, bluish, argillaceous		10
16.	Limestone, bluish gray		4

26 Iowa Geol. Survey, vol. XII, pp. 255-258; 1902.

15.	Shale, soft, bluish, argillaceous	1	4
14.	Limestone, bluish gray, medium-grained, weathering into thin layers	4	2
13.	Shale, bluish, argillaceous	1	6
12.	Limestone, dark gray, medium-grained		10
11.	Shale, and gray subcrystalline limestone in alternating layers. The limestone is filled with bryozoans	7	
10.	Limestone, gray, subcrystalline, with wavy boundaries	1	6
9.	Shale, bluish, argillaceous above but calcareous below. No fossils noted	4	2
8.	Limestone, gray, subcrystalline and cherty above; bluish gray and medium-grained below	3	
7.	Shale, bluish, argillaceous	1	
6.	Limestone, gray and subcrystalline above but bluish and coarse-grained below; shaly in middle part; with a band of fine-grained, cherty limestone 3 to 10 inches thick in lower part	4	6
5.	Shale, bluish, argillaceous	1	
4.	Limestone, ash-colored, soft, impure, dolomitic, nonfossiliferous	7	
3.	Limestone, bluish gray, medium-grained, contact with bed above not seen 2 to	3	
2.	Shale, bluish, argillaceous	8	
1.	Limestone, gray, medium-grained, with a band of chert at the top	1	

Collections made from the various beds were identified as follows:

List of fossils from bed 1 of Keokuk limestone near Webster's mill.

BRACHIOPODA—
- Pustula alternata (N. and P.)
- Spirifer logani Hall
- Spirifer keokuk Hall
- Reticularia pseudolineata (Hall)

List of fossils from bed 3 of Keokuk limestone near Webster's mill.

ANTHOZOA—
- Amplexus sp.

BRACHIOPODA—
- Productus mesialis Hall
- Pustula alternata (N. and P.)
- Orthotetes keokuk (Hall) ?
- Tetracamera sp.
- Spirifer keokuk Hall

List of fossils from bed 6 of Keokuk limestone near Webster's mill.

ANTHOZOA—
- Zaphrentis varsoviensis Worthen
- Palaeacis obtusus (M. and W.)

CRINOIDEA—
- Batocrinus sp.
- Dorycrinus sp.

BRACHIOPODA—
- Productus sp.
- Pustula alternata (N. and P.)
- Tetracamera subtrigona (M. and W.)
- Rhipidomella dubia (Hall)
- Brachythyris cf. B. suborbicularis (Hall)
- Reticularia pseudolineata (Hall)

VERTEBRATA—
- Fish teeth

List of fossils from bed 8 of Keokuk limestone near Webster's mill.

BRACHIOPODA—
- Productus sp.
- Orthotetes keokuk (Hall)
- Rhipidomella dubia (Hall)
- Dielasma sp.
- Spiriferina sp.
- Spirifer rostellatus Hall
- Spirifer cf. S. keokuk Hall
- Cliothyridina parvirostris (M. & W.) ?

List of fossils from bed 10 of Keokuk limestone near Webster's mill.

BRACHIOPODA—
- Pustula biseriata (Hall)
- Spirifer keokuk Hall
- Spirifer tenuicostatus Hall
- Composita trinuclea (Hall)

List of fossils from bed 11 of Keokuk limestone near Webster's mill.

ANTHOZOA—
- Zaphrentis varsoviensis Worthen
- Triplophyllum dalei (M.-E. and H.)
- Amplexus sp.
- Monilopora beecheri Grabau

BRYOZOA—
- Stenopora sp.
- Leioclema punctatum (Hall)
- Cystodictya pustulosa Ulrich
- Cystodictya lineata Ulrich
- Phractopora trifolia (Rominger)
- Bactropora simplex Ulrich
- Rhombopora attenuata Ulrich
- Rhombopora transversalis Ulrich
- Streblotrypa major Ulrich
- Streblotrypa radialis Ulrich
- Fenestella tenax Ulrich
- Fenestella multispinosa Ulrich
- Fenestella rudis Ulrich
- Fenestella limitaris Ulrich
- Fenestella serratula Ulrich
- Hemitrypa sp.
- Polypora simulatrix Ulrich
- Polypora radialis Ulrich
- Worthenopora spinosa Ulrich

BRACHIOPODA—
- Productus setigerus Hall
- Camarotoechia mutata (Hall) ?
- Spiriferina sp.
- Spirifer tenuicostatus Hall
- Cliothyridina parvirostris (M. and W.)

TRILOBITA—
- Griffithides portlocki (M. and W.) ?

List of fossils from bed 12 of Keokuk limestone near Webster's mill.

ANTHOZOA—
- Palaeacis obtusus (M. and W.)
- Zaphrentis varsoviensis Worthen
- Zaphrentis sp.

BRACHIOPODA—
- Productus sp.
- Camarotoechia mutata (Hall)
- Rhipidomella dubia (Hall)
- Dielasma sp.
- Spirifer keokuk Hall
- Reticularia pseudolineata (Hall)

List of fossils from bed 14 of Keokuk limestone near Webster's mill.

ANTHOZOA—
- Zaphrentis sp.

BRYOZOA—
- Leioclema punctatum (Hall)
- Fenestella tenax Ulrich
- Fenestella serratula Ulrich
- Cystodictya lineata Ulrich

BRACHIOPODA—
- Orthotetes keokuk (Hall)
- Pustula alternata (N. and P.)
- Rhipidomella dubia (Hall)
- Dielasma ? sp.
- Dielasma sp.
- Spirifer tenuicostatus Hall
- Eumetria verneuiliana (Hall)
- Cliothyridina incrassata (Hall)
- Composita trinuclea (Hall) ?

List of fossils from bed 19 of Keokuk limestone near Webster's mill.

ANTHOZOA—
- Monilopora beecheri Grabau

BRYOZOA—
- Leioclema punctatum (Hall)
- Fenestella rudis Ulrich
- Fenestella serratula Ulrich
- Hemitrypa sp.
- Cystodictya lineata Ulrich
- Rhombopora varians Ulrich
- Rhombopora attenuata Ulrich
- Stenopora sp.

BRACHIOPODA—
- Productus setigerus Hall
- Productus sp.
- Pustula alternata (N. and P.)
- Dielasma sp.
- Spiriferina sp.
- Spirifer keokuk Hall

Louisa County.—Only the lowermost beds of the Keokuk limestone, corresponding to the Montrose chert horizon, are known to occur in Louisa county. These have been recognized by Udden[27] in a number of exposures.

A section in a Honey creek quarry opening one-fifth mile up-

27 Iowa Geol. Survey, vol. XI, pp. 72-89; 1901.

stream from the main quarry, which is located near the north line of the southwest quarter of section 28, Morning Sun township, has been measured and redescribed by the writer.

Section of Keokuk limestone on Honey creek.

		FEET	INCHES
8.	Drift	1	
7.	Limestone, brownish yellow, soft, dolomitic, cherty; with occasional layers and lenses of gray subcrystalline, nondolomitic fossiliferous limestone	3	6
6.	Limestone, gray, tough, crinoidal; with small irregular chert nodules		10
5.	Limestone, brownish yellow, soft, dolomitic, fine-grained, with a chert band in the lower part	1	4
4.	Limestone, gray, compact, tough, crinoidal	1	4
3.	Limestone, soft, brownish, dolomitic, crinoidal in upper part	1	8
2.	Shale, bluish, argillaceous		10
1.	Limestone, crinoidal, bluish with greenish specks below but brownish and with soft fine-grained dolomitic seams above; a chert band 2 to 8 inches thick in upper part	3	

A few identifiable fossils collected from beds 1 and 7 are listed below:

List of fossils from bed 1 of Keokuk limestone on Honey creek.

ANTHOZOA—
- Zaphrentis sp.

BRACHIOPODA—
- Chonetes sp.
- Rhipidomella sp.
- Schizophoria sp.
- Spirifer tenuicostatus Hall
- Spirifer grimesi Hall
- Brachythyris suborbicularis (Hall)
- Cliothyridina sp.

List of fossils from bed 7 of Keokuk limestone on Honey creek.

BRACHIOPODA—
- Productus sp.
- Dielasma sp.
- Spirifer rostellatus Hall
- Spirifer sp.
- Reticularia pseudolineata (Hall)
- Composita globosa Weller
- Composita trinuclea (Hall)

In the Elrick quarry located near the south county line on the left bank of Smith creek, Udden[28] found twenty-two feet of weathered limestone overlying the Upper Burlington. However, no fossils are listed by him from this exposure. Again Udden[29] reports fifteen feet of "weathered shaly limestone and shale with cherty layers" of this horizon in an exposure along Long creek in the southeast corner of section 33 of Columbus township.

The following section from Udden[29], located in the south bank of Long creek near the west line in the northwest quarter

[28] Iowa Geol. Survey, vol. XI, p. 75; 1901.
[29] Idem, p. 81.

of section 32, Columbus township, also represents the basal Keokuk.

Section of Keokuk limestone in section 32, Columbus township (After Udden).

		FEET
3.	Shaly limestone	5
2.	Blue shale	1
1.	Yellow limestone, somewhat fine-grained	8

Keokuk County.—Several exposures of the Keokuk limestone have been reported from Keokuk county. The more important ones appear along Rock creek northwest of Ollie. One of the more typical of these is shown in the "Granite" quarry in the southwest quarter of the southeast quarter of section 10, Jackson township.

Section of Keokuk limestone in "Granite" quarry

		FEET	INCHES
8.	Concealed. With chips of soft brownish dolomitic limestone on slope. Indications of bluish argillaceous shale in upper part. Probably consists of shale with interbedded layers of brownish dolomitic limestone	8	
7.	Limestone, brownish, soft, dolomitic, cherty	1	10
6.	Concealed, chips of soft brownish dolomitic limestone on slope	7	10
5.	Limestone, soft, brownish, dolomitic, with irregular bands of compact gray chert	3	6
4.	Shale, bluish, argillaceous	3	6
3.	Limestone, bluish gray, coarse-grained	2	7
2.	Shale, bluish, argillaceous	2	
1.	Limestone, bluish gray, coarse-grained, crinoidal; in rather heavy layers. Top layer weathering into thin shaly seams	5	

Collections were made from beds 1 and 8. These have been identified as follows:

List of fossils from bed 1 of Keokuk limestone in "Granite" quarry.

ANTHOZOA—
- Triplophyllum dalei (M.-E. and H.)
- Zaphrentis varsoviensis Worthen
- Palaeacis obtusus (M. and W.)

CRINOIDEA—
- Platycrinus sp.

BRACHIOPODA—
- Orthotetes keokuk (Hall)
- Productus sp.
- Pustula alternata (N. and P.)
- Rhipidomella dubia (Hall)
- Girtyella indianensis (Girty)
- Spirifer keokuk Hall
- Spirifer rostellatus Hall
- Brachythyris suborbicularis (Hall)
- Reticularia pseudolineata (Hall)
- Cliothyridina parvirostris (M. and W.)
- Cliothyridina incrassata (Hall)

PELECYPODA—
- Conocardium sp.

GASTROPODA—
- Platyceras sp.
- Platyceras sp.

TRILOBITA—
- Griffithides ? sp.

List of fossils from bed 8 of Keokuk limestone in "Granite" quarry.

BRYOZOA—
- Leioclema punctatum (Hall)
- Rhombopora varians Ulrich
- Fenestella sp.
- Fenestella sp.
- Streblotrypa sp.

BRACHIOPODA—
- Orthotetes ? sp.
- Spirifer sp.

Three hundred yards south of the above section a small abandoned quarry opening shows several beds of the Upper St. Louis. The basal bed of the section lies about twenty-two feet above the level of the top of bed 8 of the "Granite" quarry. It is believed that the Lower St. Louis limestone occupies the concealed interval between the two beds and that the latter formation succeeds the Keokuk formation directly, the Warsaw beds and the Spergen limestone being absent in this area.

Less than half a mile north of the "Granite" quarry a good exposure of the Keokuk beds appears in the north bank of Rock creek, just west of the wagon bridge, in the northeast quarter of the southwest quarter of section 10, Jackson township.

Section of Keokuk beds in section 10, Jackson township.

		FEET	INCHES
11.	Drift	1	
10.	Limestone, buff, dolomitic, soft, rotten, with chert bands. Bed 5 of "granite" quarry section	3	
9.	Shale, bluish, argillaceous. Bed 4 of "granite" quarry section	2	6
8.	Limestone, bluish gray, coarse-grained except in middle part, which is dolomitic, buff and fine-grained. Bed 3 of "granite" quarry section	2	8
7.	Concealed. Shale. Bed 2 of "granite" quarry section	3	
6.	Limestone, bluish gray, coarse-grained, with intercalated layers of gray subcrystalline limestone. A layer at top filled with *Spirifer keokuk*. Bed 1 of "granite" quarry section	5	
5.	Limestone, ash-colored, fine-grained, dolomitic, impure, soft, weathering yellowish	2	6
4.	Limestone, gray, subcrystalline, cherty; interbedded with layers of soft buff cherty dolomitic limestone	6	
3.	Shale, calcareous, ash-gray in color, weathering slightly yellowish	2	6
2.	Limestone, gray, dense, brittle, subcrystalline, cherty	2	
1.	Limestone, gray, crinoidal, with occasional chert bands. Lower part poorly exposed	5	9

The following species were identified from the various beds:

List of fossils from bed 1 of Keokuk limestone in section 10, Jackson township.

ANTHOZOA—
- Zaphrentis varsoviensis Worthen
- Triplophyllum dalei (M.-E. and H.)

CRINOIDEA—
- Macrocrinus verneuilianus (Shumard)
- Actinocrinus sp.

BRACHIOPODA—
- Orthotetes keokuk (Hall)
- Orthotetes ? sp.
- Productus sp.
- Pustula alternata (N. and P.)
- Rhipidomella dubia (Hall)
- Tetracamera subtrigona (M. and W.)
- Dielasma sp.
- Spirifer grimesi Hall
- Spirifer sp.
- Brachythyris suborbicularis (Hall)
- Syringothyris sp.
- Reticularia pseudolineata (Hall)
- Cliothyridina incrassata (Hall)

GASTROPODA—
- Platyceras sp.
- Platyceras sp.
- Platyceras sp.
- Orthonychia sp.

TRILOBITA—
- Phillipsia ? sp.

List of fossils from bed 2 of Keokuk limestone in section 10, Jackson township.

BRYOZOA—
- Fenestella serratula Ulrich
- Fenestella multispinosa Ulrich ?
- Fenestella sp.
- Cystodictya sp.

BRACHIOPODA—
- Productus setigerus Hall ?
- Pustula sp.
- Spirifer tenuicostatus Hall
- Brachythyris suborbicularis (Hall)
- Reticularia pseudolineata (Hall)

GASTROPODA—
- Platyceras sp.

List of fossils from bed 4 of Keokuk limestone in section 10, Jackson township.

ANTHOZOA—
- Amplexus sp.

BRYOZOA—
- Stenopora ? sp.

BRACHIOPODA—
- Chonetes sp.
- Productus sp.
- Pustula sp.
- Avonia sp.
- Camarophoria bisinuata (Rowley)
- Cranaena globosa Weller ?
- Dielasma sp.
- Spirifer keokuk Hall
- Spirifer tenuicostatus Hall
- Spirifer rostellatus Hall
- Syringothyris sp.
- Spiriferella neglecta (Hall)
- Reticularia pseudolineata (Hall)
- Athyris lamellosa (Leveille)
- Cliothyridina obmaxima (McChesney)
- Composita trinuclea (Hall)

GASTROPODA—
- Phanerotinus ? sp.
- Orthonychia ? sp.

List of fossils from bed 6 of Keokuk limestone in section 10, Jackson township.

ANTHOZOA—
- Zaphrentis varsoviensis Worthen
- Monilopora sp.
- Palaeacis obtusus (M. and W.)

CRINOIDEA—
- Eucladocrinus sp.

BRYOZOA—
- Stenopora sp.
- Leioclema gracillimum Ulrich
- Fenestella multispinosa Ulrich ?
- Hemitrypa sp.
- Polypora sp.
- Rhombopora varians Ulrich
- Rhombopora attenuata Ulrich
- Cystodictya sp.
- Glyptopora keyserlingi (Prout)

BRACHIOPODA—
- Orthotetes keokuk (Hall)
- Productus setigerus Hall
- Pustula sp.
- Rhipidomella dubia (Hall)
- Tetracamera subtrigona (M. and W.)
- Spirifer keokuk Hall
- Spirifer tenuicostatus Hall
- Syringothyris textus (Hall)
- Spiriferella neglecta (Hall)
- Reticularia pseudolineata (Hall)
- Eumetria verneuiliana (Hall)

PELECYODA—
- Schizodus sp.

GASTROPODA—
- Orthonychia sp.

List of fossils from bed 8 of Keokuk limestone in section 10, Jackson township.

BRACHIOPODA—
- Spirifer keokuk Hall

GASTROPODA—
- Bulimorpha ? keokuk (Worthen)

One-half mile north of the preceding section is located the Weber quarry now owned by Elbert Davis (NW. ¼ NE. ¼ sec. 10, Jackson township). Sixteen feet of gray coarse-grained cherty crinoidal limestone, interbedded with gray subcrystalline cherty limestone and soft buff cherty dolomitic limestone is exposed. The outcrop is believed to represent beds 1 to 5 of the preceding bluff section.

Bain[30] describes the Keokuk ("Augusta") limestone in Con-

30 Iowa Geol. Survey, vol. IV, p. 273; 1894.

nor's quarry, in the southwest quarter of the southeast quarter of section 15, Sigourney township, as being in contact with the St. Louis limestone. His section is as follows:

Section in Connor's quarry (after Bain).

		FEET
2.	Limestone, yellow, soft, magnesian; apparently arenaceous in part, massive. Exposed	10
1.	Limestone, coarse, subcrystalline. Exposed at water's edge	4

He refers bed 1 to the "Augusta" and bed 2 to the St. Louis. Bed 1 is concealed at the present time. Bain[31] further makes the following statement:

"About two and one-half miles west of Conner's quarry (Tp. 75 N., R. 12 W., sec. 18, SE. qr., SE.¼) the Augusta limestone having the usual characteristics rises above the water four feet. Both above and below this point the St. Louis is well developed."

At the Springvale mill five miles south of the town of Delta in Warren township an exposure of bluish calcareous shales appears in a low bluff of Skunk river. In the Keokuk county report Bain[32] designates these shales the Springvale beds and correlates them provisionally with the lower division of the St. Louis limestone. These shales possess all the characteristics of those present in the upper part of the Keokuk limestone elsewhere in Keokuk county and although they have not been found to contain fossils sufficiently well preserved to make this correlation positive they are referred to this formation on lithologic grounds. The term Springvale as applied to the lower division of the St. Louis limestone in this part of Iowa is therefore believed to be a misnomer.

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31 Idem, p. 273.
32 Idem, pp. 277-279; 1894.

CHAPTER IV

THE MERAMEC GROUP

Definition of Meramec

Ulrich[1] proposed the name Meramec in 1904 to include the Warsaw, Spergen Hill and St. Louis formations which outcrop along Meramec river in Missouri. Several later authors have restricted the group to include only the St. Louis and Spergen, the underlying Warsaw being referred to the Osage.

Weller[2] in his report on the geology of Hardin county, Illinois, includes the Warsaw in this group as well as the Ste. Genevieve formation. The following quotation from his report will make his position in the matter clear:

"As originally defined, the Meramec group included in ascending order, the Warsaw limestone, the Spergen (Salem) limestone, and the St. Louis limestone. In the present report the Ste. Genevieve limestone is also included as a fourth formation in the group, above the St. Louis limestone. For many years after the original definition of the Ste. Genevieve limestone by Shumard in 1859, the formation was scarcely or not at all recognized, the beds representing it being commonly included with the St. Louis limestone. Ulrich revived the name of the formation in 1905, but excluded it from the Meramec group, making it the lowest formation of the Chester group, an interpretation that he still holds to at this time. All the evidence, however, that has been gathered during a period of a dozen years, shows the much closer relationship of the Ste. Genevieve to the St. Louis limestone than to any of the Chester formations. In a number of publications during recent years, as a compromise measure, the Ste. Genevieve has been treated as a separate unit in the Mississippian system, being united with neither the Meramec group below, nor the Chester group above, but the time has now come when it is desirable to place the Ste. Genevieve limestone where it properly belongs, with the St. Louis limestone. In order to accomplish this result it is necessary either to modify the original definition of the Meramec group so that it shall include the Ste. Genevieve limestone, or to

1 U. S. Geol. Survey Prof. Paper 24, table opp. p. 90.
2 Illinois Geol. Survey, Bull. 41, pp. 96, 97; 1920.

propose a new group name for the four formations. As it seems more desirable to retain the name already in use with a slightly modified definition, than to add confusion to the nomenclature by introducing a totally new name, such a procedure is consequently followed here."

The revised usage of the term Meramec as recommended by Weller is adopted in this report.

Distribution of the Group

The Warsaw and Spergen members of the Meramec group are restricted to the southeastern part of the state, but the St. Louis and Ste. Genevieve formations extend far beyond to the north-central part. On the geologic map of Iowa, the Warsaw deposits are included in the Osage areas while the Spergen, St. Louis and Ste. Genevieve, all of which were formerly identified as St. Louis limestone, are mapped under that heading. The group forms the highest consolidated rock over a much larger area in southeastern Iowa than farther northwest. It appears in the southern and northwestern parts of Lee county, over almost the entire area of Henry county, the southwestern parts of Louisa and Washington counties, and the greater part of Keokuk county. It has been mapped also along the valleys of Skunk and Des Moines rivers and some of their larger tributaries in Van Buren, Jefferson, Wapello, Mahaska, Marion and southern Poweshiek counties.

In west-central Story county, the St. Louis member of the group has been exposed as a result of the erosion of the overlying Pennsylvanian rocks over a low dome. Small inliers of the Ste. Genevieve and St. Louis also appear in Webster county, while farther north in central and western Humboldt county there are restricted outliers of the St. Louis in the Kinderhook area. The extent of the group to the southwest beneath the Pennsylvanian is not definitely known, but evidently is considerable.

Lithologic Character

The Meramec group is made up of a larger proportion of clastic material and is much more diversified in character than is true of the preceding Osage deposits. It is represented in

Iowa by marginal facies of formations which are thicker, more typically developed and more uniform in character farther south in the Mississippi valley.

The Warsaw formation consists of bluish argillaceous shales with thin intercalated layers of gray fine-grained fossiliferous limestone. The Spergen is represented typically by brownish arenaceous magnesian limestone but locally some layers pass into shales or cross-bedded crinoidal limestone. The St. Louis consists for the most part of limestone which in the unaltered condition is thin-bedded, gray, fine-grained and dense. Locally it grades laterally in part into brownish massive dolomite or into sandstone. In some of its exposures it is brecciated. The Ste. Genevieve is normally made up of a fine-grained bluish gray basal sandstone, followed above by shale and then limestone, but in north-central Iowa it is nearly all shale.

Thickness

The Meramec group attains its maximum thickness in Iowa only in the southeastern part of the state where all its members are present. The aggregate thickness there is approximately two hundred feet. However, this value is subject to considerable variation from place to place owing to the thickening and thinning of the individual formations.

Stratigraphic Relations

In Lee, Henry, Van Buren and Des Moines counties, where the Warsaw beds are present, there appears to be a transition from the Osage into the Meramec group but farther northwest the Spergen and St. Louis formations overlap the Warsaw and there a disconformity is present. Disconformities appear within the group between the Spergen and St. Louis and between the St. Louis and Ste. Genevieve. However, these represent erosion intervals of limited duration. Between the Meramec and basal Pennsylvanian deposits there exists a profound stratigraphic break.

The Warsaw Formation

NOMENCLATURE AND DISTRIBUTION

The Warsaw formation as defined by Hall[3] and described by

[3] Geol. of Iowa, vol. I, pt. I, p. 97; 1858.

later writers, consists of approximately forty feet of interbedded shale and limestone, typically developed near the town of Warsaw, in Hancock county, western Illinois. The present investigation, however, has demonstrated the advisability of including the underlying Geode bed with this formation. This division, as has been pointed out, was included with the Keokuk limestone by Hall and his successors. But a study of its fauna indicates a stronger relationship to the Warsaw. In the present report it is designated the Lower Warsaw, while the Warsaw of Hall is referred to the Upper Warsaw. Altogether one hundred and twelve fossils have been specifically identified from this member by the writer. According to all the evidence at hand, about forty-five of these (chiefly crinoids and bryozoans) appear for the first time. Eighteen of this number occur either in the Warsaw of Hall or in the overlying Spergen formation.

The fauna of the Warsaw of Hall, or the Upper Warsaw as revised, is noted for its profusion of bryozoans and other fossils. Many of these fossils are of a distinctly Spergen aspect, in spite of the fact that in Iowa a disconformity separates the two members.

Both divisions of the Warsaw pinch out to the north and northwest, probably due in part to the proximity of the old shore line in that direction, and in part to pre-Spergen erosion. The upper division pinches out much more abruptly than the lower. At Keokuk, Iowa, about four miles northwest of Warsaw, this member is less than two-thirds as thick as at the type locality, and a few miles beyond, it evidently wedges out completely. It has been found nowhere north of the limits of Lee county. The northernmost exposures of beds known certainly to represent the Lower Warsaw occur along Mud creek near Lowell in southern Henry county and in the banks of Long creek about two miles northwest of the town of Augusta in southern Des Moines county. To the northwest it has been observed as far as Van Buren county. In the marginal areas this member is usually succeeded above by the Spergen due to the overlap of that formation beyond the Upper Warsaw but at some localities the Lower St. Louis limestone appears above as a result of the disconformity between this formation and the Spergen.

THE LOWER WARSAW BEDS

LITHOLOGIC CHARACTER

This division is approximately thirty-six feet in thickness in the vicinity of Warsaw, Illinois, which is the type locality. Near Warsaw and at Keokuk, Iowa, it is divisible into three portions. The lower one-third is usually represented by a fine-grained soft ash-colored massive, impure, geode-bearing magnesian limestone which upon exposed surfaces scales off obliquely to the surface of the bluff. At some localities this is interbedded with thin layers of grayish blue fossiliferous limestone similar to that of the underlying Keokuk formation. A layer of gray thin-bedded cherty limestone overlies this bed. It is locally brownish and dolomitized and is two to four feet thick.

The upper portion of the Lower Warsaw is a tough argillaceous or slightly calcareous shale which breaks down readily to a gritty clay on exposure. It is laminated in many exposures, a character which is in contrast to the massive beds below. At some localities geodes are more numerous in this than in the lower portion, but they are generally much smaller and more poorly developed.

The Lower Warsaw is represented by geodiferous and non-geodiferous phases. In places these pass into each other laterally within short distances. The only apparent physical difference between the two phases is the usual presence of fossils in that phase which bears no geodes, and their paucity in the geodiferous portions. The Lower Warsaw at some localities contains calcareous nodules, whose relationship to the containing rock is the same as that of the geodes.

The composition of the lower portion of the Lower Warsaw at a point along Soap creek at Keokuk, where it contains large well developed geodes, is shown by the following analysis:

	PER CENT
Insoluble matter (largely free silica)	33.80
$Fe_2O_3+Al_2O_3$	2.80
$CaCO_3$	39.99
$MgCO_3$	12.50
Moisture and carbonaceous matter	7.70
Undetermined	3.21
	100.00

Satisfactory outcrops of the Lower Warsaw are not often found where the formation is not capped by more resistant layers, because of the tendency of the shaly parts to weather back in the form of gentle slopes which become covered by vegetation. Slumping of the shale, which likewise is common, also has obscured many exposures. Well defined outcrops of this division of the Warsaw occur locally along the banks of the larger streams and their tributaries in southern and eastern Lee county, southeastern Van Buren county, and southern Henry and Des Moines counties. Good exposures appear also in Hancock county, Illinois, and Clark county, Missouri.

AREAL DESCRIPTION BY COUNTIES

Hancock County, Illinois.—The most typical exposure of the fossiliferous facies of the Lower Warsaw known to the writer is that along the creek known as Soap Factory Hollow, which joins the Mississippi from the east about one-half mile south of Lower Warsaw, Illinois. The section begins with the city quarry. From this point the exposures continue along the creek bed and in its banks for nearly one-half mile up stream.

In the upper part of the quarry there is exposed a few feet of shales, with thin layers of limestone interbedded, followed below by three and one-half feet of gray thin-bedded cherty limestone, representing the middle member of the Lower Warsaw. Under this comes eleven and one-half feet of fine-grained bluish magnesian, cherty limestone with interbedded seams and layers of grayish to bluish coarse-grained fossiliferous limestone which is correlated with the lower member. Geodes are wanting except for an occasional imperfectly developed one. About three feet of bluish fossiliferous Keokuk limestone is shown in the quarry face below this member. Still lower layers of the Keokuk limestone are shown in the creek bed nearby.

The lower member of the Lower Warsaw is excellently exposed along the bed of the creek above the quarry. Some of the limestone layers of this member bear sinuous pipelike fucoid markings on their surfaces. A few of these are selectively replaced by chert. They range from a fraction of an inch to an inch or more in greatest diameter. They are somewhat compressed vertically. Excellent opportunities are afforded for collecting from this member at this locality. At no other known place is the Lower Warsaw so highly fossiliferous.

The middle limestone member of the Lower Warsaw is well exposed in the creek bed a short distance farther up stream around the first bend. It grades gradually upward into the upper member of the Lower Warsaw.

The upper member of the Lower Warsaw is represented farther up the creek by the following beds listed in descending order:

Section of upper member of Lower Warsaw beds in Soap Factory Hollow.

		FEET
6.	Shale, bluish, argillaceous, overlain by thin-bedded, nonmagnesian fossiliferous limestone of the basal Upper Warsaw	2
5.	Geode bed, with many siliceous geodes	½–1
4.	Shale, argillaceous, bluish	3
3.	Limestone, in thin shaly, cherty layers filled with bryozoa	2
2.	Shale, ash-colored, calcareous; weathering to very irregular flakes with a few poorly preserved fossils	¾
1.	Limestone, shaly; with thin interbedded cherty layers of gray subcrystalline limestone, which is increasingly prevalent towards the base. The shaly limestone layers bear a rich bryozoan fauna, while the subcrystalline limestone bears a fauna nearly identical with the middle member of the Lower Warsaw, which it resembles very closely physically. This division outcrops along the bed of the creek only and its thickness could not be determined accurately. It is believed to be about ten feet	10±

The geodes of bed 5 range in diameter from a few inches to over two feet. Locally they are so closely crowded as to form a continuous layer for several yards. In such cases of crowding the geodes are very irregular in shape, and in some instances several specimens are grown closely together. Many of them are imperfectly developed. Quartz and dolomite appear to be the common minerals lining their interiors. Pockets of kaolin appear in the chalcedonic shells and in the interiors of imperfect specimens.

The faunules of the three members of the Lower Warsaw at Soap Factory Hollow are listed below:

List of fossils from the basal member of the Lower Warsaw beds.

ANTHOZOA—
- Triplophyllum dalei (M.-E. and H.)
- Amplexus sp.
- Monilopora beecheri Grabau

CRINOIDEA—
- Barycrinus sp.
- Uperocrinus nashvillae (Hall)
- Agaricocrinus wortheni Hall

BLASTOIDEA—
- Schizoblastus granulosus (M. and W.)

ECHINOIDEA—
- Archaeocidaris keokuk Hall

BRYOZOA—
- Stenopora sp.
- Fenestella serratula Ulrich
- Fenestella limitaris Ulrich
- Fenestella triserialis Ulrich
- Fenestella tenax Ulrich
- Fenestella multispinosa Ulrich
- Fenestella funicula Ulrich

Fenestella compressa Ulrich
Fenestella sp.
Fenestella sp.
Hemitrypa pateriformis Ulrich
Archimedes owenanus Hall
Polypora gracilis Prout
Polypora varsoviensis Prout
Ptilopora sp.
Ptilopora sp.
Pinnatopora conferta Ulrich
Rhombopora varians Ulrich
Rhombopora attenuata Ulrich
Cystodictya pustulosa Ulrich
Cystodictya lineata Ulrich
Worthenopora spinosa Ulrich

BRACHIOPODA—
Orthotetes keokuk (Hall) ?
Productus ovatus Hall
Productus setigerus Hall
Pustula alternata (N. and P.)
Camarotoechia mutata (Hall)
Dielasma sp.
Spirifer rostellatus Hall ?
Spirifer cf. S. keokuk Hall
Spirifer tenuicostatus Hall
Brachythyris suborbicularis (Hall)
Brachythyris subcardiformis (Hall)
Spiriferella neglecta (Hall)
Reticularia setigera (Hall)
Cliothyridina parvirostris (M. and W.)
Composita trinuclea (Hall)

GASTROPODA—
Platyceras equilateralis Hall ?

List of fossils from the middle member of the Lower Warsaw beds.

ANTHOZOA—
Triplophyllum dalei (M.-E. and H.)
Zaphrentis (?) sp.
Amplexus sp.

VERMES—
Spirorbis (?) sp.

BRYOZOA—
Fenestella tenax Ulrich
Fenestella serratula Ulrich
Fenestella multispinosa Ulrich ?
Fenestella triserialis Ulrich
Hemitrypa pateriformis Ulrich ?
Hemitrypa sp.
Polypora retrorsa Ulrich
Rhombopora attenuata Ulrich ?
Cystodictya pustulosa Ulrich ?
Worthenopora spinosa Ulrich
Cyclopora sp.

BRACHIOPODA—
Productus setigerus Hall ?
Pustula alternata (N. and P.)
Pustula biseriata (Hall)
Camarotoechia mutata (Hall)
Dielasma sp.
Cranaena sulcata Weller
Cranaena sp.
Spirifer bifurcatus Hall
Spirifer tenuicostatus Hall
Spirifer cf. S. keokuk Hall
Brachythyris subcardiformis (Hall)
Brachythyris suborbicularis (Hall)
Reticularia setigera (Hall)
Eumetria verneuiliana (Hall)
Cliothyridina parvirostris (M. and W.)
Composita trinuclea (Hall)
Composita globosa Weller

PELECYPODA—
Allorisma sp.
Aviculopecten sp.
Aviculopecten sp.

SCAPHOPODA—
Laevidentalium sp.

GASTROPODA—
Holopea proutana Hall
Strophostylus ? carleyama (Hall) ?

List of fossils from the upper member of the Lower Warsaw beds.

ANTHOZOA—
Zaphrentis spergenensis Worthen
Triplophyllum dalei (M.-E. and H.)
Amplexus sp.
Monilopora beecheri Grabau
Monilopora ? sp.

VERMES—
Spirorbis sp.

CRINOIDEA—
Barycrinus sp.

BRYOZOA—
Fistulipora ? sp.
Meekopora sp.
Batostomella (?) sp.
Stenopora sp.
Leioclema punctatum (Hall)
Fenestella serratula Ulrich
Fenestella tenax Ulrich
Fenestella rudis Ulrich
Fenestella triserialis Ulrich
Fenestella exigua Ulrich
Fenestella multispinosa Ulrich
Fenestella compressa Ulrich
Fenestella sp.
Archimedes owenanus Hall
Archimedes wortheni Hall
Hemitrypa pateriformis Ulrich
Hemitrypa sp.
Polypora biseriata Ulrich
Polypora varsoviensis Prout
Polypora gracilis Prout
Polypora retrorsa Ulrich
Ptilopora valida Ulrich
Ptilopora sp.

Ptilopora sp.
Rhombopora attenuata Ulrich
Rhombopora varians Ulrich
Rhombopora sp.
Cystodictya pustulosa Ulrich
Glyptopora keyserlingi (Prout)
Worthenopora spinosa Ulrich
Cyclopora sp.

BRACHIOPODA—
Orbiculoidea sp.
Productus setigerus Hall ?
Productus indianensis Hall ?
Productus sp.
Pustula biseriata (Hall) ?
Pustula alternata (N. and P.)
Pustula sp.
Avonia sp.
Camarotoechia mutata (Hall) ?
Dielasma sp.
Spiriferina sp.
Spirifer cf. S. keokuk Hall
Spirifer bifurcatus Hall
Spirifer tenuicostatus Hall
Spiriferella neglecta (Hall)
Reticularia setigera (Hall)
Eumetria verneuiliana (Hall)
Cliothyridina parvirostris (M. and W.)
Composita trinuclea (Hall)
Composita globosa Weller ?

PELECYPODA—
Schizodus cf. S. circulus Worthen
Schizodus sp.
Edmondia varsoviensis Worthen
Edmondia illinoisensis Worthen
Aviculopecten sp.
Lithophagus illinoisensis Worthen

GASTROPODA—
Platyceras ? sp.
Straparollus sp.

Good exposures of the Lower Warsaw in contact with the Upper Warsaw are present in the bluffs of a small creek tributary to the Mississippi, a short distance northeast of the town of Warsaw. The Lower Warsaw is geode-bearing at this locality and is almost barren of recognizable fossils. The section is as follows:

Section of Lower Warsaw beds northeast of Warsaw.

		FEET	INCHES
4.	Upper Warsaw shales and limestone	18	6
3.	Shale, argillaceous, weathering into thin laminæ; more resistant layers slightly projecting; bearing numerous small geodes arranged in bands	23	
2.	Limestone, impure, buff, magnesian, containing discontinuous bands and nodules of chert	3	3
1.	Limestone, drab, fine-grained, impure, magnesian, massive, scaling off obliquely to the face of the bluff; geodes few and scattered in upper part but more abundant below; many of them broken because of the fragile condition of their shells. Exposed	6	

The Lower Warsaw in its typical development comprises numbers 1 to 3 of this section. Attention is called to the fact that the middle member is here dolomitic.

The Lower Warsaw is exposed also near Hamilton, Illinois, four miles north of Warsaw, in the clay pits of the Hamilton Clay Company. The blue calcareous shale of the upper member is here used in the manufacture of brick and tile and large numbers of geodes which have been picked from the clay are available for study.

In the vicinity of Niota, in Hancock county, the Lower Warsaw is exposed at several localities. The following beds outcrop on the west bluff of a small creek one-half mile east of the town.

Section of Lower Warsaw beds east of Niota.

		Feet
2.	Shale, argillo-calcareous, with flakes of impure nonfossiliferous limestone; bearing a few geodes ranging up to four inches in diameter	19
1.	Limestone, impure, fine-grained, magnesian; interstratified near the middle with bands of bluish fossiliferous limestone 6 to 8 inches thick; a few geodes in the more impure parts	15

At the Fort Madison-Appanoose quarries, which are located in the Mississippi river bluff two miles above Niota, twenty-two and one-half feet of dolomitic Spergen limestone rests disconformably upon the bluish calcareous geodiferous shale of Lower Warsaw age. The Upper Warsaw, if ever present at this place, was completely eroded before the deposition of the Spergen.

Many of the geodes which are found to the south of Niota bear asphaltic material and the rocks in which they occur are locally also bituminous. About one-half mile south of the town the Lower Warsaw may be studied along a small creek. A section of the strata at this place follows:

Section of Lower Warsaw beds south of Niota.

		Feet	Inches
5.	Drift		
4.	Shale, argillaceous, bluish, with thin layers of limestone intercalated near the top	5	
3.	Shale, calcareous, ash-colored; upper part bearing small geodes whose shells are fragile and usually stained with bitumen; lower part with a bituminous band which bears broken geodes	3	6
2.	Shale, argillaceous	1	8
1.	Limestone, in bed of creek		

Another section of interest is located two miles south of Niota on the north branch of the first main creek below that town.

Section of Lower Warsaw beds south of Niota.

		Feet	Inches
11.	Till, yellow, bearing bowlders of St. Louis limestone	9	
10.	Shale, argillaceous, bluish gray when fresh but weathering yellow; some layers more calcareous and bearing geodes	4	6
9.	Shale, calcareous, geodiferous	1	6
8.	Shale, bluish when fresh; few or no geodes	1	3
7.	Shale, highly calcareous, gray, bearing many geodes studded with dolomite	2	

6.	Limestone, impure, buff, magnesian; bearing fronds of a fenestelloid bryozoan; small masses of sphalerite common........		6
5.	Shale, argillaceous; breaking down to ash-colored clay; no geodes noted	3	10
4.	Shale, argillaceous, grayish blue; bituminous geodes scattered throughout, although shale is not appreciably stained with this material	2	
3.	Shale, highly calcareous, ash-colored, bearing a few geodes, none of which was found to contain bitumen	1	7
2.	Shale, argillaceous, grayish blue in color, no geodes noted	2	10
1.	Limestone, gray, crinoidal	1	10

All of the members of this section except 1 and 11, which represent the Keokuk and Pleistocene respectively, belong to the Lower Warsaw.

Lee County, Iowa.—Numerous exposures showing the Lower Warsaw in contact with both the Keokuk limestone and the Upper Warsaw may be seen in and near the city of Keokuk, Iowa, in the extreme southern part of Lee county. These occur in the bluffs of Soap creek, and in the north bluff of Mississippi river, at intervals from the Union Station to the Taber lumber mills, two miles down stream (fig. 4).

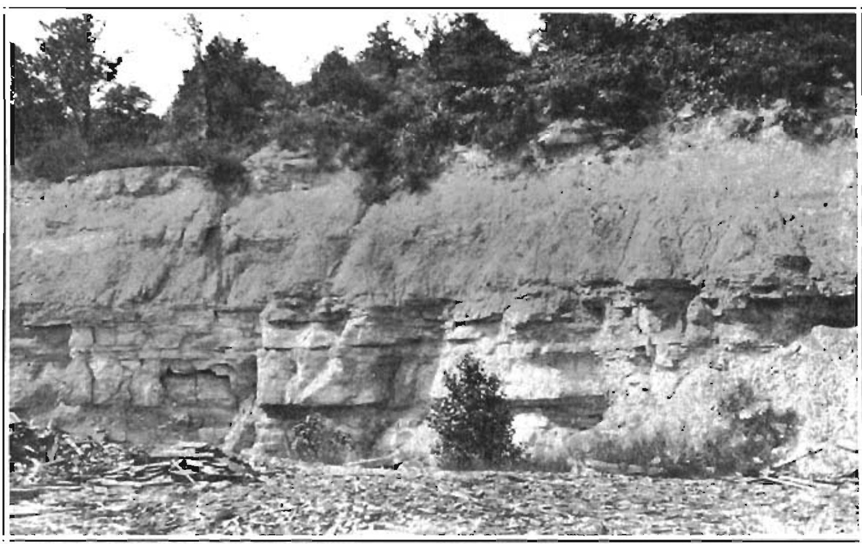

FIG. 4.—The "Geode bed," or Lower Warsaw. Mississippi river bluff back of Taber lumber mills, Keokuk.

The section on Soap creek near the end of Fourteenth Street is typical (fig. 5).

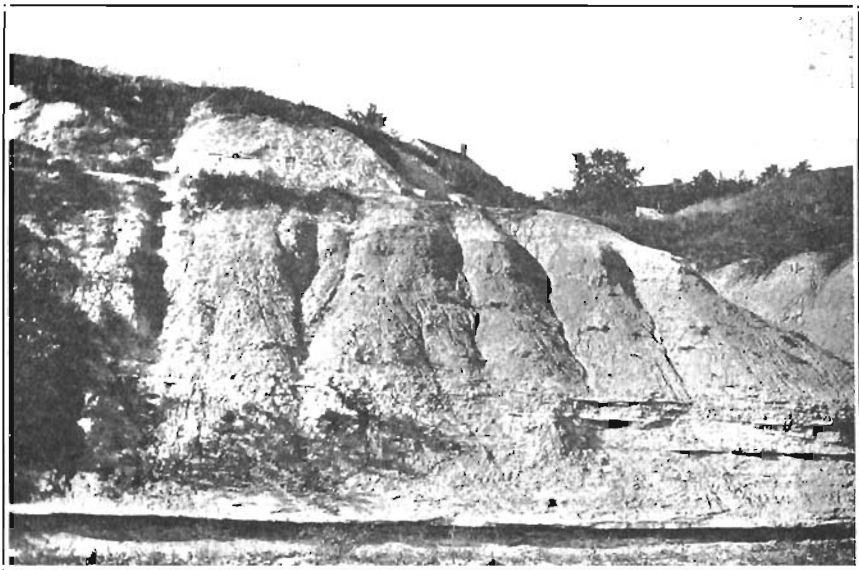

FIG. 5.—View of Lower Warsaw bed along Soap creek at Keokuk.

Section of Lower Warsaw beds on Soap creek.

		FEET
3.	Shale, bluish, argillaceous, geodiferous, with occasional thin layers of magnesian limestone near the top	20
2.	Limestone, light gray, fine-grained, cherty	1–2½
1.	Limestone, ash-colored, impure, siliceous, magnesian, geodiferous; with occasional seams and layers of grayish or bluish fossiliferous limestone	7½

The following faunal lists were prepared from collections made by the writer along Soap creek and in the Mississippi river bluff sections.

List of fossils from bed 1 of the Lower Warsaw beds at Keokuk.

ANTHOZOA—
- Zaphrentis sp.
- Triplophyllum dalei (M.-E. and H.)
- Monilopora beecheri Grabau

CRINOIDEA—
- Dizygocrinus ? sp.
- Uperocrinus nashvillae (Hall)
- Dorycrinus mississippiensis Roemer
- Dorycrinus sp.
- Agaricocrinus americanus var. tuberosus Hall
- Barycrinus spurius (Hall)
- Barycrinus sp.

ECHINOIDEA—
- Archaeocidaris sp.

BRYOZOA—
- Fistulipora ? sp.
- Fenestella compressa Ulrich
- Fenestella multispinosa Ulrich
- Fenestella exigua Ulrich
- Fenestella tenax Ulrich
- Fenestella serratula Ulrich
- Fenestella sp.
- Hemitrypa sp.
- Archimedes owenanus Hall
- Polypora gracilis Prout
- Polypora varsoviensis Prout
- Pinnatopora conferta Ulrich
- Rhombopora dichotoma Ulrich
- Rhombopora sp.

Cystodictya lineata Ulrich
Worthenopora spinosa Ulrich

BRACHIOPODA—
Productus ovatus Hall
Productus setigerus Hall
Productus sp.
Avonia sp.
Pustula alternata (N. and P.)
Pustula biseriata (Hall)
Orthotetes keokuk (Hall)
Rhipidomella dubia (Hall)
Camarotoechia mutata (Hall)
Dielasma sp.
Spirifer tenuicostatus Hall
Spirifer keokuk Hall
Brachythyris subcardiformis (Hall)
Spiriferella neglecta (Hall)
Reticularia pseudolineata (Hall)
Eumetria verneuiliana (Hall)
Composita sp.
Cliothyridina parvirostris (M. and W.)

PELECYPODA—
Pinna subspatulata Worthen
Aviculopecten sp.

GASTROPODA—
Platyceras equilateralis Hall

In the Mississippian crinoid collection at the Walker Museum, University of Chicago, the following species of crinoids listed from Keokuk, Iowa, are believed to have been collected from this bed as suggested by the character of their matrix.

Gilbertsocrinus sp.
Batocrinus sp.
Dizygocrinus biturbinatus (Hall)
Eutrochocrinus planodiscus (Hall)
Agaricocrinus wortheni Hall
Agaricocrinus nodulosus var. macadamsi Worthen
Agaricocrinus nodulosus Worthen
Actinocrinus pernodosus Hall
Platycrinus saffordi Hall
Platycrinus sp.
Forbesiocrinus wortheni Hall
Synbathocrinus swallowi Hall
Halysiocrinus tunicatus (Hall)
Barycrinus spurius (Hall)
Barycrinus magister (Hall)
Barycrinus tumidus (Hall)
Barycrinus stellatus (Hall)
Barycrinus bullatus (Hall)
Pachylocrinus sp.
Scylatocrinus sp.

List of fossils from bed 2 of the Lower Warsaw beds at Keokuk.

ANTHOZOA—
Amplexus sp.
Zaphrentis sp.

BRYOZOA—
Stenopora sp.
Fenestella serratula Ulrich
Fenestella tenax Ulrich ?
Hemitrypa proutana Ulrich
Polypora sp.
Cystodictya lineata Ulrich
Worthenopora spinosa Ulrich

BRACHIOPODA—
Productus sp.
Productus sp.
Pustula alternata (N. and P.)
Pustula biseriata (Hall)
Camarotoechia mutata (Hall)
Cranaena sulcata Weller
Dielasma ? sp.
Dielasma sp.
Dielasma sp.
Spiriferina norwoodana (Hall)
Spiriferina sp.
Spirifer tenuicostatus Hall
Spirifer keokuk hall
Brachythyris suborbicularis (Hall)
Pseudosyrinx keokuk Weller ?
Reticularia setigera (Hall)
Eumetria verneuiliana (Hall)
Cliothyridina parvirostris (M. and W.)

PELECYPODA—
Aviculopecten sp.

GASTROPODA—
Holopea cf. H. proutana Hall

VERTEBRATA—
Fish teeth

List of fossils from bed 3 of the Lower Warsaw beds at Keokuk.

ANTHOZOA—
Triplophyllum dalei (M.-E. and H.)
Zaphrentis spergenensis Worthen
Zaphrentis sp.
Amplexus sp.
Monilopora beecheri Grabau

CRINOIDEA—
Dorycrinus sp.

BRYOZOA—
Fistulipora sp.
Stenopora sp.
Leioclema punctatum (Hall)
Archimedes cf. A. owenanus Hall

Fenestella serratula Ulrich
Fenestella multispinosa Ulrich
Fenestella tenax Ulrich
Fenestella compressa Ulrich ?
Fenestella triserialis Ulrich ?
Polypora varsoviensis Prout
Polypora cf. P. biseriata Ulrich
Polypora retrorsa Ulrich ?
Polypora spininodata Ulrich
Polypora sp.
Hemitrypa aspera Ulrich
Hemitrypa proutana Ulrich
Hemitrypa perstriata Ulrich
Hemitrypa plumosa Prout ?
Hemitrypa sp.
Ptilopora prouti Hall
Rhombopora sp.
Rhombopora attenuata Ulrich
Cystodictya lineata Ulrich
Cystodictya pustulosa Ulrich
Glyptopora elegans (Prout)
Glyptopora keyserlingi (Prout)
Glyptopora sp.
Worthenopora spinosa Ulrich
Cyclopora fungia Ulrich

BRACHIOPODA—
Pustula biseriata (Hall)
Orthotetes keokuk (Hall)
Rhipidomella dubia (Hall)
Camarotoechia mutata (Hall)
Dielasma sp.
Spiriferina sp.
Spirifer cf. S. keokuk Hall
Spirifer tenuicostatus Hall
Reticularia setigera (Hall)
Cliothyridina parvirostris (M. and W.)

Worthen has described several species of crinoids from the upper shales of the Geode bed one mile below Keokuk in Volume VII of the Geological Survey of Illinois. Inasmuch as these undoubtedly came from bed 3 of the writer's section they are listed here, the revised nomenclature being used.

Rhodocrinus coxanus Worthen
Scaphiocrinus briaerius (Worthen)
Scaphiocrinus extensus W. and S.
Scaphiocrinus iowensis (Worthen)
Scaphiocrinus obscurus W. and S.
Scaphiocrinus orestes (Worthen)
Zeacrinus keokuk Worthen
Woodocrinus asperatus (Worthen)
Woodocrinus tentaculatus (Worthen)

The Lower Warsaw outcrops seven and one-half miles north of Keokuk in the banks of a small creek just south of the town of Montrose. This member is thirty feet in thickness at this locality and is succeeded directly by the Spergen formation, the Upper Warsaw being absent.

Clark County, Missouri.—The Lower Warsaw is well exposed in Clark county, Missouri, along the north bluff of Fox river four miles northwest of Wayland and one-fourth mile northwest of Fox City. The geodes and their relation to the containing rock may be very satisfactorily studied at this place. The section is given below:

Section of Lower Warsaw beds in north bluff of Fox river near Fox City.

	FEET	INCHES
8. Drift	1	
7. Shale, argillo-calcareous, pyritiferous, bluish when fresh but breaking down readily to a gray friable clay and releasing a few small geodes	17	
6. Limestone, gray, crinoidal; shaly in places; cherty near the base	5	

5.	Limestone, impure, magnesian, fine-grained, drab; scaling off obliquely in large slabs	3	8
4.	Shale, highly calcareous, bluish; locally more argillaceous and exhibiting laminated structures. Geodes present, some exceeding 15 inches in diameter; arranged roughly in bands; many closely arranged	6	
3.	Limestone, gray, crinoidal; cherty near the base	7	
2.	Limestone, impure, shaly, fine-grained; bearing a few scattered but large geodes	1	6
1.	Limestone, gray, crinoidal; exposed	6	

Bed 1 of this section evidently represents the uppermost member of the Keokuk limestone. All of the succeeding layers are referable to the Lower Warsaw except bed 8.

Des Moines County, Iowa.—The Lower Warsaw is considerably thinner in Des Moines county than in Lee and adjacent counties to the south. The only important exposures in this county which are known to the writer occur along Long creek in the eastern part of Augusta township.

At a small quarry opening on the Wm. Madlener property, in the southwest one-fourth of the southeast quarter of section 12, twelve feet of bluish argillaceous shale with occasional siliceous nodules is exposed. This shale is overlain by thirty feet of buff, dolomitic Spergen limestone. Lower Warsaw shale of similar character outcrops a short distance down the creek. The bed is eighteen feet thick and is underlain by nine feet of Keokuk limestone and overlain by five feet of brownish massive dolomitic Spergen limestone.

Henry County.—The Lower Warsaw is exposed along Mud creek, a stream emptying into Skunk river about one mile east of Lowell in Henry county. Outcrops of this subdivision occur at intervals along the banks of the creek for a distance of one mile north of the iron bridge which crosses the stream in the southern part of section 27, Baltimore township. Farther up the creek outcrops of the Keokuk limestone appear, a fact which suggests an upward flexure of the strata at this place.

Complete sections of the Lower Warsaw are wanting at this locality as a result of erosion and slumping. But for the abundance and perfection of its geodes this place is unexcelled. The section here given was measured a few rods north of the iron bridge mentioned above, at a low bluff on the east side of the creek.

Section of Lower Warsaw beds on Mud creek.

		FEET	INCHES
6.	Drift	1	6
5.	Shale, argillaceous, bluish, breaking down to a gritty drab-colored clay; containing a few scattered irregular siliceous nodules which contain geodic cavities	10	6
4.	Limestone, impure, buff, magnesian; checking into irregular blocks and bearing the impressions of fronds of fenestelloid bryozoans; lenticular siliceous masses near the base inclose material identical with that of the surrounding rock	2	
3.	Shale, bluish when fresh; thickly set with geodes less than 6 inches in diameter, which are not confined to bands	2	8
2.	Shale, highly calcareous, gray and buff in color; geodes scarce	1	6
1.	Shale, calcareous, bluish. Some of the fossils collected from this layer are: *Orthotetes keokuk, Spirifer keokuk ?, Reticularia* sp., imperfectly preserved bryozoa, and numerous small fish teeth. Exposed		8

An outcrop a short distance up the creek at a point just west of the second bridge over Mud creek exposes number 1 of the previous section to a height of about three feet. The upper part of this member at this place bears many rounded concretionary nodules of material which appears to be more calcareous than the containing rock. These nodules range from less than an inch to more than six inches in diameter.

Bluffs of the Lower Warsaw beds about thirty feet in height are present about three-fourths of a mile north of the last mentioned point, in the extreme northern part of section 27 and the southernmost part of section 22, on the east bank of the stream. The nature of the beds at this point, however, is largely obscured on account of slumping and the encroachment of vegetation upon the weathered slopes of the material. Many geodes occur in the beds and the weathered slopes of the deposit are strewn with specimens. Some of these have a diameter as great as eighteen inches. The following section of the Lower Warsaw was measured in a ravine which opens into Mud creek from the east about one-fourth mile north of these bluffs:

Section of Lower Warsaw beds in section 22, Baltimore township.

		FEET	INCHES
5.	Limestone, massive, magnesian, yellowish, no geodes nor fossils noted	4	
4.	Shale, bluish, calcareous; grading upward into limestone	2	
3.	Limestone, impure, buff, magnesian	1	8
2.	Shale, calcareous, bearing several large geodes	2	
1.	Shale, bluish, argillaceous; bearing rounded calcareous nodules near the top. Exposed	4	

A section along the bed and banks of a creek emptying into

Skunk river from the south a short distance west of Webster's mill in the western part of section 4 of Jackson township, shows the Lower Warsaw in contact with the overlying St. Louis and the underlying Keokuk limestone. The section of the Keokuk at this point is described on pages 174 and 175 of this report.

Section in western part of Jackson township.

		Feet	Inches
Lower St. Louis.			
11.	Limestone, buff, dolomitic, massive, exposed along the bed of the creek	5–6	
10.	Limestone, dark gray, compact, dense, fine-grained, much brecciated and mashed; forming low mounds along the bed of the creek a short distance above	1½–2½	
Lower Warsaw.			
9.	Limestone, brownish, dolomitic, thin-bedded, locally arenaceous in part	1	1
8.	Sandstone, soft, fine-grained, bluish	3	8
7.	Sandstone, bluish, fine-grained, filled with large angular fragments of white chert	1	
6.	Shale, bluish, argillaceous, soft	2	3
5.	Limestone, ash-colored, soft, impure, shaly, arenaceous in the upper part	1	3
4.	Shale, bluish, argillaceous	1	6
3.	Concealed, probably soft shale	6	
2.	Limestone, soft, gray, shaly, with bands of irregular siliceous segregations; exposed in a little gully near the main stream	2	
1.	Limestone, brownish, dolomitic, medium-grained in middle part but fine-grained above and below. Shaly in lower part. Contact with Keokuk limestone below concealed	3	

The following species were collected from bed 1: *Pustula biseriata* (Hall), *Spirifer tenuicostatus* Hall, and *Composita trinuclea* (Hall). Beds 7, 8 and 9 possibly represent the Spergen formation in an attenuated condition.

Van Buren County.—The Lower Warsaw is present in Van Buren county though it is somewhat thinner and less typically developed than at Warsaw, Illinois, the type locality.

The beds may be studied to good advantage in this county along Indian creek near Farmington, on Bear creek at Vernon, on Copperas creek above Bentonsport, in the north bluff of Des Moines river just below Bentonsport and on Potters branch near Bonaparte.

The Lower Warsaw is well exposed in the north bluff of Des Moines river one-fourth mile below the railroad station at Bentonsport. It yields numerous fossils throughout its exposure. A section of the underlying Keokuk beds at this locality has been described in a preceding chapter.

Section of Lower Warsaw beds one-fourth mile below Bentonsport.

	FEET	INCHES
8. Concealed (to brow of bluff)		
DES MOINES		
7. Sandstone, gray to whitish, weathering yellowish, bearing a few plant remains. Exposed	1	5
6. Concealed	4	
LOWER ST. LOUIS		
5. Limestone, brownish, dolomitic	4	
4. Concealed	27	10
LOWER WARSAW		
3. Shale, bluish, argillaceous, with occasional layers of brownish impure limestone, containing a few imperfect siliceous geodes. Poorly exposed on slope of bluff	20	
2. Limestone, gray, fine-grained, brittle, fucoidal, with occasional thin layers of coarse-grained bluish gray limestone in middle part and in the basal parts a few fine-grained impure layers which weather yellowish	4	
1. Limestone, shaly, grayish weathering yellowish, filled with bryozoans	3	

The fossils identified from beds 1, 2 and 3 of the Lower Warsaw are as follows:

List of fossils from bed 1 of Lower Warsaw beds near Bentonsport.

ANTHOZOA—
- Triplophyllum dalei (M.-E. and H.)
- Amplexus sp.
- Monilopora sp.

BLASTOIDEA—
- Metablastus wortheni (Hall)

CRINOIDEA—
- Dorycrinus sp.
- Barycrinus sp.
- Barycrinus sp.

ECHINOIDEA—
- Archaeocidaris sp.

BRYOZOA—
- Meekopora sp.
- Meekopora sp.
- Fistulipora ? sp.
- Stenopora sp.
- Leioclema punctatum (Hall)
- Leioclema foliatum Ulrich
- Fenestella serratula Ulrich
- Fenestella multispinosa Ulrich
- Fenestella rudis Ulrich
- Fenestella triserialis Ulrich
- Fenestella tenax Ulrich
- Fenestella exigua Ulrich
- Fenestella sp.
- Fenestella sp.
- Fenestella sp.
- Fenestella sp.
- Hemitrypa proutana Ulrich
- Hemitrypa nodosa Ulrich
- Hemitrypa aspera Ulrich
- Hemitrypa perstriata Ulrich
- Hemitrypa cf. H. beedei Cumings
- Hemitrypa sp.
- Archimedes owenanus Hall ?
- Archimedes negligens Ulrich
- Archimedes sp.
- Archimedes sp.
- Archimedes sp.
- Polypora retrorsa Ulrich
- Polypora halliana Prout
- Polypora spininodata Ulrich
- Polypora sp.
- Polypora sp.
- Pinnatopora sp.
- Rhombopora attenuata Ulrich
- Rhombopora varians Ulrich
- Bactropora simplex Ulrich
- Streblotrypa cf. S. radialis Ulrich
- Streblotrypa major Ulrich
- Cystodictya nitida Ulrich
- Cystodictya americana Ulrich
- Cystodictya sp.
- Phractopora trifolia (Rominger)
- Glyptopora sagenella (Prout)
- Glyptopora keyserlingi (Prout)
- Glyptopora elegans (Prout)
- Glyptopora sp.
- Glyptopora sp.
- Cyclopora sp.
- Worthenopora spinosa Ulrich

BRACHIOPODA—
- Schuchertella ? sp.
- Camarotoechia mutata (Hall)
- Dielasma sp.
- Spiriferina sp.
- Spirifer cf. S. pellaensis Weller
- Spirifer tenuicostatus Hall
- Brachythyris subcardiformis (Hall)
- Syringothyris subcuspidatus (Hall)
- Reticularia pseudolineata (Hall)

Cliothyridina parvirostris (M. and W.)
GASTROPODA—
Platyceras sp.
Orthonychia cf. O. acutirostre Hall
Orthonychia sp.
TRILOBITA—
Griffithides ? sp.

List of fossils from bed 2 of Lower Warsaw beds near Bentonsport.

ANTHOZOA—
Zaphrentis sp.
Triplophyllum pellaensis (Worthen)
Amplexus sp.
Syringopora sp.
Monilopora sp.
CRINOIDEA—
Actinocrinus sp.
ECHINOIDEA—
Archaeocidaris keokuk Hall
Pholidocidaris irregularis (M. and W.)
BRYOZOA—
Stenopora sp.
Leioclema punctatum (Hall)
Fenestella serratula Ulrich
Fenestella multispinosa Ulrich
Fenestella exigua Ulrich
Fenestella sp.
Fenestella sp.
Fenestella sp.
Hemitrypa sp.
Archimedes sp.
Polypora cf. P. varsoviensis Prout
Polypora varsoviensis Prout
Polypora sp.
Polypora sp.
Ptilopora ? sp.
Rhombopora varians Ulrich
Rhombopora transversalis Ulrich
Rhombopora ? sp.
Bactropora simplex Ulrich
Taeniodictya ramulosa Ulrich
Cystodictya sp.
Phractopora trifolia (Rominger)
Glyptopora sagenella var. ?
Glyptopora sp.
Cyclopora ? sp.
BRACHIOPODA—
Schuchertella ? sp.
Productus ovatus Hall
Productus setigerus Hall
Productus sp.
Productus sp.
Productus sp.
Avonia ? sp.
Pustula alternata (N. and P.)
Pustula biseriata (Hall)
Pustula sp.
Rhipidomella dubia (Hall)
Camarotoechia mutata (Hall)
Dielasma inflata Weller ?
Dielasma sp.
Girtyella indianensis (Girty)
Spiriferina sp.
Spirifer rostellatus Hall.
Spirifer tenuicostatus Hall
Spirifer sp.
Brachythyris subcardiformis (Hall)
Spiriferella neglecta (Hall)
Reticularia pseudolineata (Hall)
Reticularia setigera (Hall)
Eumetria verneuiliana (Hall)
Cliothyridina obmaxima (McChesney)
Cliothyridina parvirostris (M. and W.)
PELECYPODA—
Concardium sp.
Schizodus sp.
Schizodus sp.
Schizodus sp.
Schizodus sp.
Aviculopecten ? sp.
Aviculopecten sp.
Aviculopecten sp.
Aviculopecten sp.
Lithophagus illinoisensis Worthen
Cypricardinia sp.
SCAPHOPODA—
Laevidentalium sp.
GASTROPODA—
Orthonychia sp.
TRILOBITA—
Griffithides ? sp.

List of fossils from bed 3 of Lower Warsaw beds near Bentonsport.

BRYOZOA—
Stenopora sp.
Leioclema punctatum (Hall)
Fenestella serratula Ulrich
Fenestella tenax Ulrich
Fenestella multispinosa Ulrich
Archimedes negligens Ulrich
Archimedes owenanus Hall
Polypora varsoviensis Prout
Ptilopora sp.
Rhombopora attenuata Ulrich
Rhombopora ? asperula Ulrich
Cystodictya lineata Ulrich
Phractopora trifolia (Rominger)
Glyptopora sp.
BRACHIOPODA—
Orthotetes keokuk (Hall)
Rhipidomella dubia (Hall)
Spirifer keokuk Hall
Spiriferella neglecta (Hall) ?
Reticularia setigera (Hall)
Composita globosa Weller

The following section is exposed along Indian creek a short distance back from its mouth, near Farmington:

Section on Indian creek near Farmington.

		FEET	INCHES
7.	Loess	2	
6.	Till, yellowish, arenaceous; passing locally into an incoherent stratified sand	19	
5.	Shale, bluish, argillaceous, laminated; no geodes nor calcareous nodules	4	10
4.	Limestone, bluish, fine-grained, magnesian; pinching out laterally	1	10
3.	Shale, bluish, argillaceous, no geodes	2	
2.	Limestone, bluish, fine-grained, magnesian; passing laterally into shale	1	
1.	Shale, bluish, laminated, argillaceous; bearing geodes and calcareous nodules in lower part	4	

Beds 1 to 5 represent the Lower Warsaw.

A similar section may be studied along Bear creek in the northeast quarter of section 11 of Henry township, about six miles northwest of the Indian creek locality.

Section of Lower Warsaw beds on Bear creek.

		FEET	INCHES
3.	Shale, bluish, argillaceous; with occasional impure fossiliferous limestone flakes; more calcareous and bearing siliceous geodes in basal part	15	
2.	Limestone, grayish, medium-grained, fossiliferous		2–19
1.	Shale, bluish, argillaceous; with thin seams of impure fossiliferous limestone. Exposed to bed of creek	11	6

The species collected from the various beds are as follows:

List of fossils from bed 1 of above section.

ANTHOZOA—
- Triplophyllum dalei (M.-E. and H.)
- Monilopora beecheri Grabau

BRYOZOA—
- Stenopora sp.
- Leioclema punctatum (Hall)
- Fenestella rudis Ulrich
- Fenestella serratula Ulrich
- Fenestella multispinosa Ulrich
- Fenestella sp.
- Hemitrypa sp.
- Archimedes negligens Ulrich
- Rhombopora attenuata Ulrich
- Rhombopora varians Ulrich
- Bactropora simplex Ulrich
- Cystodictya lineata Ulrich
- Worthenopora spinosa Ulrich

List of fossils from bed 2 of above section.

BRYOZOA—
- Stenopora sp.
- Fenestella multispinosa Ulrich
- Archimedes sp.
- Bactropora simplex Ulrich
- Cystodictya lineata Ulrich
- Glyptopora michelinia (Prout)
- Worthenopora spinosa Ulrich

BRACHIOPODA—
- Rhipidomella dubia (Hall)
- Spiriferina sp.

List of fossils from bed 3 of above section.

BRYOZOA—
- Stenopora sp.
- Leioclema punctatum (Hall)
- Fenestella exigua Ulrich
- Fenestella serratula Ulrich
- Fenestella tenax Ulrich
- Hemitrypa sp.
- Polypora retrorsa Ulrich
- Polypora varsoviensis Prout
- Rhombopora attenuata Ulrich
- Phractopora trifolia (Rominger)
- Glyptopora michelinia (Prout)
- Glyptopora sp.
- Worthenopora spinosa Ulrich

BRACHIOPODA—
- Rhipidomella dubia (Hall)
- Spiriferina (species undescribed)
- Spirifer tenuicostatus Hall

Geodes do not occur at this place but they are common in the shale farther up the creek.

The following section of the Lower Warsaw is exposed along Copperas creek two miles northwest of Bentonsport.

Section of Lower Warsaw beds along Copperas creek.

		FEET
4.	Drift	1½
3.	Shale, bluish, weathering drab	4
2.	Limestone, fine-grained, impure, shaly in middle	2
1.	Shale, bluish, nonfossiliferous; bearing imperfect geodes and discontinuous bands of siliceous material in lower part	11

At an exposure on Potter's branch in the southeast one-fourth of the southeast quarter of section 9, Bonaparte township, eleven feet of Lower Warsaw shale, argillaceous above but calcareous below, is overlain by thirty-three feet of Spergen shales and limestones.

The following section is shown a few rods farther down in the north bank:

Section on Potters branch.

		FEET	INCHES
LOWER WARSAW			
8.	Slope strewn with imperfect siliceous geodes	21	6
7.	Limestone. buff, massive, dolomitic, shaly in lower part	13	10
KEOKUK			
6.	Limestone, bluish gray, subcrystalline, unaltered, fossiliferous	2	
5.	Limestone, yellowish, dolomitic, vesicular, tough, massive	2	
4.	Shaly parting		8
3.	Limestone, bluish, compact, massive, dolomitic, with molds of fossils	2	1
2.	Shale, bluish, argillaceous	1	9
1.	Limestone, bluish gray, unaltered, with shaly seams in upper and lower part. Exposed to bed of creek	4	

An outcrop of bluish Lower Warsaw shale appears in the east bank of Rock creek about one hundred yards above the railway bridge in the northwest quarter of section 21, Washington township, Van Buren county. It is nine feet in thickness and contains thin intercalated flakes of limestone. Both the shale and the limestone are fossiliferous. A thin bed of fine-grained cream-colored limestone is exposed at the top of the section. The following species were collected from the shale:

List of fossils from Lower Warsaw shale on Rock creek.

BRYOZOA—
- Stenopora sp.
- Leioclema punctatum (Hall)
- Fenestella serratula Ulrich
- Hemitrypa sp.
- Archimedes sp.
- Rhombopora attenuata Ulrich
- Rhombopora ? asperula Ulrich
- Cystodictya lineata Ulrich
- Worthenopora spinosa Ulrich

BRACHIOPODA—
- Pustula biseriata (Hall) ?
- Rhipidomella dubia (Hall)
- Spiriferina sp.
- Spirifer tenuicostatus Hall

PELECYPODA—
- Cypricardinia indianensis Hall

About ten feet of bluish calcareous shale of a slightly lower horizon outcrops in the west bank near the mouth of the creek. Reddish siliceous segregations appear in this member.

THE UPPER WARSAW BEDS

DESCRIPTION OF THE TYPE SECTION

The Upper member of the Warsaw formation is typically developed near the town of Warsaw in Hancock county, Illinois, where it was examined and described by Hall[4] under the heading of "Warsaw, or Second Archimedes limestone." The most satisfactory exposures appear along a small tributary of Mississippi river a short distance northeast of the town. The upper layers of the Keokuk limestone, the entire section of the Lower and Upper Warsaw, the Spergen limestone, and the basal part of the St. Louis limestone are excellently exposed along this creek. The upper layers of the Keokuk limestone appear at the north of the creek, and along its bed for a short distance up stream. The Warsaw beds outcrop thence in the bed of the creek and along its bank continuously as far as a small waterfall beyond the first stone arch bridge. The basal limestone of the Upper Warsaw caps the ledge at the fall. Above this point the Upper Warsaw beds are exposed in the bed of the stream and along its banks for a considerable distance, finally giving way to the Spergen and St. Louis limestones.

The section of the Upper Warsaw, which was carefully measured in the bluffs below the first stone bridge, and along the

[4] Geol. of Iowa, vol. I, part 1, p. 97; 1858.

stream above the small waterfall, is given below, the succession being from above downwards:

Section of Upper Warsaw beds northeast of Warsaw.

		FEET
5.	Limestone, bluish, magnesian, locally arenaceous or shaly in part; the "arenaceo-magnesian limestone" of authors. Fossils scarce except in lower part	3 to 7½
4.	Shale, bluish, argillaceous; with interbedded layers and flakes of gray subcrystalline limestone, some layers of which are shaly. A fine-grained bluish fossiliferous sandstone near the middle	18½
3.	Limestone, bluish gray, lenticular, subcrystalline, locally dolomitic in part. Massive where fresh but weathering to thin layers	0 to 3
2.	Shale, bluish, argillaceous, with occasional thin layers of shaly, fossiliferous limestone	7
1.	Limestone, bluish, magnesian; layers thin and undulating in creek bed, but thicker and more even in bank of creek further down	4 to 8

Bed 1 represents the basal member of the Upper Warsaw. At Keokuk, and in the Soap Factory Hollow section, two miles below Warsaw, this member is represented by an unaltered thin-bedded fossiliferous limestone. Evidently dolomitization has affected this bed locally and incompletely. Occasional seams in the dolomitic limestone are filled with the molds of fossils, mainly of bryozoans. It also bears a few small irregular and imperfect siliceous geodes lined with quartz or calcite, or both. Surfaces of the layers are pitted locally due to the weathering and removal of small pyrite nodules. The contact of this bed with the topmost shale member of the Lower Warsaw is gradational.

The uppermost part of bed 2 furnishes a clay product valued for molding purposes. It has been worked in a desultory manner just west of the first stone bridge. This bed bears few well preserved fossils except in the interbedded limestone layers.

Bed 3 may aptly be called the lenticular limestone member. The thickening and thinning appears to take place from the lower side only. In places it pinches and swells very abruptly and at one point in the bank of the creek it disappears completely for a distance of several yards. It is there replaced by shale. It is usually in the form of a massive ledge when fresh but weathers into thin layers. It is divided locally into two parts by a shaly parting. The surfaces of the layers are pitted and are blotched here and there with limonite, a condition which is caused by the oxidation and weathering of pyrite nodules which are common in the fresh rock.

This bed of limestone is locally dolomitic in part, but the dolomite occurs at no definite level. At one point it is in the upper part, at another it is in the lower. Evidently the alteration was very local and imperfect. Where it is dolomitized the limestone carries molds of fossils only.

In bed 4 a conspicuous ten-inch layer of bluish fossiliferous sandstone with fucoidal markings appears seven feet ten inches below the top. Ten and one-half feet below the top there occurs an eight inch layer of limestone which thickens abruptly in the bed of the creek below Main street bridge. It attains a thickness of four feet at one point. It bears many spiral axes of *Archimedes wortheni* and may be designated the *Archimedes* limestone. The following detailed section will show the nature of the individual layers of this member:

Layers of Bed 4.

	FEET	INCHES
Shale, with thin layers of fossiliferous limestone interbedded. Well exposed along creek between the bend and the falls of the north fork	7	10
Sandstone, fine-grained, bluish, fucoidal		10
Shale, bluish, argillaceous	1	10
Limestone, gray, filled with *Archimedes* and other fossils		8
Shale	1	6
Limestone, shaly	1	3
Shale		10
Limestone		7
Shale	3	3

Bed 5 is typically represented by massive layers of arenaceous magnesian limestone, but in a ravine east of the high school it is shaly. The shaly facies is bluish and weathers into irregular chips. The arenaceo-magnesian facies becomes brownish when weathered.

The fossils collected from the individual members of the Upper Warsaw at this locality are listed below:

List of fossils from bed 1 of the Upper Warsaw near Warsaw.

BRYOZOA—
- Stenopora sp.
- Fenestella serratula Ulrich
- Polypora varsoviensis Prout
- Worthenopora spinosa Ulrich

BRACHIOPODA—
- Productus sp.
- Productus setigerus Hall
- Pustula alternata (N. and P.)
- Pustula biseriata (Hall) ?
- Camarotoechia mutata (Hall)
- Dielasma sp.
- Girtyella indianensis (Girty)
- Spiriferina sp.
- Spirifer pellaensis Weller
- Spirifer tenuicostatus Hall

Brachythyris subcardiformis (Hall)
Reticularia setigera (Hall)
Eumetria verneuiliana (Hall)
Composita sp. ?

PELECYPODA—
Cypricardinia indianensis Hall ?
Lithophagus illinoisensis Worthen

GASTROPODA—
Orthonychia sp.

TRILOBITA—
Phillipsia ? sp.

List of fossils from bed 2 of the Upper Warsaw near Warsaw

ANTHOZOA—
Triplophyllum dalei (M.-E. and H.)

BRYOZOA—
Stenopora sp.
Leioclema punctatum (Hall)
Archimedes owenanus Hall
Archimedes wortheni Hall
Fenestella multispinosa Ulrich ?
Fenestella tenax Ulrich
Fenestella serratula Ulrich
Fenestella exigua Ulrich ?
Fenestella triserialis Ulrich ?
Fenestella sp.
Hemitrypa proutana Ulrich
Hemitrypa proutana var. nododorsalis Cumings
Hemitrypa sp.
Polypora varsoviensis Prout
Polypora biseriata Ulrich
Ptilopora sp.
Rhombopora attenuata Ulrich
Rhombopora varians Ulrich
Cystodictya lineata Ulrich
Cystodictya pustulosa Ulrich ?
Glyptopora sp.
Cyclopora sp.
Cycloporella (?) sp.

BRACHIOPODA—
Lingula varsoviensis Worthen
Productus ovatus Hall
Spirifer pellaensis Weller
Brachythyris subcardiformis (Hall)
Reticularia setigera (Hall)
Eumetria verneuiliana (Hall)

PELECYPODA—
Lithophagus illinoisensis Worthen
Cypricardinia indianensis Hall ?
Aviculopecten sp.

GASTROPODA—
Orthonychia sp.

VERTEBRATA—
Fish teeth

List of fossils from bed 3 of the Upper Warsaw near Warsaw.

BRYOZOA—
Stenopora sp.
Archimedes sp.
Glyptopora elegans (Prout) ?
Worthenopora spinosa Ulrich

BRACHIOPODA—
Lingula varsoviensis Worthen ?
Productus setigerus Hall
Productus ovatus Hall
Productus sp. ?
Pustula biseriata (Hall)
Tetracamera subcuneata (Hall)
Dielasma sp.
Spirifer pellaensis Weller
Brachythyris subcardiformis (Hall)
Spiriferella neglecta (Hall)
Reticularia pseudolineata (Hall)
Eumetria verneuiliana (Hall)

List of fossils from bed 4 of the Upper Warsaw near Warsaw.

ANTHOZOA—
Zaphrentis spinulifera Hall
Zaphrentis cassedyi M.-E. and H.
Aulopora sp.
Monilopora beecheri Grabau ?
Monilopora sp.

VERMES—
Spirorbis sp.

BLASTOIDEA—
Pentremites conoideus Hall

ECHINOIDEA—
Archaeocidaris sp.

BRYOZOA—
Fistulipora sp.
Stenopora sp.
Leioclema punctatum (Hall)
Leioclema foliatum Ulrich
Fenestella tenax Ulrich
Fenestella serratula Ulrich
Fenestella rudis Ulrich
Fenestella exigua Ulrich
Fenestella multispinosa Ulrich
Fenestella sp.
Fenestella sp.
Hemitrypa proutana Ulrich
Hemitrypa nodosa Ulrich
Hemitrypa sp.
Archimedes wortheni Hall
Archimedes negligens Ulrich
Archimedes sp.
Fenestralia sancti-ludovici Prout
Polypora biseriata Ulrich
Polypora varsoviensis Prout
Polypora spininodata Ulrich
Polypora sp.
Ptilopora prouti Hall
Ptilopora sp.
Ptilopora sp.

Rhombopora varians Ulrich
Rhombopora attenuata Ulrich
Rhombopora sp. ?
Bactropora simplex Ulrich ?
Cystodictya sp.
Cystodictya sp.
Glyptopora elegans (Prout)
Glyptopora michelinia (Prout)
Glyptopora sagenella (Prout)
Glyptopora sagenella var. caliculosa Ulrich ?
Glyptopora plumosa (Prout)
Cyclopora sp.
Worthenopora spinosa Ulrich
Worthenopora spatulata (Prout)
Worthenopora sp.

BRACHIOPODA—
Lingula varsoviensis Worthen ?
Orthotetes ? sp.
Productus altonensis N. and P. ?
Pustula biseriata (Hall)
Rhipidomella dubia (Hall)
Tetracamera subcuneata (Hall)
Dielasma sp.
Girtyella turgida (Hall)
Spiriferina sp.
Spirifer tenuicostatus Hall
Spirifer indianensis Weller ?
Spirifer pellaensis Weller
Spirifer bifurcatus Hall
Brachythyris subcardiformis (Hall)
Spiriferella neglecta (Hall)
Reticularia setigera (Hall)
Eumetria verneuiliana (Hall) ?
Cliothyridina parvirostris (M. and W.)
Composita trinuclea (Hall)

PELECYPODA—
Schizodus sp.
Aviculopecten sp.
Aviculopecten sp.
Cypricardinia indianensis Hall
Cypricardinia sp.

GASTROPODA—
Platyceras sp.
Orthonychia sp.

TRILOBITA—
Phillipsia ? sp.

VERTEBRATA—
Fish teeth

List of fossils from bed 5 of the Upper Warsaw near Warsaw.

BRYOZOA—
Stenopora sp.
Archimedes wortheni Hall
Fenestella rudis Ulrich
Fenestella serratula Ulrich
Fenestella multispinosa Ulrich
Hemitrypa proutana Ulrich
Polypora biseriata Ulrich
Polypora varsoviensis Prout
Rhombopora attenuata Ulrich ?
Cyclopora sp.
Cyclopora sp.
Worthenopora spinosa Ulrich
Worthenopora spatulata (Prout)

BRACHIOPODA—
Lingula sp.
Streptorhynchus ruginosum (Hall and Clarke)
Pustula biseriata (Hall)
Tetracamera subcuneata (Hall)
Dielasma sp.
Spirifer pellaensis Weller
Spirifer tenuicostatus Hall
Spiriferella neglecta (Hall)
Reticularia setigera (Hall)

PELECYPODA—
Aviculopecten sp.

GASTROPODA—
Platyceras sp.

The composite section of the Lower and Upper members of the Warsaw formation as they are developed at the type localities is given below:

General section of Warsaw Beds at Warsaw and Soap Factory Hollow.

	FEET
UPPER WARSAW	
8. Limestone, bluish, magnesian	3–7½
7. Shale, bluish, argillaceous, with interbedded layers of gray fossiliferous limestone and fine bluish sandstone	18½
6. Limestone, bluish gray, lenticular	0–3
5. Shale, bluish, argillaceous, with thin flakes of fossiliferous limestone	7
4. Limestone, bluish, magnesian	4–8
LOWER WARSAW	
3. Shale, bluish, argillaceous; geodiferous and nearly barren of fossils at the town of Warsaw but richly fossiliferous in the Soap Factory Hollow section two miles south	23

2.	Limestone, cherty; impure, buff-colored and magnesian at Warsaw; thin-bedded, gray and nonmagnesian at Soap Factory Hollow	3¼
1.	Limestone, drab, fine-grained, impure, magnesian. Fossils scarce in geodiferous phase at Warsaw but common in Soap Factory Hollow section	11½

The accompanying chart indicates the vertical distribution of the more characteristic species of the Warsaw fauna through the several members of the formation as developed at Warsaw and Soap Factory Hollow.

Table showing Range of Species in the Warsaw Formation at Warsaw and Soap Factory Hollow.

	Lower Warsaw			Upper Warsaw				
	1	2	3	4	5	6	7	8
ANTHOZOA								
Zaphrentis spergenensis Worthen			x					
Zaphrentis cassedyi M.-E. and H.							x	
Zaphrentis spinulifera Hall							x	
Triplophyllum dalei (M.-E. and H.)	x	x	x		x			
Amplexus sp.	x	x	x					
Monilopora beecheri Grabau	x		x				x?	
Monilopora sp.							x	
Aulopora sp.							x	
CRINOIDEA								
Agaricocrinus wortheni Hall	x							
Uperocrinus nashvillae (Hall)	x							
Barycrinus sp.	x							
BLASTOIDEA								
Pentremites conoideus Hall							x	
Schizoblastus granulosus (M. and W.)	x							
ECHINOIDEA								
Archaeocidaris keokuk Hall	x							
VERMES								
Spirorbis sp.		x?	x				x	
BRYOZOA								
Meekopora sp.			x					
Leioclema foliatum Ulrich							x	
Leioclema punctatum (Hall)			x		x		x	
Cystodictya lineata Ulrich	x				x			
Cystodictya pustulosa Ulrich	x	x	x		x			
Glyptopora keyserlingi (Prout)			x					
Glyptopora elegans (Prout)						x?	x	
Glyptopora michelinia (Prout)							x	
Glyptopora sagenella (Prout)							x	

Table showing Range of Species in the Warsaw Formation at Warsaw and Soap Factory Hollow.—Continued.

	Lower Warsaw			Upper Warsaw				
	1	2	3	4	5	6	7	8
Glyptopora sagenella var. caliculosa Ulrich ?							x	
Glyptopora plumosa (Prout)							x	
Bactropora simplex Ulrich ?							x	
Rhombopora varians Ulrich	x		x		x		x	
Rhombopora attenuata Ulrich	x	x	x		x		x	x?
Fenestella serratula Ulrich	x	x	x	x	x		x	x
Fenestella limitaris Ulrich	x							
Fenestella triseriallis Ulrich	x	x	x		x			
Fenestella tenax Ulrich	x	x	x		x		x	
Fenestella multispinosa Ulrich	x	x	x		x		x	x
Fenestella funicula Ulrich	x							
Fenestella compressa Ulrich	x		x					
Fenestella exigua Ulrich			x		x		x	
Fenestella rudis Ulrich			x				x	x
Archimedes negligens Ulrich							x	
Archimedes owenanus Hall	x		x		x			
Archimedes wortheni Hall			x		x		x	x
Hemitrypa pateriformis Ulrich	x	x	x					
Hemitrypa proutana Ulrich					x		x	x
Hemitrypa proutana var. nododorsalis Cumings					x			
Hemitrypa nodosa Ulrich							x	
Fenestralia sancti-ludovici Prout							x	
Polypora gracilis Prout	x		x					
Polypora varsoviensis Prout	x		x	x	x		x	x
Polypora retrorsa Ulrich		x	x					
Polypora biseriata Ulrich			x		x		x	x
Polypora spininodata Ulrich							x	
Ptilopora valida Ulrich			x					
Ptilopora prouti Hall							x	
Pinnatopora conferta Ulrich	x							
Worthenopora spinosa Ulrich	x	x	x	x		x	x	x
Worthenopora spatulata (Prout)							x	x
Brachiopoda—								
Lingula varsoviensis Worthen					x	x	x?	
Orbiculoidea sp.			x					
Streptorhynchus ruginosum (Hall and Clarke)								x
Orthotetes keokuk (Hall)	x							
Productus setigerus Hall	x	x	x	x		x		
Productus ovatus Hall	x				x	x		
Productus altonensis N. and P. ?							x	
Productus indianensis Hall ?			x					
Pustula alternata (N. and P.)	x	x	x	x				
Pustula biseriata (Hall)		x	x	x		x	x	x
Rhipidomella dubia (Hall)							x	
Camarotoechia mutata (Hall)	x	x	x	x				
Tetracamera subcuneata (Hall)						x	x	x
Cranaena sulcata Weller		x						
Dielasma sp.	x	x	x	x		x	x	x
Girtyella turgida (Hall)							x	
Girtyella indianensis (Girty)				x				
Spiriferina sp.			x				x	
Spirifer rostellatus Hall ?	x		x					
Spirifer cf. S. keokuk Hall	x	x	x					
Spirifer tenuicostatus Hall	x	x	x	x			x	x

Table showing Range of Species in the Warsaw Formation at Warsaw and Soap Factory Hollow.—Continued.

	Lower Warsaw			Upper Warsaw				
	1	2	3	4	5	6	7	8
Spirifer bifurcatus Hall		x	x				x	
Spirifer indianensis Weller ?							x	
Spirifer pellaensis Weller				x	x	x	x	x
Brachythyris suborbicularis (Hall)	x	x						
Brachythyris subcardiformis (Hall)	x	x		x	x	x	x	
Spiriferella neglecta (Hall)	x		x			x	x	x
Reticularia setigera (Hall)	x	x	x	x	x		x	x
Reticularia pseudolineata (Hall)						x		
Eumetria verneuiliana (Hall)		x	x	x	x	x	x	
Cliothyridina parvirostris (M. and W.)	x	x	x				x	
Composita trinuclea (Hall)	x	x	x				x	
Composita globosa Weller		x	x					
PELECYPODA								
Edmondia varsoviensis Worthen			x					
Edmondia illinoisensis Worthen			x					
Schizodus cf. S. circulus Worthen			x					
Schizodus sp.			x					
Schizodus sp.								x
Aviculopecten sp.		x						
Aviculopecten sp.		x						
Aviculopecten			x					
Aviculopecten sp.			x					
Lithophagus illinoisensis Worthen			x	x	x			
Cypricardinia indianensis Hall				x	x		x	
Allorisma sp.			x					
SCAPHOPODA								
Laevidentalium sp.		x						
GASTROPODA								
Holopea proutana Hall		x						
Strophostylus ? carleyana Hall ?		x						
Platyceras equilateralis Hall ?	x							
Straparollus sp.			x					
TRILOBITA								
Phillipsia ? sp.							x	

THE UPPER WARSAW IN IOWA

The Upper Warsaw thins abruptly to the north from the type section and is absent from the exposures within a distance not exceeding fifteen miles.

The section in the Mississippi river bluff back of the wholesale office of the Taber Lumber Company situated two miles below the Union station at Keokuk, Iowa, involves the upper part of the Keokuk limestone, which is exposed at the foot of the bluff, the whole of the Lower and Upper Warsaw, the Spergen limestone and the lower and upper divisions of the St. Louis limestone. The Upper Warsaw is considerably thinner at this point than at Warsaw and has a total thickness of only twenty-two feet. The beds are described below:

Section two miles below Keokuk Union Station.

	FEET
ST. LOUIS	
SPERGEN	
3. Limestone, brownish, dolomitic	2½
UPPER WARSAW	
2. Shale, bluish, argillaceous	18
1. Limestone, gray, with interbedded shale	4
LOWER WARSAW	

The following species were collected from the Upper Warsaw at this place:

List of fossils from bed 1 of Upper Warsaw in above section.

BRYOZOA—
- Leioclema punctatum (Hall)
- Archimedes owenanus Hall ?
- Archimedes cf. A. owenanus Hall
- Fenestella serratula Ulrich
- Fenestella tenax Ulrich
- Hemitrypa plumosa Prout ?
- Polypora retrorsa Ulrich
- Rhombopora attenuata Ulrich
- Cystodictya lineata Ulrich
- Cystodictya pustulosa Ulrich
- Cyclopora sp.
- Worthenopora spinosa Ulrich

BRACHIOPODA—
- Pustula biseriata (Hall)
- Rhipidomella dubia (Hall)
- Spiriferina sp.
- Spirifer cf. S. keokuk Hall
- Spirifer tenuicostatus Hall
- Spiriferella neglecta (Hall)
- Reticularia setigera (Hall)
- Cliothyridina parvirostris (M. and W.)

PELECYPODA—
- Pinna subspatulata Worthen ?

GASTROPODA—
- Orthonychia cf. O. acutirostre Hall

List of fossils from bed 2 of Upper Warsaw in above section.

ANTHOZOA—
- Zaphrentis sp.

BRYOZOA—
- Fistulipora (?) sp.
- Stenopora (?) sp.
- Leioclema punctatum (Hall)
- Archimedes wortheni Hall
- Archimedes owenanus Hall
- Archimedes sp.
- Fenestella tenax Ulrich
- Fenestella serratula Ulrich
- Fenestella exigua Ulrich
- Fenestella triserialis Ulrich ?
- Hemitrypa sp.
- Polypora varsoviensis Prout
- Rhombopora attenuata Ulrich
- Glyptopora keyserlingi (Prout)
- Glyptopora sp.
- Cystodictya pustulosa Ulrich
- Cystodictya lineata Ulrich
- Worthenopora spinosa Ulrich

BRACHIOPODA—
- Productus ovatus Hall
- Rhipidomella dubia (Hall)
- Tetracamera subcuneata (Hall)
- Dielasma sp.
- Spiriferina sp.
- Spirifer cf. S. keokuk Hall
- Spirifer tenuicostatus Hall
- Spiriferella neglecta (Hall) ?
- Reticularia setigera (Hall)

PELECYPODA—
- Aviculopecten sp.
- Aviculopecten sp.

A low bluff on B street near its intersection with Reid street, West Keokuk, shows seven feet of interbedded limestone and shale containing *Archimedes wortheni* and other characteristic Upper Warsaw fossils. It is overlain directly by the brecciated nondolomitic basal bed of the St. Louis limestone which is here three and one-half feet thick (fig. 6). As a result of the disconformity at the base of the St. Louis the Spergen limestone is

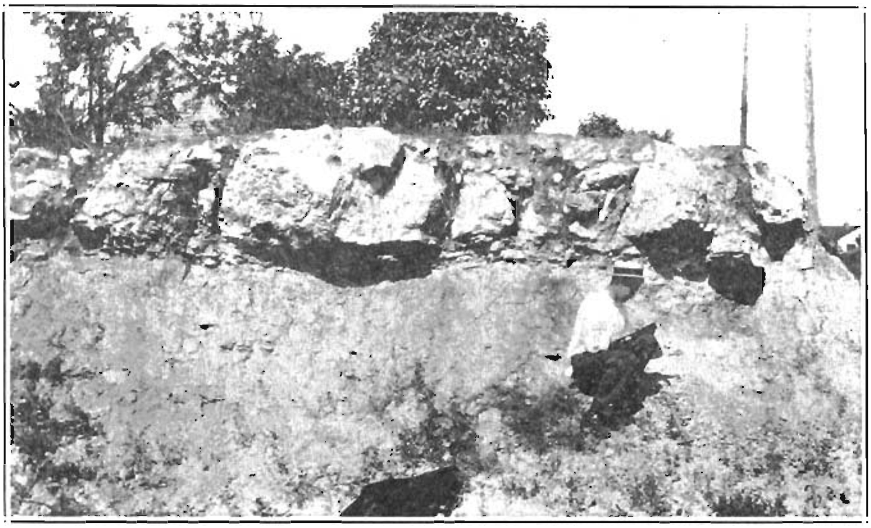

FIG. 6.—St Louis limestone resting upon Upper Warsaw shale on B street near its intersection with Reid street, Keokuk.

not present in this section. Inasmuch as the base of the Upper Warsaw is not exposed at this locality its total thickness could not be determined.

In the vicinity of Ballinger Siding, five and one-half miles north of Keokuk, the Spergen limestone rests upon shales which are believed to represent the Lower Warsaw. The outcrops along a small creek near the centre of section 25, Township 66 North, Range 5 West, show about twenty-five feet of bluish argillaceous shale underlying the Spergen limestone. The contact of the Spergen with the shales appears to be even and regular although a disconformity undoubtedly exists. Exposures along the banks of a small creek seven and one-half miles north of the city of Keokuk and just south of the town of Montrose show Spergen dolomitic limestone in contact with the Lower Warsaw in its typical development.

A similar though apparently less abrupt thinning of the Upper Warsaw beds takes place westward from Warsaw, Illinois. Exposures along Des Moines river and its tributaries show the Spergen limestone underlain by shales which probably represent an attenuated equivalent of the Upper Warsaw.

The following layers are exposed below the Spergen beds in the Deamude quarries located near the center of section 13 of Des Moines township, Lee county:

Section in Deamude quarries.

SPERGEN LIMESTONE	
UPPER WARSAW BEDS	FEET
3. Concealed, probably shale; *Archimedes wortheni* found on weathered slope	6¼
2. Limestone, bluish, lenticular, arenaceo-magnesian; weathering to thin layers	0–4½
1. Shale, bluish, argillaceous, bearing a few calcareous nodules. Exposed	4

Bed 2 contains the following species:

BRYOZOA—
- Streblotrypa sp.

BRACHIOPODA—
- Lingula varsoviensis Worthen
- Productus sp.
- Girtyella indianensis (Girty) ?
- Spiriferella neglecta (Hall) ?
- Reticularia setigera (Hall)

PELECYPODA—
- Aviculopecten sp.

GASTROPODA—
- Conularia sp.

The presence of *Lingula varsoviensis* and *Archimedes wortheni* in this exposure suggests the Upper Warsaw age of the beds.

In his report on Van Buren county[5] Gordon reports fifty-five feet of shales above the Keokuk limestone and refers the upper part of these to the Warsaw of Hall. In the present report these are referred to the Lower Warsaw because of the lack in them of fossils indicative of their Upper Warsaw age. However, the possibility of their upper part representing the Upper Warsaw must be granted.

THE SPERGEN FORMATION

NOMENCLATURE

The term Spergen was applied first as a formation name by Ulrich[6] in 1904 although several authors in publications dating back to 1860 referred to the highly fossiliferous strata of this age at Spergen Hill, Indiana, as "Spurgen's Hill beds", "Sper-

[5] Iowa Geol. Survey, vol. IV, pp. 213-214; 1895.

[6] U. S. Geol. Survey Prof. Paper 24, table opp. p. 90.

gen Hill limestone'', etc. The name Salem limestone as proposed for this formation by Cumings[7] in 1901 has appeared in the literature on Mississippian geology many times, but the U. S. Geological Survey now favors the use of Spergen.

This formation was recognized by the writer[8] as a distinct unit in the Mississippian column of Iowa several years ago.

AREAL DISTRIBUTION

The Spergen formation has a very restricted areal distribution in Iowa. In earlier reports it has usually been mapped as St. Louis limestone. Exposures of rocks of this age appear only in the southeastern part of the state, the most conspicuous ones being in Des Moines river valley in Lee and Van Buren counties. Small isolated outcrops appear at a few other localities in Lee. Des Moines, Henry and Jefferson counties.

CHARACTER AND STRATIGRAPHIC RELATIONS

The Spergen is represented in southeastern Iowa by an attenuated, near-shore facies, to which the name Belfast beds is given, because of the excellent exposures of the formation near the town of Belfast in Lee county.

Until recent years the Spergen has not been recognized in Iowa owing to the fact that it was confused in some places with the Warsaw formation and in others with the basal member of the St. Louis limestone. This confusion was due in large part to the failure of earlier workers to recognize the disconformities at the base and at the top of this formation. The apparent tendency of the Spergen to grade laterally into the Warsaw or the Lower St. Louis evidently is due to this relationship. The Spergen as developed in the area in question has a wide range in character, owing in part to original conditions of sedimentation and in part to differences in the degree of dolomitization. It is not uncommon to find a cross-bedded crinoidal limestone passing laterally into a massive brown dolomitic limestone, and this again into a brownish arenaceous dolomite, which may in turn give way to a fine-grained bluish sandstone. In Van Buren county the formation contains a large proportion of shale. Such

[7] Jour. Geol., vol. IX, pp. 232-233.
[8] Iowa Acad. Sci. Proc., vol. 19, pp. 167, 168; 1912.

differences clearly suggest near-shore conditions of deposition. This also is suggested by the limited areal extent of the formation in Iowa, and by its thinning to the northwest. It has not been found north of Jefferson county. As a result of the disconformity below the Spergen it may rest upon either the Upper or the Lower Warsaw. Owing to the hiatus above, it is in some places entirely cut out by the St. Louis limestone. The thickness of the formation thus ranges from almost nothing to thirty-five feet.

AREAL DESCRIPTION BY COUNTIES

Lee County, Iowa.—The most representative sections of the Spergen formation in Iowa are those in the quarries in the east bluff of Des Moines river south of the town of Belfast in Lee county. Several different exposures are described in this area in order to emphasize the variability of the beds. The formation is well exposed in the old Deamude quarry, located near the middle of section 13, Des Moines township. At the northeast end of the quarry opening the following section of the Spergen was measured:

Section of Spergen formation in Deamude quarry.

		FEET	INCHES
4.	Limestone, gray, crinoidal, cross-bedded, overlain disconformably by conglomeratic St. Louis limestone	2	9
3.	Limestone, bluish, massive, arenaceo-magnesian, with occasional highly fossiliferous seams	4	6
2.	Shale, drab, arenaceous	1–2	6
1.	Limestone, bluish, massive, magnesian, very arenaceous. Exposed	4	6

Beds 1, 2 and 4 contain only fragmentary fossils but bed 3 yields molds of numerous species which are listed below:

List of fossils from bed 3 of Spergen formation in Deamude quarry.

BRYOZOA—
- Fenestella serratula Ulrich
- Hemitrypa sp.

BRACHIOPODA—
- Productus altonensis N. and P. ?
- Pustula biseriata (Hall)
- Tetracamera arctirostrata (Swallow)
- Dielasma sp.
- Girtyella indianensis (Girty)
- Spirifer tenuicostatus Hall
- Brachythyris subcardiformis (Hall)
- Spiriferella neglecta (Hall)
- Reticularia setigera (Hall)
- Eumetria verneuiliana (Hall)

GASTROPODA—
- Orthonychia sp.
- Conularia sp.

At the mouth of a ravine forty yards southeast of the preceding section lower layers, which are believed to represent the Upper Warsaw, outcrop below the Spergen.

Section in a ravine at the Deamude quarry.

		Feet	Inches
Spergen			
8.	Limestone, gray, crinoidal, cross-bedded, overlain by conglomeratic St. Louis limestone	2	3
7.	Shale, drab, arenaceous with thin layers of arenaceous magnesian limestone; containing mica flakes	5	9
6.	Limestone, arenaceo-magnesian, weathering yellowish, in layers about 6 inches thick	3	
5.	Shale, bluish, arenaceous; containing mica flakes	2	7
4.	Limestone, bluish, arenaceo-magnesian, in layers 2 to 9 inches thick	3	
Upper Warsaw			
3.	Concealed, probably shale in large part. *Archimedes wortheni* found on weathered slope	6	3
2.	Limestone, bluish, lenticular, arenaceo-magnesian, weathering to thin layers, thickening and thinning abruptly on lower surface. Bearing a few fossils. Passing into shales at one point	0 to 4	6
1.	Shale, bluish, argillaceous, bearing a few calcareous nodules. Exposed	4	

A comparison of this section with the preceding one will illustrate the range in character of the Spergen in this region. Bed 8 of the last section corresponds to number 4 of the former. The lower beds of the Spergen in the two sections possess little in common.

Other excellent sections of the Spergen appear in the Des Moines river bluff along the Chicago, Rock Island & Pacific railway a short distance below Belfast. The most satisfactory exposures are in the old Fox quarry openings, and in the ravines which cut through the bluff at intervals between these, in the western part of section 12, Des Moines township. A detailed study of these sections brings to light some very puzzling features in the way of lithologic differences of the formation.

The first quarry opening, three-fourths of a mile below Belfast, presents the following section:

Section of Spergen formation in upper Fox quarry.

		Feet
Drift.		
Spergen		
4.	Limestone, brownish, magnesian, with molds of bryozoans	2
3.	Shale, bluish, arenaceous	1 to 2
2.	Limestone, dolomitic, bluish to brownish, arenaceous	5 to 7
1.	Limestone, gray, fossiliferous, cross-bedded in upper part. Exposed	6

An irregular lens of unaltered gray fossiliferous cross-bedded limestone four inches to one foot thick and about ten feet long occurs at one point in bed 2.

A few yards south of the above exposure the following succession appears at the mouth of a ravine:

Section at mouth of ravine below Belfast.

	FEET
ST. LOUIS	
4. Limestone, conglomeratic	8 to 10
SPERGEN	
3. Limestone, brownish, dolomitic, somewhat arenaceous, bearing small angular whitish chert fragments	2
2. Shale, bluish, argillaceous	3½ to 4
1. Limestone, heavy bedded, consisting of bluish dolomitic limestone, locally arenaceous, with interbedded seams and layers of grayish nondolomitic, fossiliferous limestone. Exposed	11½

Twenty-five yards up the same ravine at a small waterfall the following section was measured:

Section of Spergen formation in ravine below Belfast.

	FEET	INCHES
4. Drift.		
SPERGEN		
3. Limestone, brownish, dolomitic, massive; with molds of fenestelloid bryozoans; thickening abruptly locally at the expense of the thin-bedded limestone beneath owing to uneven dolomitization	1 to 4	4
2. Limestone, gray, in the form of thin cross-bedded highly fossiliferous layers. The slope of the cross-bedding ranges from about 9 degrees to 20 degrees. Direction of slope, west, southwest, and southeast. At one point the lower one and one-half feet of this limestone bed passes abruptly into a massive dolomitic layer, which continues ten to fifteen feet, and thence grades gradually back into thin-bedded unaltered limestone	2 to 6	6
1. Limestone, bluish, arenaceo-magnesian, in heavy layers when fresh but weathering into thinner layers	5	6

The species listed below were collected from bed 2 of this section:

ANTHOZOA—
- Monilopora beecheri Grabau
- Zaphrentis sp.

BLASTOIDEA—
- Pentremites sp.
- Metablastus sp.

BRYOZOA—
- Fistulipora sp.
- Stenopora sp.
- Leioclema gracillimum Ulrich
- Fenestella serratula Ulrich
- Fenestella multispinosa Ulrich
- Hemitrypa sp.
- Polypora biseriata Ulrich
- Rhombopora bedfordensis Cumings
- Rhombopora varians Ulrich
- Rhombopora attenuata Ulrich
- Bactropora simplex Ulrich
- Cystodictya lineata Ulrich
- Glyptopora sagenella (Prout)
- Glyptopora sp.
- Worthenopora spinosa Ulrich

BRACHIOPODA—
- Productus indianensis Hall
- Productus altonensis N. and P.
- Pustula biseriata (Hall)
- Rhipidomella dubia (Hall)
- Tetracamera subcuneata (Hall)
- Tetracamera arctirostrata (Swallow)
- Girtyella turgida (Hall)
- Girtyella indianensis (Girty)
- Spirifer tenuicostatus Hall
- Spirifer bifurcatus Hall
- Brachythyris subcardiformis (Hall)
- Reticularia setigera (Hall)
- Eumetria verneuiliana Hall
- Cliothyridina parvirostris (M. and W.)
- Composita trinuclea (Hall)

GASTROPODA—
- Orthonychia acutirostre (Hall)

TRILOBITA—
- Griffithides ? sp.

Some interesting relationships of limestone and dolomite are shown in a quarry face in the bluff just south of the ravine mentioned above. In addition to layers of dolomite, which grade laterally into limestone, there occurs a lens of dolomite in a limestone bed. Two bowlder-like masses of dolomite appear in the same limestone nearby. The lens of dolomite has a rounded surface in the outcrop. It is seven and one-half feet long and has a maximum thickness of ten inches. It is of about the same texture as the limestone, and bears the same types of fossils, but it is bluish to brownish in color while the limestone is gray.

The contact of the upper cross-bedded limestone member (bed 2 of preceding section) with the dolomitic beds above and below is irregular owing to uneven dolomitization. It appears that the dolomitization of the Spergen must have taken place after all of the beds were deposited. The arenaceous limestones of the Spergen are believed to have been more susceptible to alteration than the purer limestones for they are dolomitic in nearly every exposure in which they appear.

The following succession is shown in a quarry opening about ninety yards below the last section:

Section in a quarry below Belfast.

	FEET
ST. LOUIS	
4. Limestone, conglomeratic, in the form of a mound with less disturbed layers of brownish dolomitic limestone lapping up on its flanks	12 to 15
SPERGEN	
3. Limestone, brownish, dolomitic with small scattered subangular quartz grains and occasional small angular fragments of whitish chert	1
2. Limestone, gray, crinoidal, filled with bryozoans; massive when fresh but weathered surfaces show thin cross-bedded layers. The lower part passes locally into dolomite indistinguishable from the dolomite below. At the north end of the opening the lower 3 feet of this bed is represented entirely by dolomite. This is very massive where it is dolomitic, although it was thin-bedded originally. At the south end of this opening there is a large lenticular layer of bluish dolomitic limestone near the middle of this member. It attains a maximum thickness of about 2 feet and is 25 to 30 feet long. Large irregular bowlders of dolomite and a smaller lens of dolomite also were noted in the upper part of this member	14½
1. Limestone, arenaceo-magnesian, bluish when fresh but weathering brownish, bearing thin discontinuous seams of compact bluish dolomitic limestone. The arenaceous material is very fine-grained. Exposed	11

About ninety yards farther down stream there is another good exposure in a quarry opening.

Section in a quarry near the preceding one.

	Feet	Inches
St. Louis		
3. Limestone, conglomeratic, marly in lower part	15	
Spergen		
2. Limestone, bluish, arenaceo-magnesian, massive when fresh but weathering to thin layers and scaling off obliquely. Locally with shaly streaks	9	10
1. Limestone, massive, bluish when fresh but weathering brownish; bearing molds of bryozoans. Exposed	8	6

Bed 2 is correlated with bed 2 of the preceding section, in part at least. The upper parts of the beds were traced into each other but the transition of the lower beds is concealed by talus. The transition observed was abrupt. The limestone first graded into arenaceous material and thence became dolomitic. Fossils are scarce and poorly preserved in the dolomitic facies but are abundant in the cross-bedded limestone facies.

Two hundred and sixty yards farther down the following beds appear in the bluff:

Section in the Des Moines river bluff below Belfast.

	Feet
St. Louis	
4. Limestone, much disturbed, some blocks dolomitic	15
Spergen	
3. Limestone, brownish, arenaceous, with chert fragments	1
2. Limestone, gray, thin-bedded, crinoidal, shaly in lower part; resting on the irregular surface of bed beneath	0 to 5
1. Limestone, dolomitic, slightly arenaceous; bluish when fresh but weathering brownish; in heavy layers which in lower part are separated by layers of bluish arenaceous shale. Exposed	18½

At one point in this exposure bed 2 is cut out completely by the local thickening of bed 1. This relationship is believed to be due to uneven dolomitization.

A few yards farther downstream the following section appears in a quarry:

Section near the preceding.

	Feet
St. Louis	
7. Limestone, conglomeratic, dolomitic and nondolomitic blocks indiscriminately mixed, marly toward the base	11
Spergen	
6. Limestone, gray, crinoidal, thin-bedded, slightly cross-bedded	4
5. Limestone, brownish, dolomitic, slightly arenaceous	4 1/3
4. Shale, calcareous and arenaceous	2
3. Limestone, bluish, dolomitic, arenaceous	1 to 2
2. Limestone, gray, crinoidal	4
1. Limestone, brownish, arenaceo-magnesian, in one massive ledge. Exposed	10

Bed 3 differs greatly in thickness and lies upon the irregular surface of bed 2. Bed 2 passes laterally into dolomite at one point in the quarry face.

The quarries end at a ravine one mile below the station at Belfast. Beyond this point a few good natural exposures may be seen in the bluff. One such exposure occurs sixty rods below this ravine.

Section in bluff of Des Moines river one mile below Belfast.

		FEET	INCHES
ST. LOUIS			
10.	Limestone, conglomeratic, poorly exposed.		
SPERGEN			
9.	Limestone, bluish to brownish, with large rounded quartz grains and occasional angular chert fragments	2	4
8.	Sandstone, fine-grained, bluish, shaly	2	3
7.	Limestone, bluish, arenaceo-magnesian	5	9
6.	Shale, bluish, arenaceous, bearing small mica flakes	1	4
5.	Limestone, arenaceo-magnesian, shaly in upper part	3	1
4.	Limestone, arenaceo-magnesian, shaly in upper part	3	8
3.	Shale, bluish, arenaceous, with mica flakes	6	6
2.	Limestone, bluish, arenaceous	6	10
1.	Shale, bluish, argillaceous. Exposed at foot of bluff		6

Some very interesting sections occur on Mumm creek two and one-half miles west of Belfast. A short distance above the mouth of the creek, the following succession is shown in an east branch (SE.¼ sec. 33, T. 67 N., R. 7 W.).

Section in the east branch of Mumm creek.

	FEET
SPERGEN	
Limestone, arenaceo-magnesian, bluish weathering yellowish to brownish; with thin discontinuous seams of bluish magnesian limestone which weather in relief. Massive when fresh, but weathering to thin layers. Weathered surface of a massive ledge in lower part shows indications of cross-bedding. Bearing molds of fenestelloid bryozoans	19
WARSAW	
Shale, bluish to black, argillaceous, more calcareous in upper part and grading into the beds above. No fossils found, but occasional bands of small imperfect siliceous geodes were noted. Exposed	14½

About two hundred and thirty-five yards up the creek the section given below was measured in a small ravine in the east bank.

Section in small branch of Mumm creek near preceding section.

		FEET	INCHES
LOWER ST. LOUIS			
5.	Limestone, compact, buff, magnesian	1	
4.	Limestone, buff, magnesian in the nodular layers	1	6
3.	Limestone, yellowish, conglomeratic, magnesian; the structure partly obliterated by dolomitization; resting on the irregular surface of the bed beneath	2	6
SPERGEN			
2.	Shale, drab, arenaceous, bearing small mica flakes	6	
1.	Limestone, arenaceous and magnesian, massive; a small amount of buff cherty magnesian limestone in upper part. Exposed	17	6

In a small branch about eighty yards north of the above described section, the conglomeratic and dolomitic basal limestone layer of the St. Louis succeeds twenty and one-half feet of arenaceo-magnesian Spergen limestone. About one foot of shale is exposed at the mouth of the branch beneath the Spergen. The weathering out of the shale undermines the massive limestone ledge for many feet, and several huge blocks of the latter have tumbled down into the bed of the creek. Some seams in the Spergen at this place are less arenaceous and are highly fossiliferous. These tend to weather out in relief and in many cases indicate the existence of cross-bedding in the original rock.

Two hundred yards farther upstream a section in the creek bank extends from the top of the Warsaw shale to the Upper St. Louis limestone. The Spergen is very much attenuated here, averaging only about one foot in thickness in the face of the bluff. The abrupt thinning of the Spergen in passing from the previously described Mumm creek sections to this point is undoubtedly due to pre-St. Louis erosion.

The Spergen limestone has a thickness of thirteen to fourteen feet in the east bank of Monk creek just northwest of Belfast. It is underlain by shales provisionally referred to the Warsaw and is overlain by the Lower St. Louis limestone. There is a possibility that the shales belong, in part at least, to the Spergen. In the absence of well preserved fossils their age cannot be determined definitely.

Section in the east bank of Monk creek northwest of Belfast

	Feet	Inches
LOWER ST. LOUIS		
4. Limestone, conglomeratic, matrix calcareous above but shaly below	13	
SPERGEN		
3. Limestone, brownish, magnesian, soft, thin-bedded, bearing molds of fenestelloid bryozoans	2	6
2. Limestone, brownish, arenaceo-magnesian, in one massive ledge which shows faint indications of cross-bedding at one point, but composed of thin rotten layers a few yards downstream, where it is much weathered	11	3
WARSAW		
1. Shale, argillaceous, dark blue to black where fresh but weathering drab; bearing effloresence of a mineral which appears to be gypsum; containing a few small crushed imperfect siliceous geodes; somewhat calcareous in upper part and grading into the bed above. A few poorly preserved fossils in the upper part. Exposed	24	5

At and in the vicinity of the city of Keokuk the Spergen ranges from practically nothing to a little more than eight feet in thickness. The St. Louis limestone lies directly upon the Upper Warsaw shale at an exposure in B street near its intersection with Reid street, but in the Mississippi river bluff back of the Taber lumber mill, two miles below the Union Station, the Spergen is represented by a layer of bluish gray sandy limestone which weathers brownish and is two and one-half to six feet thick. Upper Warsaw shales underlie the limestone while conglomeratic St. Louis limestone outcrops above it.

Good exposures of the Spergen and associated beds may be seen along a small creek in the northeast quarter of section 24 of Jackson township, about three-fourths of a mile northwest of Rand Park at Keokuk. The following section was measured at this locality.

Section near Rand Park, Keokuk.

	FEET
LOWER ST. LOUIS	
3. Limestone, for the most part conglomeratic; consisting chiefly of irregularly disposed blocks and subangular bowlders of compact gray limestone; matrix shaly below but more calcareous above; bearing silicified corolla of *Lithostrotion canadensis*. Upper two to three feet more evenly-bedded. A more regular layer of compact gray limestone ranging in thickness from a few inches up to 2 feet or more appears at the base. It rests upon an irregular and eroded surface of the Spergen	16
SPERGEN	
2. Sandstone, grayish blue, fine-grained, with scattered subangular quartz grains ranging up to 1 mm. or more in diameter. This bed becomes somewhat yellowish on weathered surfaces. The upper half exhibits a tendency towards cross-bedding of the torrential type and the uppermost two feet is weathered into thin layers. Locally some of the arenaceous layers pass into a bluish compact magnesian limestone. The fronds of fenestelloid bryozoans so commonly observed in the Spergen are seldom seen here. The lower two feet of the formation is somewhat shaly and appears to pass gradually downward into the Warsaw shales below	8¼
WARSAW	
1. Shale, bluish, argillaceous	12

Several outcrops of Spergen limestone appear along the north and south forks of a small creek near the center of section 25, Montrose township, five miles north of Keokuk. The greatest exposed thickness of the formation is ten feet. In some of the exposures the limestone is brownish, arenaceous and dolomitic. In others it consists chiefly of gray subcrystalline slightly altered limestone. The formation is shown at several points in contact with the disturbed facies of the St. Louis limestone. At a small fall in the creek a short distance below the confluence of the two branches the Spergen is nine and one-half feet in thickness. The upper half consists of shale and the lower half of bluish to brownish arenaceo-magnesian limestone with abundant molds of fenestelloid bryozoans. The formation is here overlain by the basal disturbed layer of the St. Louis limestone one and one-half feet in thickness, and is underlain by the Lower Warsaw shale with an exposed thickness of four feet. Farther down the creek lower beds of the Lower Warsaw appear.

The Spergen limestone outcrops again just south of the town of Montrose along a small tributary of the Mississippi. It is ash-colored to brownish in color and arenaceous and dolomitic in character. Poorly preserved molds of fenestelloid bryozoans are the only important fossils. The formation here has a thickness of twenty-one feet. Thirty feet of geodiferous Lower Warsaw shales is exposed below it along the banks of the creek while conglomeratic St. Louis limestone of variable thickness appears above.

The Spergen appears in the following bluff section in the northern part of section 13 of Pleasant Ridge township:

Section in Pleasant Ridge township.

	Feet
SPERGEN	
6. Limestone, magnesian, brownish; cross-bedded and laminated; impure and arenaceous toward the base. Impressions of fenestelloid bryozoans abundant	8
5. Shale, argillaceous, with intercalated layers of sandstone and magnesian limestone near the top	7 1/6
4. Limestone, magnesian, in a massive ledge	3
WARSAW	
3. Shale, bluish, argillaceous	2
2. Concealed	10
1. Shale, calcareous, in bed of creek.	

Hancock County, Illinois.—The Spergen formation outcrops at a number of localities in this county. In the vicinity of Warsaw it is very thin, owing no doubt to the erosion interval which followed its deposition and preceded the incursion of the St. Louis sea (fig. 7).

In a small ravine tributary to the large creek a short distance east of the High School, the following section was measured:

Section near the High School at Warsaw.

	Feet	Inches
ST. LOUIS		
Limestone, gray, compact; the disturbed basal layer of the St. Louis	2	

	FEET	INCHES
SPERGEN		
Limestone, yellowish, magnesian, with occasional rounded sand grains	1	8
Limestone, gray, fossiliferous, thin-bedded	1	7
WARSAW		
Limestone, magnesian; upper one foot brownish and massive; lower five feet bluish and shaly	6	

The following succession may be seen in an old quarry face in the south bank of the creek, about thirty yards northeast of the ravine section:

Section in quarry near the preceding section.

	FEET	INCHES
SPERGEN		
Limestone, brownish, magnesian, with scattered rounded quartz grains about 1 mm. in diameter		6
Limestone, grayish, fossiliferous, in the form of thin cross-bedded layers; resting on the wavy surface of the bed beneath	1	6
WARSAW		
Limestone, brownish, in two massive ledges. Exposed	5	

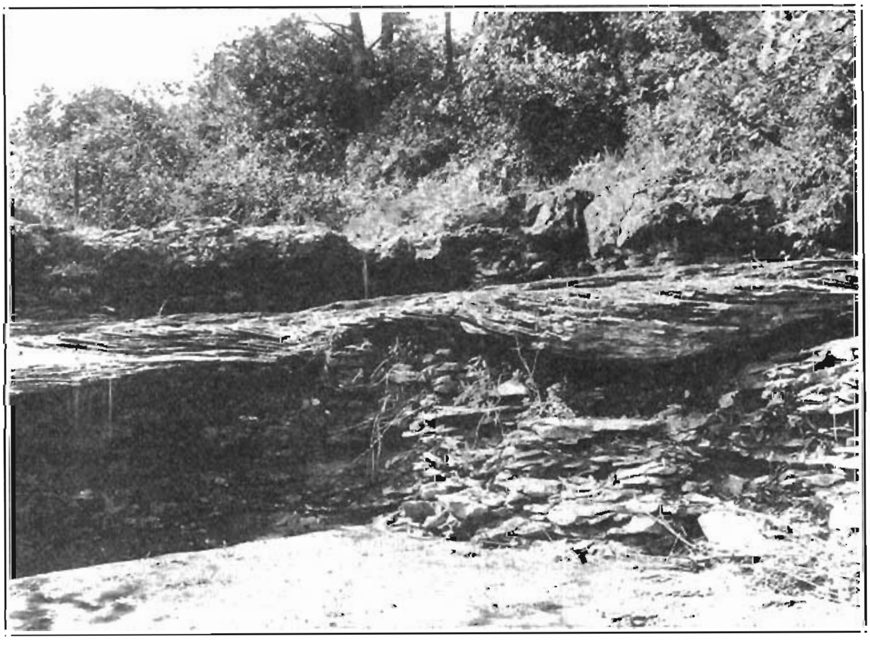

FIG. 7.—View of the Spergen and associated formations near Warsaw, Illinois.. The cross-bedded member is the Spergen, the underlying shale is Warsaw and the overlying limestone ledge is St. Louis. Notice the disconformab'e relations of the Spergen and Warsaw.

The following section is exposed at the bend of the creek a short distance above the Main Street bridge:

Section above Main Street bridge.

	FEET
ST. LOUIS	
Limestone, gray, compact, brecciated	2½
SPERGEN	
Limestone, gray, fossiliferous, cross-bedded	1
WARSAW	
Limestone, bluish, arenaceo-magnesian, weathers brownish	7½

The Spergen was formerly quarried extensively in the Mississippi river bluff one mile south of Sonora, Illinois. The formation consists of arenaceo-magnesian limestone and is twenty feet thick in the southernmost of the quarry openings, where it overlies bluish argillaceous shale presumably of Lower Warsaw age. It is succeeded above by six to twelve feet of conglomeratic St. Louis limestone. The latter pinches out a few rods north of this exposure and the Spergen is succeeded directly by sandstones and shales of Pennsylvanian age, which contain characteristic plant remains. The Sonora sandstone of Keyes[9] represents the Spergen of the above described section.

The following section appears in the Fort Madison-Appanoose Stone Company quarry about two miles northeast of Niota, Illinois.

Section in Fort Madison-Appanoose Stone Company quarry.

	FEET
ST. LOUIS	
3. Limestone, gray, compact, fine-grained, brecciated and disturbed	25
SPERGEN	
2. Shale, bluish, argillaceous	3 to 6
1. Limestone, massive, dolomitic, vesicular, bearing many impressions of fenestelloid bryozoans; brownish and buff above but drab below and containing disseminated pyrite	22½

The contact of bed 1 with the Lower Warsaw may be studied in a ravine near by.

The Spergen attains a thickness of not less than twenty-five feet along a creek skirting the Pontusac road, about two miles east of Niota. All but the upper three feet of the formation at this place is a massive magnesian limestone. The upper three feet is made up of thinly laminated and cross-bedded gray limestone which bears brachiopods and numerous bryozoans. The contact with the Lower Warsaw is shown here also.

The Spergen outcrops in a somewhat different facies about one-half mile east of Niota on the west bank of a creek.

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9 Iowa Geol. Survey, vol. III, p. 348; 1893.

Section one-half mile northeast of Niota.

		Feet	Inches
10.	Drift, yellowish, with blocks of limestone.		
St. Louis			
9.	Limestone, gray, dense, fine-grained, brecciated	4	
Spergen			
8.	Limestone, bluish, arenaceo-magnesian, lower half bearing angular fragments of white chert	1	1
7.	Sandstone, fine-grained, bluish, incoherent		2
6.	Limestone, impure, buff, magnesian, passing downward into sandstone	1	3
5.	Sandstone, fine-grained, bluish, calcareous, grading downward into bed below	3	
4.	Limestone, arenaceo-magnesian, weathering yellowish brown	2	2
3.	Shale, bluish, arenaceous, locally more calcareous and massive. Bearing impressions of fenestelloid bryozoans	14	
2.	Limestone, brownish on weathered surface, magnesian	1–2	
1.	Shale, blue, argillaceous, weathering to a grayish blue plastic clay. Upper part grading laterally into a fossiliferous magnesian limestone	3	

Des Moines County, Iowa.—The only exposures of the Spergen which are known to occur in Des Moines county appear on Long creek in section 12 of Augusta township. In an abandoned quarry on the property of Wm. Madlener, in the north bluff of the creek (SW.¼ of SE.¼ sec. 12), it has an exposed thickness of thirty-four and one-half feet. The beds are described in the accompanying section:

Section of Madlener quarry

		Feet
5.	Drift	1
Spergen		
4.	Limestone, buff, dolomitic	1
3.	Shale, bluish, argillaceous	3
2.	Limestone, buff, dolomitic, massive, filled with the molds of fenestelloid bryozoans and other fossils; with occasional streaks and patches of denser bluish dolomitic limestone	30½
Lower Warsaw		
1.	Shale, bluish, argillaceous, with occasional siliceous segregations. Exposed	12

The fossils identified from bed 2 of this section are as follows:

List of fossils from Spergen formation in Madlener quarry.

Fenestelloid bryozoa (impressions)
Productus altonensis N. and P.
Pustula biseriata (Hall)
Dielasma sp.
Spiriferina salemensis Weller
Spirifer bifurcatus Hall
Spirifer tenuicostatus Hall
Reticularia setigera (Hall)
Brachythyris subcardiformis (Hall)
Orthonychia acutirostre (Hall)

A bluff on the same bank of the creek three hundred yards farther down stream shows the following succession.

Section in bluff below preceding exposure.

	Feet
5. Drift.	
SPERGEN	
4. Limestone, soft, buff, dolomitic, filled with the molds of fenestelloid bryozoans and other fossils	6
LOWER WARSAW	
3. Concealed	7½
2. Shale, bluish, argillaceous, more calcareous in lower part; a few small imperfect siliceous geodes on slope	18
KEOKUK	
1. Limestone, bluish, medium to coarse-grained, *Orthotetes keokuk* abundant. Exposed above level of water in creek	11

Van Buren County.—The Spergen is exposed at several localities along Des Moines river and its tributaries in Van Buren county. In the northeast quarter of section 3 of Farmington township it outcrops in the banks of Indian creek. An exposure of limestone five and one-half feet high which yields many characteristic Spergen fossils appears one hundred yards below the railroad bridge across the stream. The limestone is gray in color, slightly crinoidal and thinly bedded. Locally, parts of the bed grade laterally into heavier bedded bluish dolomitic limestone. Three feet of dolomitized conglomeratic St. Louis limestone overlies the Spergen.

The following beds of the Spergen are shown in the creek bank one-fourth mile below this exposure. St. Louis limestone appears above.

Section on Indian creek.

	Feet
SPERGEN	
5. Limestone, bluish gray when fresh, weathering brownish; a few small angular chert fragments present at one point; filled with molds of bryozoans and other fossils. This bed is overlain disconformably by the St. Louis limestone except at the west end of the section where the Pennsylvanian sandstone rests upon the Spergen	0 to 1½
4. Limestone, arenaceo-magnesian, bluish; with molds of fenestelloid bryozoans and other fossils. Consists typically of a bluish dolomitic sandstone with irregular, discontinuous seams of fine-grained bluish dolomitic limestone. Locally this member passes completely into a fine-grained bluish sandstone, nearly barren of fossils. One large fish tooth was found in the sandstone. This facies tends to flake off obliquely to the weathered surface. The shaly portion at the top bears mica flakes	4 to 5¼
3. Shale, bluish, argillaceous, slightly arenaceous in the basal part, and grading down into the bed below. Thin seams of bluish fine-grained sandstone in lower part	3½
2. Shale, calcareous, arenaceous in upper part; approaching an impure limestone below; ash-colored, grading into the bed above, bearing *Spirifer* sp., *Conularia* sp. and bryozoans	1 to 2
LOWER WARSAW	
1. Shale, bluish, argillaceous. No fossils noted. Contact with the bed above mostly concealed. Exposed	7

Other important exposures of the Spergen are shown along Reed creek in the northeast quarter of section 15, Bonaparte township. The following section is exposed in an abandoned quarry about half a mile above the mouth of the stream:

Section in abandoned quarry on Reed creek.

	FEET
ST. LOUIS	
5. Limestone, brownish, dolomitic, mashed and broken in lower part	15
SPERGEN	
4. Limestone, brownish, arenaceo-magnesian	5 to 8
3. Sandstone, fine-grained, soft, bluish	1
2. Concealed	6
WARSAW	
1. Shale, bluish, argillaceous. Exposed to bed of creek	22½

Another outcrop of the Spergen, twelve feet high, appears about two hundred yards farther upstream and is capped by drift. The formation as here exposed consists of fine-grained bluish sandstone the upper two-thirds of which is massive when fresh but weathers into thin layers. The lower third is thinly and irregularly bedded and locally is shaly.

The same beds appear again in the banks of the creek one hundred and twenty-five yards east of the above section. At this point the Spergen is represented dominantly by shale. Sixteen feet of bluish argillaceous shale with thin layers and discontinuous seams of bluish sandstone is overlain by drift.

A small exposure on Potters branch in the southeast quarter of section 9, Bonaparte township, shows the Spergen in contact with the Warsaw shales.

Section on Potters branch.

	FEET
SPERGEN	
Shale, argillaceous, bearing a few imperfect siliceous geodes	12
Limestone, brownish, dolomitic	16
Shale, arenaceous and calcareous, with a band of siliceous nodules near the middle; bearing fenestelloid bryozoans. Resting unevenly on the bed beneath	5¼
WARSAW	
Shales	11

The following section of the Spergen is exposed in the south bank of Bear creek, in the northeast quarter of section 10, Henry township.

Section of Spergen formation on Bear creek.

	FEET	INCHES
7. Sandstone, bluish, fine-grained; blocks of St. Louis limestone on slope above		3
6. Shale, bluish, argillaceous	4	

5.	Sandstone, fine-grained, yellowish; resting unevenly on the bed beneath; with angular white chert fragments in basal part	1 to 2	
4.	Limestone, cream-colored, with irregular seams and nodules of whitish chert; weathering to polyhedral blocks	2	6
3.	Shale, bluish, argillaceous	2	
2.	Sandstone, fine-grained, bluish, calcareous, massive when fresh but weathering to shaly layers	2	3
1.	Shale, bluish, argillaceous. To bed of creek	6	6

A second exposure in the creek bank a little more than one-fourth mile east of the above section shows a considerable difference in the character of the above beds.

Section of Spergen formation east of preceding section.

		FEET	INCHES
6.	Sandstone, fine-grained	1	
5.	Limestone, cream-colored, bed 4 of preceding section	2	6
4.	Shale, bluish, argillaceous	6	6
3.	Limestone, brownish, dolomitic	1	2
2.	Shale, bluish, argillaceous	10	10
1.	Limestone, bluish when fresh but weathering yellowish; dolomitic; bearing fenestelloid bryozoans. Exposed above bed of creek	4	

Considerable arenaceous limestone has been removed from the Spergen in the old Bear creek quarries which were located in the northwest quarter of section 11, Henry township. At present about three feet of arenaceous dolomite with impressions of fenestelloid bryozoans is exposed in the floor of the quarry. This is overlain by five feet of arenaceous shale which in turn is capped by drift. The limestone ledge which appears in the quarry has an exposed thickness of eight feet in the bank of the creek near by.

Henry County.—The only exposure of the Spergen formation observed by the writer in Henry county appears in the bed of a small branch of Mud creek about one and one-half miles northeast of the town of Lowell in Baltimore township. At this locality it is represented by a wedge-shaped bed of brownish to buff massive dolomitic limestone between the St. Louis limestone and the Warsaw shale. It is filled with molds of *Productus altonensis* and impressions of fenestelloid bryozoans. The maximum exposed thickness of the limestone is about four feet. It thins abruptly from this point downstream and within a few yards disappears completely, thus permitting the basal bed of the St. Louis limestone to succeed the Lower Warsaw shale directly.

Jefferson County.—The northernmost exposures of the Spergen formation observed by the writer in Iowa occur in Lockridge township of Jefferson county. Twenty-one feet of Spergen sandstone underlies an unusually complete exposure of the St. Louis limestone in the Cedar Bluff section on Skunk river, one-fourth mile east of the southwest corner of section 12. The base of the Spergen is not exposed. The section is as follows:

Section of Spergen formation in Cedar Bluff.

		FEET	INCHES
4.	Sandstone, gray with slight greenish tint, fine-grained, weathering yellowish, soft, incoherent	7	8
3.	Sandstone, as above, thin-bedded, weathering yellowish	2	
2.	Sandstone, as above, with greenish tint, massive, soft	8	4
1.	Sandstone, fine-grained, gray with greenish tint, with numerous small greenish patches and occasional thin buff dolomitic seams. *Worthenopora spinosa, Stenopora* sp., *Polypora* sp.	3	

Fifteen and one-half feet of Spergen sandstone is exposed below the St. Louis limestone in an abandoned quarry in the north bank of Turkey creek, near the center of the northeast quarter of section 11, Lockridge township.

Section of Spergen formation on Turkey creek.

		FEET
2.	Sandstone, soft, weathering brownish, probably gray when fresh; less massive than bed below; bearing minute mica flakes; dolomitic below	4½
1.	Sandstone, gray with bluish tint when fresh, micaceous; in one great massive ledge; lower half dolomitic and showing oblique stratification lines on weathered surface. This also has small lenses and streaks of bluish dolomitic limestone free from sandstone; sand grains coarser in lower half. Bearing *Worthenopora spinosa* and other bryozoans. Exposed	11

The St. Louis Limestone

CHARACTER AND GENERAL RELATIONS

The St. Louis limestone is named from the city of St. Louis. This formation, like the Spergen, has been poorly understood in Iowa, owing to the great lateral range in its character, a range which is due to original differences in sedimentation, to differences in the degree of dolomitization, to the presence of a disconformity at the base and to extensive brecciation at some localitites. According to the old definition the St. Louis in Iowa includes three distinct subdivisions, designated by Bain[10] the Springvale, or basal member, the Verdi, and

[10] Geol. of Keokuk County, Iowa Geol. Survey, vol. IV, pp 277-282; 1895.

the Pella. It is now known that the Pella member is formationally distinct. This bears a Ste. Genevieve fauna, and is separated from the true St. Louis beneath by a disconformity. Again it is now recognized that the arenaceo-magnesian limestone locally exposed above the Warsaw, and formerly included with the St. Louis, is a distinct formation and belongs to the Spergen limestone. Furthermore the type section of the Springvale as defined by Bain is believed to be of Keokuk age (see page 181) rather than St. Louis. Consequently this term should be abandoned. In its place the name Croton is substituted, since the lower division of the St. Louis is typically developed in the vicinity of that town in Lee county. The terms Croton and Lower St. Louis are used synonymously in this report. The Croton limestone is by far the more extensive of the two divisions of the St. Louis, for it extends far to the north, overlapping all the earlier divisions of the Mississippian except the Kinderhook, upon which it rests in Humboldt county (fig. 2, page 44). This relationship is believed to be due in part to greater uplift and erosion in the northern region prior to the Croton submergence and to nondeposition of the Warsaw and Spergen formations in the northern area. This division consists for the most part of massive, compact buff to brownish dolomitic limestone, but frequently these beds are found to grade laterally in short distances into dense, fine-grained gray nondolomitic limestone. Again, the two phases may have an interbedded relationship. Furthermore the Croton limestone is brecciated at many localities. At the close of Croton time, the sea retreated to the southward as a result of an elevation of the northern area. An intraformational disconformity between this division and the Verdi has been traced as far south as Alton, Illinois, but there is no evidence of it in the St. Louis section in Ste. Genevieve county, Missouri, where the formation has a greater thickness than in Iowa. The Croton limestone is about thirty feet in thickness.

Following a short interval of erosion at the close of Croton time the sea returned and deposition of limestone in the region began again. The returning seas, however, probably did not extend so far north at this time as during the Croton. The Verdi or Upper St. Louis limestones, which were formed at this time, are, for the most part, light gray in color and fine-grained and compact in texture. But interbedded layers of granular to oölitic limestone occur at a few localities. This member is dolomitic at only a few places but locally the beds pass laterally in whole or in part into sandstone. Its thickness is nowhere more than thirty-five feet. The type section is in the old railroad quarries near Verdi in Washington county.

The fauna of both divisions of the St. Louis is meagre. The coral, *Lithostrotion canadensis,* which normally occurs in a zone at the very top of the Croton, is the most important horizon marker of that member. The fauna of the Verdi is more varied, consisting of several species of *Productus,* a few other brachiopods and occasional gastropods and pelecypods.

The unstable conditions of the St. Louis were terminated by a greater and more widespread uplift than that which occurred in this region during preceding Mississippian time. However, the duration of the erosion interval which followed the uplift could not have been great, for the deposits of the returning Ste. Genevieve sea, which must have rivalled that of the early St. Louis in size, have not been found in Iowa to rest upon formations older than the Croton.

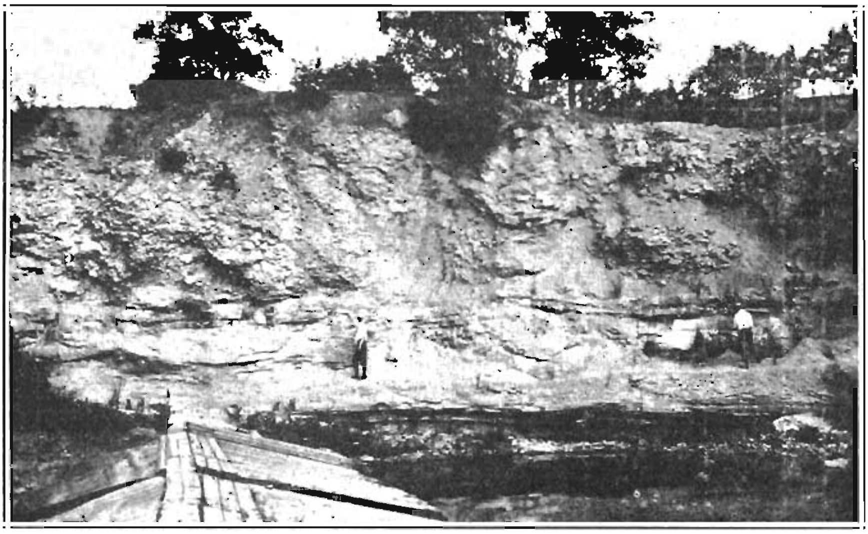

FIG. 8.—Brecciated Lower St. Louis limestone overlying regularly bedded Spergen limestone. Near Colchester, Illinois.

BRECCIATION EFFECTS

The brecciated and disturbed facies of the St. Louis limestone received considerable attention from the writer in the course of field work in southeastern Iowa. The brecciation is confined almost entirely to the St. Louis limestone as revised, although locally the succeeding Pella beds are slightly affected. The underlying Spergen beds nowhere share in the fracturing. The disturbance may involve beds only a few feet in thickness at any horizon, or it may affect the whole formation from top to bottom. Where it is confined to beds only a few feet in thickness it is usually very local and the disturbed facies passes laterally into undisturbed layers within short distances. Where it is more general, however, the beds are affected over a much larger area, but even there the signs of disturbance eventually die out and give place to evenly lying beds showing no signs whatever of brecciation. The tendency of the beds to grade laterally into material of an entirely different character within short distances is very confusing and this coupled with the puzzling features produced by variations in the intensity of dolomitization at different localities complicates the situation considerably.

By previous workers it has usually been assumed that the brecciated character of the St. Louis limestone is an original feature which was produced by disturbed conditions during deposition. Thus, C. H. Gordon[11] offers the following possible explanations:

(1) Wave action upon a rock-bound coast.

(2) Sytematic alternation of vigorous and quiet action of wind waves in connection with tidal oscillation in regions where the sea bottom is subjected to wave action at low tide.

(3) Wave action especially facilitated by the development of coral reefs.

The second of these, according to Gordon, best suits the facts.

Again, Bain[12] in his discussion of the Verdi limestone of Washington county expresses himself as follows:

"The Verdi contains the record of a time of considerable disturbance. Shore formations and open sea deposits succeed each

11 Jour. Geology, vol. III, pp. 307, 308; 1895.

12 Iowa Geol. Survey, vol. V, p. 150; 1896.

other in rapid alternation. Huge blocks of the previously formed limestone were torn from their beds and buried in the sands, apparently at the foot of a series of cliffs; or they were beaten upon each other and reduced, in part, to fragments of varying degrees of coarseness, and in part to finest powder that eventually cemented the fragments together. Considering the turbulent conditions under which the beds were formed, it is not strange that fossils are rare."

In his report on the geology of Henry county, Savage interprets the disturbed St. Louis in much the same way. Quoting from him:[13]

"The second or middle division is recognized by the extreme variableness of its beds and its generally disturbed condition. It consists of irregular layers of sandstones and shales with an occasional bed of brecciated limestone near the upper portion. It is a record of a time of great disturbance and of rapidly changing conditions. It is for the most part a deposit near the margin of some troubled sea. The presence of local layers which thin out rapidly in a short distance, the pockets of sand and shale, the numerous lenticular beds, and the general irregular appearance of the strata indicate a vigorous wave action. The ripple marks which are beautifully preserved in the sandstone at numerous points, and the local development of oölitic limestone testify to the close proximity of an old shore line."

The most important outcrops of the St. Louis from the standpoint of brecciation are located at Montrose in Lee county and along the creeks tributary to Des Moines river in Van Buren county.

The brecciation effects in the formation may be grouped into three main types. In the first the disturbed portions assume the form of small mounds or reefs of limestone blocks, usually in a calcareous or sandy matrix, with undisturbed layers lapping up on the flanks and filling in the depressions. These appear at all horizons in the formation, but are most characteristic of the basal Croton and basal Verdi. In the second type the brecciation is developed along one bed of the Lower St. Louis owing to differential movements. The latter type is accompanied in a few cases by tongue-like extensions of broken limestones which are forced into the beds below, especially where the underlying layers are soft shales. The third type embraces

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13 Iowa Geol. Survey, vol. XII, p. 263;1902.

the major part if not the entire formation over an area of differing but usually limited extent. In this type the disturbance has been produced by mashing on a large scale and the brecciation is in many places associated with small overthrust faults and folds. The Pella beds also are involved to a slight extent in this disturbance but in no instances have the underlying formations been found to exhibit signs of brecciation.

Regarding the origin of the brecciation, at least three periods of disturbance are believed to have been involved in its production. The mounds or reef-like masses of the first type are believed to have been formed under conditions of violent wave action possibly induced by local shallowing of the sea during deposition. The presence in the formation of local disconformties, of stratified breccia, and of cross-bedded limestone sands supposedly formed by the grinding up of layers already deposited is in favor of this view. Other features which suggest wave action at the time of deposition are contemporaneous erosion phenomena, wave-marks and cross-bedding.

The brecciation of the second type was formed as a result of deformation. The importance of this cannot be definitely evaluated since its effects are in many cases overshadowed by the disturbance of the third type. That this disturbance is distinct from the third is suggested by the fact that there is evidence of dolomitization having intervened between the two. Thus, the reefs produced by the first disturbance and the shattered areas and fracture lines produced by the second are in numerous instances either wholly undolomitized or are very imperfectly altered while the undisturbed limestone about them is uniformly dolomitized. This relationship supports the theory that dolomitization succeeded the first and second periods of disturbance and that the brecciated areas were more resistant to alteration. But a later disturbance involves both the poorly dolomitized areas and the uniformly dolomitized ones and a later series of fractures cuts the earlier ones. The latter relationship is shown by the displacement of calcite veinlets which occupy the older fractures. (See page 257.)

Furthermore, the fact that dolomitization apparently nowhere affects the topmost limestone layers of the St. Louis nor any layers of the Pella indicates that the alteration took place prior to the close of the St. Louis. Now since the brecciation of the second type is known to have taken place still earlier and appears to be confined to the Lower St. Louis it seems probable that this shattering may be related to the uplift which brought this division to a close.

The third period of disturbance was by far the most important. To this is ascribed the extensive mashing and shearing effects and the overthrust faulting and folding on a small scale so common in the formation. These were influenced to a large extent by the effects of the preceding disturbances, and at the same time they obscured to a large degree the evidence of these earlier activities. That the deformation which produced the later disturbances is post-Pella but pre-Pennsylvanian in age is indicated by the fact that blocks of Pella limestone have been found sheared down into basal Pella shales and sandstones and thus preserved at a locality where Pennsylvanian sandstone rests directly upon these basal beds. (See page 292.)

The general parallelism of the strike of the faults and of the tilted layers formed at this time with certain folds in the region, notably the Bentonsport anticline, which trends approximately N. 68°W., suggests a common mode of origin of these two types of deformation.

Moreover, it seems probable that both the last period of brecciation and the folds are closely related to the extensive uplift and tilting to the southwest which affected the region in late Mississippian time. It is well known that the Mississippian formations were profoundly eroded prior to the deposition of the Pennsylvanian beds. The belted arrangement of the Mississippian areas in southeastern Iowa was brought about largely by this period of erosion as is shown by the fact that Pennsylvanian beds are now found resting upon truncated Mississippian formations of all ages. That the present boundaries of the formations do not represent old shore lines seems certain. The strata at many localities consist of limestone up to the very margins and exhibit no shore facies.

AREAL DISTRIBUTION

The areal distribution of the St. Louis limestone is greatest in southeastern Iowa, where it forms a broad belt, with occasional Pennsylvanian outliers, extending from central Lee county northward through Henry county and into northeastern Jefferson and southern Washington counties, thence northwestward through Keokuk county and into southwestern Iowa and southeastern Poweshiek counties. Southwest of this belt there are long, linear southeasterly trending areas of St. Louis limestone along the larger streams, notably Skunk and Des Moines rivers and their larger tributaries, which have cut down through the Coal Measures. The Des Moines river exposures appear in southwestern Lee, Van Buren, Wapello, southwestern Mahaska and eastern Marion counties while those related to the Skunk are chiefly in the northern half of Mahaska county. In southern Lee county there is an imperfect outlier, elliptical in outline, extending from Keokuk northward to Montrose. In west-central Story county there is an irregular inlier of St. Louis limestone surrounded on all sides by Pennsylvanian strata.

The most northerly exposures of the St. Louis in Iowa are in Webster and Humboldt counties where there are several small isolated exposures chiefly along Des Moines river and its tributaries.

The St. Louis limestone has a widespread distribution in southern Iowa beneath the Coal Measures as is indicated by artesian well records.

AREAL DESCRIPTION BY COUNTIES

Lee County.—A section exposed in the Mississippi river bluff two miles below the Keokuk Union Station ranges from Keokuk limestone up to the base of the Des Moines sandstone. The St. Louis limestone is well exposed at several points near the brow of the bluff. One of the most typical sections appears a short distance below the planing mill of the Taber Lumber Company. The formation is about thirty-two feet thick at this point and there is evidence of an intraformational disconformity in the upper part. The lower or Croton division here is eighteen to twenty-three feet thick and consists for the most part of massive disturbed layers of dark gray magnesian limestone which weathers brownish. The lower part is somewhat conglomeratic and some of the limestone pebbles in this part are compact, white and unaltered. The matrix and many of the pebbles, on the other hand, are magnesian and weather brownish. About one foot of drab sandstone of Spergen age is exposed at the base at one point.

The contact of the Verdi member with the Croton is very irregular. The Verdi is greatly disturbed and consists essentially of conglomeratic, compact, dense whitish limestone with a calcareous matrix. The maximum thickness is fourteen feet.

In a ravine back of the wholesale office of the Taber Lumber Company the St. Louis limestone is overlain disconformably by ten feet of Des Moines sandstone. The St. Louis is conglomeratic throughout its thickness of thirty feet. A very irregular contact line separates the conglomeratic, compact white Verdi limestone above from a conglomeratic gray limestone, with blocks and layers of brownish magnesian limestone, below. Near the base of the St. Louis there is a bed composed of cemented grains and pebbles of limestone.

The basal Pennsylvanian sandstones are in disconformable contact with the Croton member of the St. Louis in a bluff section a short distance northwest of Rand Park at Keokuk as indicated in the following section:

Section in a bluff northwest of Rand Park, Keokuk.

	FEET
DES MOINES	
Sandstone, whitish and with carbonaceous seams below, but yellowish above; cross-bedded and irregularly stratified. Weathered surfaces pitted and cavernous. A few eroded corals and quartz pebbles in basal part; resting on a very uneven and irregular surface of the Lower St. Louis	11 to 12
LOWER ST. LOUIS	
Limestone, compact, gray, conglomeratic, with calcareous matrix; reef-like and structureless. One block measures 4 by 8 feet. Maximum thickness	18 to 19

The Upper Warsaw shale, with intercalated layers of bluish and gray fossiliferous limestone underlies the St. Louis at this place, but the total thickness could not be ascertained owing to poor exposure.

Several exposures of Lower St. Louis limestone appear in the south part of the town of Montrose along a small creek which flows into Mississippi river. The following bluff section was measured a short distance below the wagon bridge.

Section in the south part of Montrose.

	FEET	INCHES
4. Drift.		
LOWER ST. LOUIS		
3. Limestone, conglomeratic; more regularly stratified above. A layer near the middle bears small irregular quartz grains	6	6

2. Irregular blocks and layers of limestone in a shaly matrix. The blocks in the lower part are brownish and magnesian but the limestone in the upper part is whitish or ash-colored	6	8
SPERGEN		
1. Sandstone, gray, calcareous, with a few irregular and discontinuous seams of compact gray limestone. Close inspection reveals the presence of fenestelloid bryozoans and other fossils in this member. Exposed	6	

A few rods north of the bluff section described above there is another good exposure of the Lower St. Louis in a quarry face. At the base of the section is the Spergen formation, consisting of four feet seven inches of fine-grained bluish sandstone overlain by two feet four inches of arenaceous shale. In the middle of the quarry face there is a mound of conglomeratic and disturbed limestone and on the flanks of this are more regularly bedded layers of limestone (fig. 9).

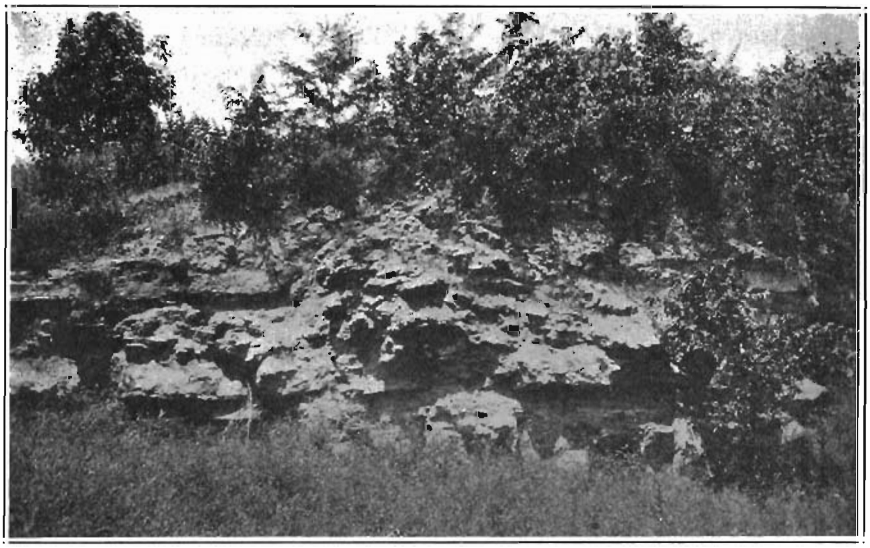

FIG. 9.—Reef-structure in Lower St. Louis limestone near Montrose.

The mound evidently represents a reef built up by vigorous wave action in Lower St. Louis time. The disturbance probably took place after the basal limestones had been deposited and consolidated.

Several exposures of the St. Louis limestone in the interior of Lee county have been described by Keyes.[14] The more important-

14 Iowa Geol. Survey, vol. III, pp. 334-337; 1895.

ant of these are on the east branch of Sugar creek. The following description from Keyes is of an outcrop on this stream in the northeast quarter of section 20, T. 68 N., R. 5 W.

Section of St. Louis limestone on east branch of Sugar creek (After Keyes).

		FEET
6.	Concealed	5
5.	Limestone, hard, bluish white; breaking with conchoidal fracture	3
4.	Sandstone, light brown, soft, saccharoidal	10
3.	Limestone, fine, white, chertlike	1
2.	Limestone, soft, or calcareous sandstone grading downward into next	10
1.	Limestone, brecciated, roughly stratified	10

It will be observed that the formation as exposed here contains considerable sandstone.

Excellent exposures of the St. Louis appear in the southwestern part of the county near Belfast. In the Deamude quarries, located near the center of section 13, Des Moines township, the formation is typically developed. The occurrence of the Spergen and Upper Warsaw beds at this locality has been described on a previous page. (See pages 213 and 215.)

The succession of beds in the St. Louis at the northeast end of the quarry is given below:

Section of St. Louis limestone in Deamude quarry.

		FEET
UPPER ST. LOUIS		
3.	Limestone, conglomeratic, light gray, consisting of subangular blocks rudely stratified. The matrix is of a lighter gray color. Rests irregularly on the surface of the bed beneath	9½
LOWER ST. LOUIS		
2.	Limestone, compact, massive, brownish on weathered surface, magnesian; locally passing laterally into unaltered limestone	6½
1.	Limestone, conglomeratic. Cross-bedded Spergen limestone below	10 to 14½

At one point in this part of the quarry a small outlier of Pennsylvanian sandstone occurs. This appears to occupy a small valley cut into the St. Louis. The contact is concealed.

Bed 1 has a marly matrix which is more prevalent in the lower part. Some of the blocks have a fine contorted stratification and many show stylolytic structure on their surfaces. The conglomerate consists of confusedly mingled angular and subangular blocks of compact dark gray limestone; gray somewhat shaly fossiliferous limestone; gray subcrystalline limestone filled with worm castings; compact brownish magnesian limestone; and drab fine-grained soft impure limestone. Where the blocks are not greatly disturbed they are rudely stratified. This bed thickens abruptly at one point and bed 2 arches up over it.

Bed 2 is bluish gray when fresh but weathers brownish. At one point it passes abruptly into a thin-bedded gray limestone. To the southwest in the quarry face this bed shares in the general disturbance. At this point it is only imperfectly changed to dolomite, and contains a few chert nodules. No fossils were found.

Bed 3 is composed of blocks of a rather soft gray subcrystalline limestone and of compact gray limestone. These blocks vary from a fraction of an inch to several feet in diameter. At one point this bed forms a tongue-like extension down through bed 2 apparently as a result of shearing.

The St. Louis limestones outcrop at a number of points in the Des Moines river bluff just below Belfast. Reference has been made to several of these in the description of the Spergen as developed there. The following section of the Lower St. Louis appears in the bluff about one and one-third miles south of Belfast.

Section of Lower St. Louis Limestone below Belfast.

		FEET	INCHES
LOWER ST. LOUIS			
9.	Limestone, gray, compact; in thin nodular layers	4	
8.	Limestone, dark gray, compact; showing no stratification planes and weathering to irregular chips and polyhedral blocks; receding; slightly oölitic	2	9
7.	Limestone, compact, buff, dolomitic; in layers ranging from a few inches to a foot or more in thickness	4	3
6.	Limestone, compact, gray, regularly bedded	1	4
5.	Limestone, yellowish to brownish, dolomitic, massive, evenly bedded	4	
4.	Limestone, gray, compact, indefinitely stratified and weathering to irregular chips	2	
3.	Shale, bluish, calcareous, receding from bluff about six feet; resting on the undulating surface of the bed below	2	6
2.	Limestone, gray, dense and compact; undulating and showing disturbed stratification	1	
SPERGEN			
1.	Sandstone, fine-grained, bluish; upper surface slightly undulating		

The disturbed facies of the St. Louis is seen at the same horizon only a few yards beyond.

An excellent section may be seen on Mumm creek in the southern middle part of section 33, Van Buren township, two and one-half miles west of Belfast and a little north of that village. This section includes the Warsaw, an attenuated equivalent of the Spergen and both members of the St. Louis.

Section on Mumm creek.

		FEET	INCHES
UPPER ST. LOUIS			
11.	Limestone, gray, compact, conglomeratic, rudely stratified; with occasional pockets of carbonaceous shale and irregular lines of fine-grained whitish sandstone at the very base. Resting on the irregular surface of the bed beneath. Three specimens of *Lithostrotion canadensis* were obtained from a seam of carbonaceous shale at the base. These were angular, and showed no evidence of abrasion	6	
LOWER ST. LOUIS			
10.	Limestone, brownish, tough, magnesian, bearing the silicified coralla of *Lithostrotion canadensis* 5/6 to	1	5
9.	Limestone, buff, magnesian, brittle, tending to scale off obliquely; bears a few rounded chert concretions	5	2
8.	Limestone, gray, compact, dense, unaltered here, but dolomitic at the bend farther up the creek	1	5
7.	Limestone, bluish, magnesian, soft, weathering yellowish	3	1
6.	Limestone, buff, magnesian, in two layers of about equal thickness	2	9
5.	Limestone, yellowish to brownish, dolomitic; disturbed and conglomeratic, especially in lower part; more evenly bedded above; passing gradually downward into the bed below; bearing pebbles and irregular patches of unaltered compact gray limestone. Lower surface extremely irregular 3 to	5	
4.	Shale, bluish, calcareous, with imbedded pebbles of compact gray limestone; of very variable thickness; resting on the uneven surface of the bed below, and followed unevenly by the bed above 1 to	3	
3.	Limestone, gray to buff or yellowish, magnesian; conglomeratic and disturbed. Some pebbles of unaltered gray compact limestone 2 to	3½	
SPERGEN			
2.	Limestone, bluish, arenaceo-magnesian 2/3 to	1	4
WARSAW			
1.	Shale, bluish, argillaceous, more calcareous towards the top where it carries fish remains, *Conularia* sp. and *Orbiculoidia* sp. Argillaceous part bears a few small imperfect siliceous geodes. Exposed	8	10
	Concealed to bed of creek	3	

About seven hundred yards farther up, the stream bends abruptly from the north to an easterly direction. A fine exposure is afforded here in the west bank immediately below the bend.

Section on Mumm creek above the preceding section.

		FEET
DES MOINES		
8.	Concealed to brow of hill; surface strewn with blocks of brownish sandstone.	
UPPER ST. LOUIS		
7.	Limestone, light gray, compact; some layers granular to oölitic	12
6.	Concealed, probably brecciated limestone with shaly matrix	4
5.	Limestone, gray, compact, conglomeratic, rudely stratified	12¼
LOWER ST. LOUIS		
4.	Limestone, massive, magnesian, weathering brownish; bearing a few silicified corolla of *Lithostrotion canadensis.* Very undulating and uneven	3
3.	Limestone, buff, magnesian, massive, structureless; little trace of bedding; flaking off obliquely; slightly receding. At one	

	point a small cave extends back ten to fifteen feet. Highly fossiliferous in basal part	4½ to 5½
2.	Limestone, yellowish to brownish, magnesian; in one massive ledge; resting on the undulating and hummocky surface of bed below; usually projecting	2 to 2½
1.	Limestone, bluish, magnesian, in thin, undulating layers; arching up over mounds in creek bed. Exposed to bed of creek	2 5/6

The following forms occur as molds in bed 3:

Girtyella indianensis (Girty)	Aviculopecten sp.
Spirifer (species undescribed)	Aviculopecten sp.
Brachythyris altonensis Weller	Aviculopecten sp.
Myalina sp.	Modiomorpha sp.
Myalina sp.	Conocardium sp.
Myalina sp.	Bellerophon sp.

Another excellent exposure of the St. Louis occurs two hun-

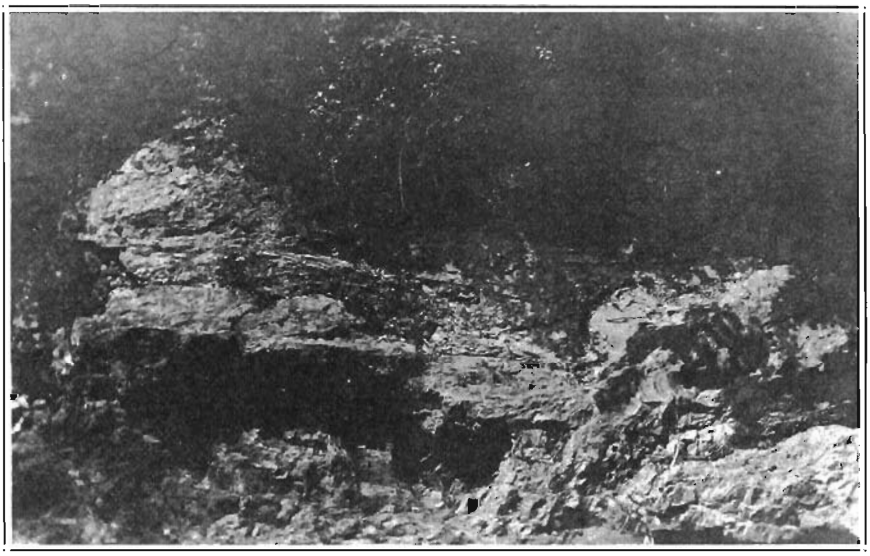

FIG. 10.—Showing irregular contact between Lower and Upper St. Louis limestones on Mumm creek, near Belfast.

dred yards east of the above mentioned bend in Mumm creek (fig. 10). The description of this exposure follows:

Section two hundred yards east of preceding one.

		FEET
UPPER ST. LOUIS		
6.	Limestone, gray, dense, compact, unevenly stratified; exposed	7¼
5.	Limestone, gray, compact	5 2/3
4.	Limestone, compact, gray, with small white kaolinic patches: in thin layers separated by laminated calcareous shale, which weathers yellowish	2
3.	Limestone, gray, compact, with seams of gray granular lime-	

	stone; locally oölitic in part; disturbed and structureless at one point, but passing laterally into evenly bedded limestone	12
2.	Limestone, gray, compact, conglomeratic, rudely stratified; lower portion with calcareous matrix; upper portion with shaly matrix; imperfectly dolomitized locally. At one point a tonguelike mass about fifteen feet wide appears in the lower part. This is filled with angular blocks of limestone many of which differ physically from those in the adjacent walls. They consist of compact light gray limestone, of light gray oölitic limestone, and of bluish fine-grained shaly limestone. The matrix is shaly and the breccia has weathered back slightly, thus emphasizing the outline of the mass	12
LOWER ST. LOUIS		
1.	Limestone, dolomitic, bluish gray when fresh but weathering brownish, massive; bearing a few rounded chert concretions; bedding very uneven and disturbed. At one point a distinct depression about six feet deep and six feet wide extends into this member and is filled with the conglomeratic limestone of the bed above. A few yards to the southeast two other such tongues appear. These are broader but less deep	2 to 10

Bed 5 of the above section yields the following species:

Streptorhynchus ruginosum (Hall and Clarke) ?
Orthotetes ? sp.
Productus ovatus Hall
Productus tenuicostatus Hall
Girtyella indianensis (Girty)
Spirifer cf. S. pellaensis Weller
Composita trinuclea (Hall)
Streblopteria ? sp.
Straparollus sp.

Good exposures of the upper St. Louis limestone may be seen along the east branch of Monk creek in the southeast quarter of section 36, T. 67 N., R. 7 W., one and one-fourth miles northeast of Belfast. The relation of conglomeratic mounds to the evenly-bedded facies is shown here on a small scale. Well up in the section a single large partly silicified corallum of *Lithostrotion canadensis* was found. Imperfect ripple marks were noted on the surface of a limestone layer a short distance farther up the branch. The mounds of limestone appear to be but little altered to dolomite, while the evenly bedded layers on the flanks are nearly everywhere uniformly altered.

One of the most complete and representative exposures of the St. Louis limestone in southeastern Iowa appears along the bed and banks of a small creek emptying into Des Moines river in the lower edge of the town of Croton (T. 67 N., R. 7 W.). The section described below begins up the creek nearly one mile from its mouth but the more important outcrops of the St. Louis are in section 20 near the town.

Section along a creek at Croton.

		FEET
PELLA		
14.	Limestone, gray, compact, lower part arenaceous	9
13.	Sandstone, fine-grained, yellowish	4½

UPPER ST. LOUIS

12. Limestone, gray, granular, in some places slightly oölitic; middle part cross-bedded. At the very base there is locally a conglomeratic layer several inches thick. The lower part of the granular limestone passes laterally into gray compact, subcrystalline evenly bedded limestone which bears small pelecypods. The upper surface of this layer shows symmetrical wave ripples, which have a general north-south trend. They measure three to five and one-half inches from crest to crest and are one-half inch to one and one-half inches deep. This member forms a series of mounds of disturbed limestone at one point in the creek bed .... 10 to 13½

11. Limestone, bluish, magnesian, thinly bedded; somewhat shaly; slightly fossiliferous; resting on uneven undulating surface of bed beneath 2

10. Limestone, conglomeratic, gradually less disturbed and more evenly bedded towards the top. More evenly bedded layers arching up over mounds of conglomeratic limestone which consists of pebbles and blocks of compact gray limestone; gray subcrystalline, brittle limestone; light gray slightly oölitic limestone and a few small blocks of fine-grained sandstone. The matrix is for the most part calcareous but locally it is sandy. Some blocks show stylolytic structure. Some of the matrix is of a lighter gray color than the blocks. Occasional blocks bear worm castings and some have small irregular patches of kaolin. Locally cherty in upper part. The more evenly bedded material towards the top consists of dense, compact gray limestone, and of gray subcrystalline limestone. This part is slightly fossiliferous 13

LOWER ST. LOUIS

9. Limestone, massive, compact, dolomitic, gray when fresh but weathering yellowish. Locally bearing remnants of compact unaltered gray limestone. The *Lithostrotion canadensis* zone 0 to 2

8. Limestone, dolomitic, buff, massive, tough; flaking off obliquely. Basal part fossiliferous .... 4½ to 5

7. Limestone, grayish weathering buff, dolomitic; locally passing wholy or in part into dark gray conglomeratic limestone .... 1 1/3 to 1 2/3

6. Limestone, bluish, dolomitic, weathers soft and buff, filled with structures resembling worm castings .... 3 to 4

5. Limestone, brownish, dolomitic, tough; with discontinuous seams of unaltered limestone in upper part .... 2/3 to 1

4. Limestone, drab, subcrystalline, rather compact, brittle; bearing small, irregular patches of kaolin and numerous small chert concretions with nuclei of greenish clay. Somewhat fossiliferous. *Lithostrotion proliferum* and *Syringopora* sp. most common fossils. Differing in thickness on account of hummocky and irregular surface of the bed beneath. This bed arches up over the mounds below, and fills some of the depressions, thus levelling up the irregular surface. Contains worm castings. Locally passes laterally into dolomitic limestone .... 2/3 to 3

3. Limestone, disturbed, conglomeratic; consisting of blocks, pebbles and subangular bowlders of compact gray limestone; gray subcrystalline limestone; brownish dolomitic limestone and rather soft bluish, impure limestone, in a calcareous to shaly matrix. Locally evenly bedded layers appear for a few yards, but these abut abruptly against conglomeratic limestone on either side. In one mound the matrix is sandy. In places the conglomeratic limestone assumes the form of mounds and hummocks, with the evenly bedded limestone above lapping up over the elevations and filling in the depressions. Locally the conglomeratic limestone is imperfectly dolomitized and discolored yellowish. The calcareous matrix seems to be the first to be affected. Occasional blocks in the

conglomerate are slightly fossiliferous. Blocks show stylolytic structure. Exposed	12 to 13
2. Limestone, compact, dense, gray; dolomitic in basal part. Upper part with thin wavy concretionary stratification, the wavy layers of which conform to the irregular surface of the limestone below	1 to 1 2/3
WARSAW	
1. Shale, bluish, argillaceous; exposed	5 5/6

The Spergen formation apparently was removed by erosion prior to the deposition of the St. Louis.

Fossils collected from beds 3, 4, 10 and 11 were identified as follows:

List of fossils from bed 3 of the St. Louis at Croton.

Syringopora sp.
Eumetria verneuiliana (Hall)
Modiomorpha ? sp.
Leperditia carbonaria Hall

List of fossils from bed 4 of the St. Louis at Croton.

Zaphrentis sp.
Lithostrotion proliferum Hall
Syringopora sp.
Fenestella serratula Ulrich
Fenestella sp.
Cystodictya sp.
Dichotrypa elegans Ulrich ?
Spirifer pellaensis Weller ?
Composita trinuclea (Hall)
Phillipsia ? sp.
Calcareous algae

List of fossils from bed 10 of the St. Louis at Croton.

Lithostrotion proliferum Hall
Spirifer cf. S. pellaensis Weller
Straparollus sp.

List of fossils from bed 11 of the St. Louis at Croton.

Productus ovatus Hall
Spirifer cf. S. pellaensis Weller

The conglomeratic mounds in beds 3 and 10, representing the basal parts of the Lower and Upper St. Louis, respectively, are believed to be due to disturbed conditions during deposition, although later fracturing undoubtedly has modified the original relationship somewhat.

A section of the St. Louis limestone in the bluff of Des Moines river a little more than one mile below Croton, in section 29 of the same township, shows some variations from the one at Croton. The succession is as follows:

Section one mile below Croton.

	FEET	INCHES
DES MOINES		
13. Sandstone, yellowish, soft, capping the hill	1 to 2	
PELLA		
12. Concealed. Loose blocks of limestone on the slope of the con-		

	cealed part seem to come from the bed which appears just above the basal sandstone in the Croton creek section	7	4
11.	Sandstone, fine-grained to medium-grained; somewhat calcareous; weathering yellowish in lower part; with some iron-stained patches. Upper part whitish and calcareous. Thinly and evenly bedded	5	2
UPPER ST. LOUIS			
10.	Limestone, gray, compact, with thin, irregular streaks and pockets of sandstone. Upper surface slightly irregular	2 to 3	
9.	Limestone, light gray, oölitic in upper part. Weathered surfaces flaking off obliquely. Contains *Conocardium* sp., a *Spirifer* resembling *S. pellaensis* and a few other fossils	5 to 8	
8.	Limestone, gray; granular in middle but compact in upper and lower parts; weathering into thin layers; bearing a few discontinuous seams of chert. Shows slight tendency toward oölitic structure	4	4
7.	Shale, bluish, argillaceous, weathering yellowish; with thin interbedded layers of compact bluish gray magnesian limestone which weathers soft and buff	3	
6.	Limestone, conglomeratic, compact, gray, rudely stratified	10	1
LOWER ST. LOUIS			
5.	Limestone, in one massive ledge, dolomitic, weathering brownish; middle part locally bears irregular patches of unaltered limestone	1½ to	3½
4.	Limestone, dolomitic, bluish when fresh but weathering buff, brittle, structureless; flaking off obliquely. Slightly fossiliferous; bearing worm burrows	8 to 9	
3.	Limestone, fine-grained, gray, compact; locally passing into dolomitic limestone which weathers buff in part. At one point the weathered rock is shaly in middle part. Upper part bears occasional sand grains. Shaly part slightly fossiliferous. Bears worm castings. Contact with bed above undulating and irregular. At one point there is a pocket of carbonaceous shale at the contact. A few yards to the north this bed is brecciated and sheared down into the beds below	2/3 to 2	
2.	Limestone, bluish, magnesian, rather soft, weathering buff	1 1/3 to 2	
1.	Limestone, buff, magnesian, massive, compact, grayish when fresh; locally even-bedded, but generally disturbed and more or less structureless. Exposed	7	8

One hundred and forty yards below the above described section, twenty feet of massive soft sandstone, whitish when fresh but weathering yellowish, rests directly upon bed 6 of the preceding section. This sandstone doubtless is of Pennsylvanian age, although no plant remains were found in it. Massive beds of sandstone here bend up over a thick dome of the same material to give the appearance of a massive arch.

Van Buren County.—Exposures of the St. Louis limestone in Van Buren county are confined to the valley of Des Moines river and its tributaries. Along Indian creek west of Farmington it outcrops at a number of points. Beginning three and one-half miles west of Farmington, a series of sections were studied along the banks of the creek, continuing almost to its mouth.

Below the Van Aucken quarry in the northwest one-fourth of the northeast quarter of section 5, T. 67 N., R. 8 W. there is a good exposure of the Upper St. Louis.

Section of Upper St. Louis limestone in and near Van Aucken quarry.

UPPER ST. LOUIS	FEET	INCHES
7. Limestone, gray, subcrystalline and compact; in rather heavy ledges; cherty in upper part; upper surface undulating and irregular. Overlain disconformably by basal sandstone of the Pella. Contains numerous shells of a large *Bellerophon*	2½ to 4½	
6. Limestone, dark gray, subcrystalline and compact; rather brittle when fresh but becoming tough when weathered; locally filled with small sinuous tubular branching fucoids which resemble worm castings; bearing large calcareous algæ some of which have a maximum diameter of over 5 inches. Upper surface bearing a few large vertically compressed sinuous pipes which represent large fucoids. Separated from the bed above by a shaly parting 1 inch thick		2 to 6
5. Shale, fissile, rather bluish when fresh, weathering drab; upper part more calcareous and passing into an impure fissile limestone. No fossils noted	1	5
4. Limestone, gray, compact, weathering to a lighter gray, cleaving easily into thin layers; bearing seams of fissile shale towards the top	1	10
3. Limestone, gray, compact; consisting of a single layer showing thin irregular stratification, the irregular surface of the individual lamellæ being imparted to the layers immediately above. Bears a few small pelecypods		5 to 6
2. Limestone, gray, compact; weathering to light gray layers 2 to 10 inches in thickness; with shaly partings in upper part. No fossils noted	1	7
1. Limestone, gray, granular to compact, locally cross-bedded in part; a layer 1 foot 6 inches thick near top consists of dense compact gray limestone. Rolled calcareous algæ on surface of bed. The lower 4 feet consists of compact gray limestone	12	6

In the northwest quarter of section 4 of the same township a small reef appears in the Upper St. Louis limestone. This is shown in a small quarry opening in the east bank of Indian creek a short distance south of the Chicago, Burlington and Quincy railway bridge. The reef is fifteen feet wide and six and one-half feet high. The lower three feet of the reef consists of subangular blocks of granular limestone in a calcareous matrix. The upper three feet consists of angular and subangular blocks of granular to oölitic limestone and of compact gray limestone filled with a branching bryozoan. The matrix of the upper part is in some places a conglomeratic limestone consisting of small limestone pebbles in a calcareous matrix and in others a gray limestone with the same species of branching bryozoan as above. On the flanks of this reef-like structure is granular cross-bedded limestone. The layers of this abut abruptly into the reef and were not found to contain the bryozoan so common in the reef. No beds are exposed above the reef with the exception of one thin layer which extends part way over it on the north side.

Associated with the bryozoan in the reef are occasional specimens of a small Conularia. Some of the blocks of granular oölitic limestone in the upper part of the reef contain calcareous algæ. These were not noted in the adjacent evenly bedded limestone. This reef structure doubtless is original in large part. Some of the disturbance, however, may be due to later mashing.

There is a good exposure of the Upper St. Louis and the topmost members of the Lower St. Louis on the White farm in the southeast quarter of section 33, T. 68 N., R. 8 W. This appears in the north bank of Indian creek two hundred and twenty-five yards above an abrupt bend of the creek to the north, and two and one-half miles west of Farmington.

Section of St. Louis limestone on Indian creek.

	FEET
7. Drift, yellowish, sandy.	
UPPER ST. LOUIS	
6. Limestone, dark gray, granular, with occasional thin layers of compact gray limestone	6
5. Limestone, dark gray, subcrystalline; with small rounded sand grains included; locally passing into brecciated limestone; in places thin-bedded and shaly. Rests on the undulating surface of the bed beneath and is separated from it by a shaly parting	1 to 2
4. Limestone, dark gray, brecciated, consisting of angular and subangular pebbles and blocks of compact gray limestone, and gray subcrystalline limestone in a calcareous matrix. Upper part less disturbed and more evenly stratified. In some places filled with fucoid-like markings resembling worm castings. Irregular lenses of buff dolomitic limestone were noted at two points in this bed and at one place a rounded bowlder of dolomite 8 inches in diameter occurs. This bed rests on the very irregular surface of the bed below as a result of uneven dolomitization. The pseudo-disconformity at the base of this bed is very striking (fig. 11)	2 to 6
3. Limestone, drab, dolomitic, conglomeratic, matrix constituting a large part of rock. Pebbles rounded and subangular. A few flinty masses occur. Lower part more massive and seeming to grade downward into the bed beneath. Upper part showing no stratification and flaking off obliquely to surface. The upper surface is very irregular and undulating. A few blocks with worm burrows were noted in the upper part. At one point two irregular lenses of unaltered compact gray limestone appear in this bed 2 feet and 3 feet 6 inches respectively below the top	3½ to 8½
LOWER ST. LOUIS	
2. Limestone, dolomitic, bluish gray when fresh but weathering brownish; bearing silicified corolla of *Lithostrotion canadensis.*	

Imperfectly preserved ripple marks on upper surface trend N.60°E. These measure 3 to 4 inches from crest to crest and ¼ to ½ inch in height. They are so poorly preserved that it cannot be determined whether they are symmetrical or not 1½

1. Limestone, bluish gray when fresh but weathering brownish, dolomitic, the topmost part of the fossiliferous bed. Exposed in bed of creek 1

A very instructive exposure appears in the east bank at the point where the creek bends abruptly to the north, two hundred and twenty-five yards below the preceding section. Both members of the St. Louis are considerably disturbed here, owing to shearing, mashing and overthrust faulting on a small scale. The Upper St. Louis attains a thickness of eleven and one-half feet

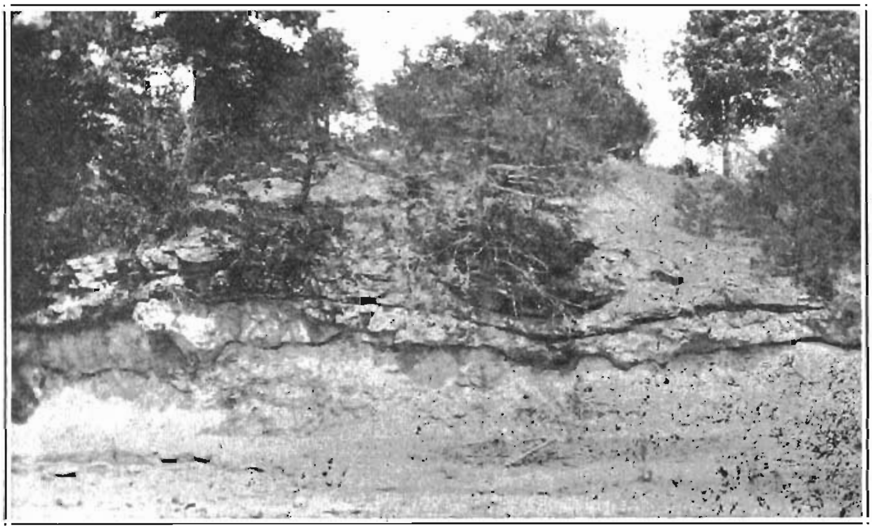

FIG. 11.—Pseudo-disconformity in St. Louis limestone marking boundary between dolomitic portion below and unaltered portion above. Indian creek, near Farmington.

and is gray, brecciated and nondolomitic. The Lower St. Louis has an exposed thickness of fourteen and one-half feet and is brownish and dolomitic.

The reverse faulting is best developed in a massive member four feet thick at the top of the Lower St. Louis. The overlying and underlying softer limestones appear to have accommodated themselves to the compressive stresses chiefly by mashing. In the largest fault the massive limestone on the north side of the break appears to have been raised almost vertically about four feet, then as a result of compression the upthrown side was made to overlap the downthrown side about ten feet while the softer beds above and below yielded by mashing. The strike of the fault is approximately N. 80° E. Several other small faults and shear zones with nearly vertical displacement appear in the bluff nearby.

Other interesting exposures of the Lower St. Louis in contact with the Upper St. Louis are shown a short distance farther down the creek in the southeast one-fourth of the southeast quarter of section 33 where the valley bends again to the eastward. The Lower St. Louis is for the most part evenly bedded and undisturbed, but at one point a large lenslike mass of brownish structureless limestone is enclosed within a blue magnesian limestone bed, which at this point thickens greatly. The limestone of the lens seems to grade into the blue magnesian limestone on the flanks. The lens has a maximum thickness of five feet and is thirty feet wide. It is believed to have been formed during the deposition of the formation.

A bluff section in the south bank of Indian creek just below the bridge of the Chicago, Burlington and Quincy Railroad, in the northeast quarter of section 3, T. 67 N., R. 8 W., shows the Des Moines sandstone in contact with the St. Louis.

Section on Indian creek in section 3.

	FEET
Drift.	
DES MOINES	
Sandstone, grayish, carbonaceous; bearing many plant remains; imperfectly stratified; locally passing in part into carbonaceous shale. Exposed	7
Sandstone, gray, carbonaceous, soft; resting on the oxidized and decomposed surface of the bed beneath; receding slightly beneath the bed above. Imperfectly stratified	2
LOWER ST. LOUIS	
Limestone, disturbed; layers undulating. Stratification obliterated in some places by brecciation. Some layers dolomitic and buff. Other layers and blocks which are interstratified and mingled with the dolomitic limestone consist of compact gray limestone. Dolomitization appears to have been very imperfect. The lower 1 to 3 feet is shaly, and grades downward into the bed beneath. Locally very much discolored by iron stains, and decomposed in places, especially in upper part, due to reaction with sulphate solutions from the bed above. At points where the limestone is decomposed and iron-stained it bears small crystals of gypsum, probably formed by the reaction of limestone with iron sulphate solutions from the sandstones above.	
Shale, bluish, calcareous, weathering into irregular chips; grading gradually upwards into the beds above and resting on the undulating surface of the bed beneath	1 1/3 to 4
Limestone, dense, bluish gray, dolomitic, showing faint stratification	2

Limestone, bluish, arenaceous and dolomitic, tough, porous; fossils poorly preserved; concealed at this point, but with an exposed thickness of 7 feet beneath the east end of the railroad bridge near by 7

An exposure on the north bank of the creek just north of the railway, two hundred yards below the preceding section, again shows the Des Moines sandstone and Lower St. Louis in contact. The Des Moines is represented by thirteen feet of light gray medium to coarse-grained sandstone locally discolored yellowish or reddish. It is massive below but thin-bedded above. A slight development of basal conglomerate appears at the base, where pebbles of chert were observed. Locally at the contact there are thin films and small crystals of gypsum.

The Lower St. Louis has an exposed thickness of fifteen feet. It is greatly disturbed and imperfectly dolomitized. At several places in the bluff limestone blocks of certain horizons were found sheared down several feet into lower layers with a different physical character. The dip of some of the deformed layers is as great as thirty-five degrees. At several points pockets of Des Moines sandstone were found in the limestone several feet below the contact. These evidently represent the fillings of solution cavities formed prior to Des Moines sedimentation. That the disturbance of the St. Louis limestone took place prior to Des Moines time is indicated by the lack of deformation in the sandstone of this age.

In another exposure in the south bank of the creek, two hundred and fifty yards down stream, the basal Des Moines sandstone, which is here five and one-half feet thick, rests directly upon the Spergen formation. However, farther along the bluff to the east the lowermost beds of the St. Louis appear between the other formations.

The exposures of St. Louis limestone along Reed creek in Bonaparte township are very important in that they illustrate some of the remarkable lateral variations in the formation due to the variable conditions of deposition and to differences in the degree of deformation.

Near the middle of the north line of section 14, T. 68 N., R. 8 W., a bluff on the south side of the creek is seventy-five feet high and about two hundred yards long. In this bluff are exposed complete sections of the Pella and St. Louis formations. The Lower St. Louis is much more brecciated and mashed than the overlying beds (figs. 12 and 13). It is probable that the presence of a shaly bed in the lower part of this member is

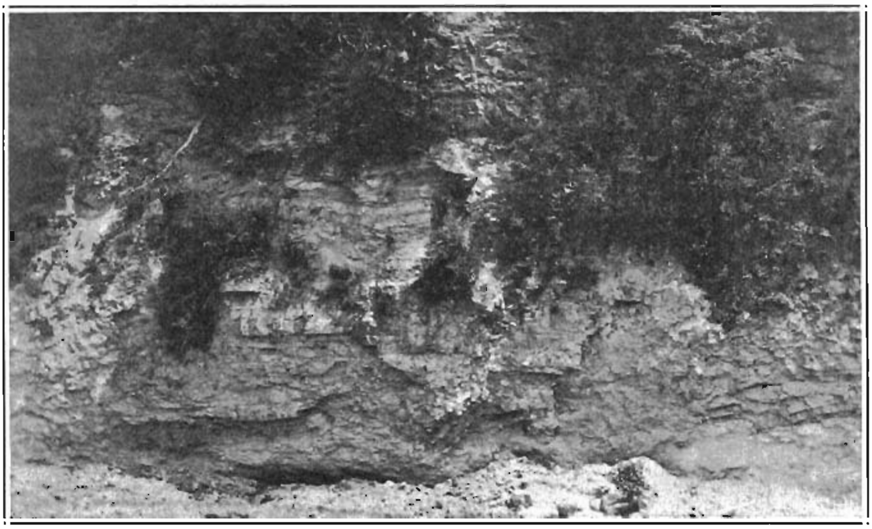

FIG. 12.—Brecciated Lower St. Louis limestone. Reed creek, near Bonaparte.

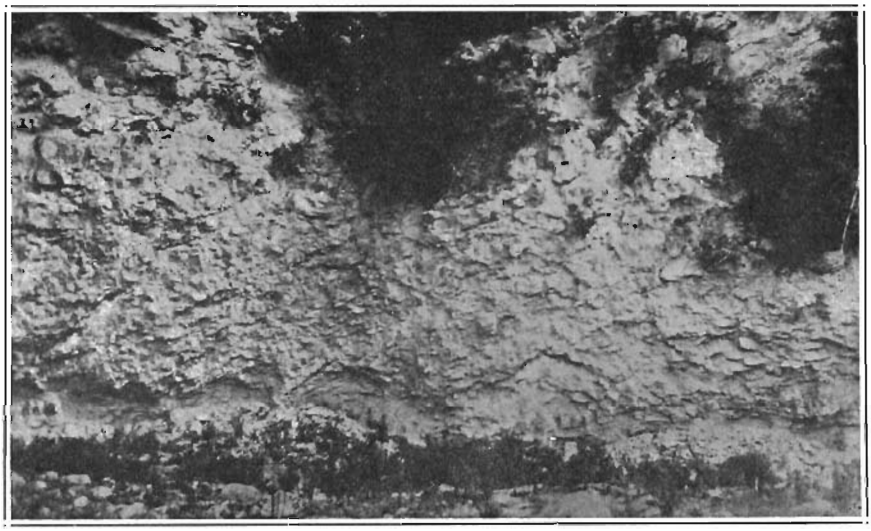

FIG. 13.—Brecciated Lower St. Louis limestone. Reed creek, near Bonaparte.

largely responsible for this relationship since the limestone layers above appear to have been mashed and sheared down into this less resistant bed. However, deformation and mashing have gone on locally in the Upper St. Louis and Pella. In these beds the disturbance tends to follow shear zones.

The Pella limestone, with a maximum thickness of twenty-one and one-half feet, caps the bluff. Below this comes fourteen feet of basal Pella sandstone with intercalated beds of shale and limestone and under it lies the St. Louis. The section of the Pella at this locality is described in a later chapter of this report (p. 291). The Pella limestone forms a sharp cliff while the underlying basal Pella sandstone and the conglomeratic Upper St. Louis below weather to a more gentle slope which terminates below in a sharp escarpment produced by the erosion of the more resistant Lower St. Louis limestone.

Near the middle of the bluff the following members appear in the St. Louis:

Section on Reed creek.

	FEET
UPPER ST. LOUIS	
4. Limestone, buff, dolomitic, with small scattered sand grains	6
3. Limestone, buff, dolomitic, massive	2¾
2. Limestone, compact; originally gray, but now altered to buff dolomite with irregular remnants of limestone. Slightly disturbed but not conglomeratic	9
LOWER ST. LOUIS	
1. Limestone, brownish, dolomitic, mashed and deformed, shaly in lower part	28

Several remarkable shear zones appear near the east end of the bluff. The Pella limestone is considerably less disturbed along these zones than are the underlying strata. Along the most pronounced line of movement blocks of Pella limestone are sheared downward for at least ten feet into the soft shales and sandstones below. This tongue-like extension of mashed limestone weathers in relief, thus forming a prominent feature in the face of the bluff. On the east side of the tongue the sandstone is but little disturbed but on the west side the layers are bent down as much as three feet. At points where all members of the Lower St. Louis are involved in the crushing the shaly bed in the lower part is locally greatly reduced in thickness and numerous tongues of mashed limestone extend down through it. At several points angular blocks of limestone several feet in length are kneaded far down into the shaly material below. Some of these shale-enclosed blocks and broken layers are highly tilted.

About 200 yards farther up the creek a second bluff section appears on the opposite bank. The succession of strata here is essentially the same as in the preceding section except that the basal Pella sandstone is much thicker and the lowermost bed of the Lower St. Louis is not exposed. At the south end of the bluff this member attains a maximum exposed thickness of twenty-nine feet. A few pockets of bluish shale were noted in the basal part.

The Lower St. Louis is greatly disturbed here on account of

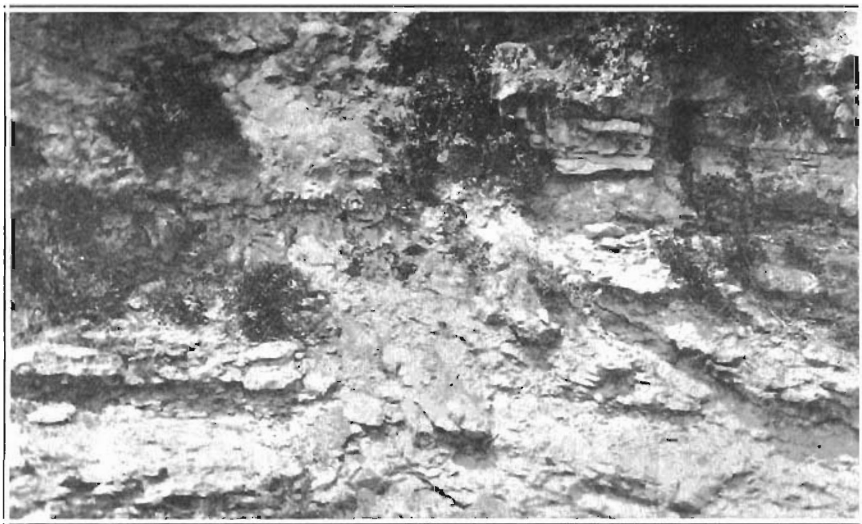

FIG. 14.—Small reversed fault in Lower St. Louis limestone. Reed creek, near Bonaparte.

faulting, crushing and shearing. Shear zones and small overthrust faults appear at several points in the bluff. Most of these have a steep dip and the displacement is slight, the maximum being not more than five feet. Their strike is approximately N. 55° W. and the upthrow side is on the north. (See fig. 14.)

The following section was measured in this bluff:

Section on Reed creek two hundred yards above preceding one.

		FEET
PELLA		
6.	Limestone, gray, fine-grained	18
5.	Shale	3½
4.	Sandstone, fine-grained, soft, bluish, massive below but thin-bedded and shaly above; lower part containing pebbles of limestone and chert. Resting on the uneven surface of the bed below	24 to 35
UPPER ST. LOUIS		
3.	Limestone, consisting typically of angular to rounded blocks	

	of gray to buff dolomitic limestone in a gray impure sandy matrix. The limestone bears small patches of kaolin and small nodules of chert. Many of the blocks contain sinuous tubes resembling worm burrows. Occasional specimens of *Lithostrotion proliferum* were noted	10
LOWER ST. LOUIS		
2.	Limestone, massive, brownish, dolomitic	3
1.	Limestone, brownish, dolomitic; much disturbed and mashed	26

The Lower St. Louis appears in its normal development in a cut along the Chicago, Rock Island and Pacific railway in the western part of section 23, T. 68 N., R. 7 W., a short distance below the mouth of Slaughters branch. A considerable thickness of sandstone appears in the slope above. The lower portion of this sandstone is believed to represent the Upper St. Louis while the upper portion probably belongs to the base of the Pella. The section follows:

Section below the mouth of Slaughters branch.

		FEET	INCHES
PELLA			
5.	Limestone, gray, brecciated; capping brow of hill	3	4
4.	Concealed	31	
3.	Sandstone, light gray, thin-bedded	5	6
UPPER ST. LOUIS			
2.	Sandstone, soft, yellowish, bearing occasional rounded and subangular blocks of compact gray dolomitic limestone	21	4
LOWER ST. LOUIS			
1.	Limestone, brownish, disturbed, imperfectly dolomitized	14	8

The St. Louis is again exposed on Slaughters branch in the northwest quarter of section 23, about one-fourth mile above the point where the railway crosses the creek. Approximately twenty feet of Pella limestone and sandstone caps the section while the Spergen and Warsaw beds appear below the St. Louis.

Section on Slaughters branch.

		FEET	INCHES
PELLA			
11.	Limestone capping brow of hill	2	6
10.	Concealed	10	4
9.	Limestone, compact, gray, somewhat speckled; passing wholly or in part into sandstone	1	6
8.	Limestone, dense, compact, gray, showing fine lamination	2	6
7.	Sandstone, light gray, fine-grained, bearing angular chert fragments. Lower part grading in part into compact gray limestone; locally shaly	2½ to 3	
UPPER ST. LOUIS			
6.	Limestone, gray, granular to compact; upper part showing fine laminations on weathered surfaces	9	4
5.	Concealed, slope covered by yellowish shales	2	6
4.	Limestone, lower portion compact, gray and disturbed; upper portion more evenly bedded and consisting of massive buff imperfectly dolomitized limestone	10	5
LOWER ST. LOUIS			
3.	Limestone, brownish, dolomitic, with bluish shale bed three feet thick in basal part	24	3

SPERGEN		
2. Limestone, bluish, massive, arenaceo-magnesian	5	
WARSAW		
1. Shale, bluish, argillaceous. Exposed	1	

A disturbed phase of the lower beds of the Lower St. Louis member appears along Potters branch, one and one-fourth miles northeast of Bonaparte, in the NW.¼ sec. 10, T. 68 N., R. 8 W. At several points the upper limestone layers appear to have been forced down into the lower shaly beds. Locally small mounds of limestone are exposed. The limestone was much fractured during at least two periods of disturbance and the fracture lines are sealed with veinlets of calcite. In several instances bands of limestone immediately adjacent to the fractures of earlier age are gray and unaltered although the rock elsewhere is brownish and dolomitic. It appears that the first disturbance here took place prior to dolomitization and that the limestone adjacent to the fractures was less susceptible to alteration, owing to its more crystalline condition or some other cause, than the surrounding rock. The fractures of later age in many instances cut across the earlier ones and their associated limestone bands, which are in such cases usually slightly displaced. The limestone is uniformly dolomitized adjacent to these younger breaks, a relationship which suggests that they were formed subsequent to dolomitization. The first period of fracturing is believed to have occurred at the close of Croton time, while the second probably occurred at the close of the Pella.

A short distance farther up the creek the following bluff section is shown in the south bank.

Section in Potters branch.

	FEET	INCHES
PELLA		
8. Sandstone, soft, yellowish, incoherent. Exposed	11	6
UPPER ST. LOUIS		
7. Limestone massive, gray, subcrystalline, stylolytic, badly fractured; shaly parting at contact with bed below	3	6
6. Limestone, buff, magnesian, soft, grades into bed beneath	11	4
LOWER ST. LOUIS		
5. Limestone, buff, magnesian; in one massive ledge	2 to 3	
4. Limestone, buff, magnesian, brittle; tending to flake off obliquely	4	6
3. Limestone, buff, magnesian; in one heavy ledge; bearing small chert nodules	1	4
2. Limestone, dense, dark gray; blotched with patches of lighter gray magnesian limestone; bears irregular seams and nodules of chert	4	to 6
1. Limestone, buff, magnesian, in rather thin layers. Exposed to bed of creek	2	6

The following species were collected from bed 7 of the above section:

Lithostrotion proliferum Hall	Spirifer sp.
Syringopora sp.	Eumetria verneuiliana Hall
Productus ovatus Hall	Straparollus sp.
Girtyella indianensis (Girty) ?	Bellerophon sp.

There is an excellent exposure of the undisturbed facies of the Lower St. Louis limestone in an abandoned quarry at the mouth of Rock creek in the northwest quarter of section 21, Washington township, and in the Des Moines river bluff a short distance above. This phase is followed above by disturbed Upper St. Louis limestone which in turn is overlain by the Pella formation. The section follows:

Section at the mouth of Rock creek.

		FEET	INCHES
PELLA			
12.	Limestone, gray, fine-grained	7	9
11.	Sandstone, fine-grained, massive, more calcareous and approaching brecciated limestone locally in upper part	11	8
UPPER ST. LOUIS			
10.	Limestone, gray, compact, fine-grained, brecciated	5 to 8	
9.	Sandstone, soft, fine-grained, bluish, locally with pebbles of limestone in lower part. Lower six inches in some places consists of arenaceous limestone	2	
8.	Limestone, buff, dolomitic; brecciated	8 to 12	
LOWER ST. LOUIS			
7.	Limestone, buff, dolomitic, the *Lithostrotion canadensis* zone	0 to 1½	
6.	Limestone, buff, dolomitic, in two massive ledges, with fucoid markings resembling worm burrows in two thin zones	7	
5.	Limestone, compact, gray, with shaly seams	2	
4.	Limestone, compact, bluish, dolomitic, weathering yellowish	4	4
3.	Limestone, buff, dolomitic, tough	2	4
2.	Limestone, dense, with slight bluish tint, checking into irregular blocks	2	4
1.	Sandstone, fine-grained, bluish, calcareous; receding. Exposed	5	

An even more typical exposure of the undisturbed Lower St. Louis limestone appears in the bank of Rock creek approximately one-third of a mile north of the quarry just described (fig. 15).

Section in the bank of Rock creek.

		FEET	INCHES
12.	Drift to brow of hill	12	
UPPER ST. LOUIS			
11.	Limestone, gray, compact, dense, brecciated	3	
LOWER ST. LOUIS			
10.	Limestone, buff, dolomitic, tough, massive, overhanging, upper surface irregular	1 to 2½	
9.	Limestone, buff, dolomitic; tough	1	6
8.	Limestone, buff, dolomitic; brittle, flaking off parallel to the face of the bluff; bearing small chert nodules in upper part	7	
7.	Limestone, soft, bluish, dolomitic, fucoid markings in middle part	3	3

6. Limestone, bluish when fresh but weathering buff; lower part soft	2	8
5. Limestone, soft, drab, dolomitic; lower part mottled and streaked with soft gray limestone	3	
4. Limestone, bluish, dolomitic, weathering yellowish, brittle, thin-bedded; checks irregularly when weathered	2	
3. Sandstone, fine-grained, bluish, calcareous, shaly in lower part. At the top it bears fucoid markings	4	
2. Sandstone, bluish, calcareous, fine-grained, with scattered grains of coarse sand and angular chert fragments included	2	
WARSAW ?		
1. Limestone, soft, cream-colored, cherty. Exposed	2	

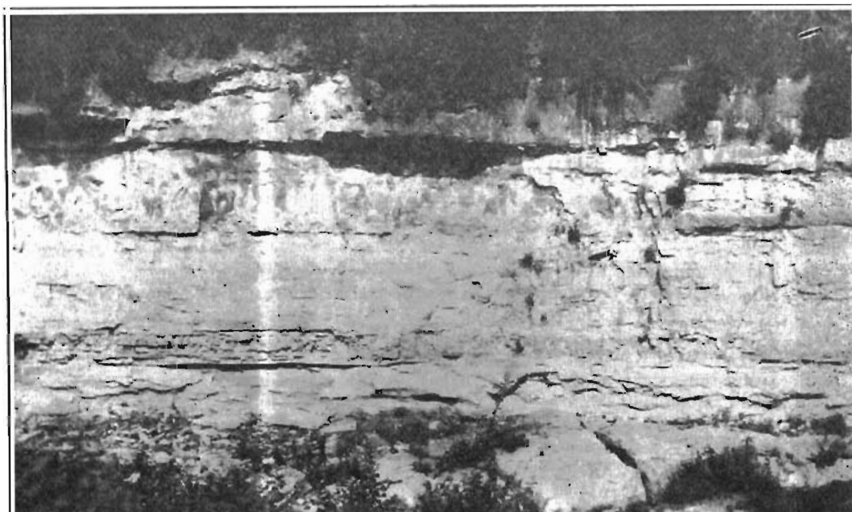

FIG. 15.—Undisturbed dolomitic phase of Lower St. Louis limestone. Rock creek, near Bentonsport.

A bed of sandstone is exposed in the south bank of Des Moines river approximately two and one-half miles below the town of Keosauqua. This has been referred to by C. H. Gordon[15] as the Keosauqua sandstone, which he regarded as a phasal development of the limestone designated in this report as the Verdi or Upper St. Louis.

The present study makes the reference of these beds in part to the basal Pella and in part to the upper portion of the Verdi appear more plausible. In the above mentioned bluff we have three to four feet of brecciated Pella limestone which is underlain by five to twenty-one and one-half feet of fine-grained massive yellowish sandstone. This in turn is followed below by rudely stratified conglomeratic limestone with a bluish sandy

15 Jour. Geol. vol. III, p. 304; 1895.

matrix. Locally this limestone is represented by sandstone containing blocks and pebbles of limestone. This bed ranges to more than fourteen feet in thickness. At the base is a brownish conglomeratic limestone ten feet thick which is believed to represent the basal beds of the Verdi. The massive sandstone of variable thickness below the Pella limestone is referred to the basal Pella while the underlying sandy conglomeratic limestone very probably belongs to the Upper St. Louis.

The Upper St. Louis is exposed on the west fork of Thatcher creek, about one hundred and fifty yards above its junction with the east fork near the middle of the west line of section 1, T. 68 N., R. 10 W. The formation at this locality contains a bed of sandstone.

Section on Thatcher creek.

		FEET
PELLA		
4.	Sandstone, soft, light gray when fresh but weathering yellowish; fine-grained, massive. Locally structureless but elsewhere exhibiting cross-bedding. Slightly overhanging. Exposed	10 to 12
UPPER ST. LOUIS		
3.	Limestone, compact, gray, rather brittle; in heavy layers when fresh but weathering to thin layers and flakes. Bears *Leperditia* sp. and shells of a small pelecypod. Apparently lenticular	2 to 4
2.	Sandstone, fine-grained, soft, bluish, calcareous. Thinnest where limestone above is thickest and vice versa	1 to 4
1.	Limestone, light gray, soft, massive, structureless, flaking off parallel to face of bluff; with occasional stylolytic seams and a few patches of greenish material. Exposed	6

At the north end of this bluff section all of the above beds are involved in a disturbance which was accompanied by considerable shearing and brecciation. The movement appears to have been due to compression which caused the converging of two blocks over a wedge-shaped mass. A tongue of mashed and brecciated Pella limestone about twenty-five feet broad is sheared down into the disturbed area although this member has been removed by erosion elsewhere in the bluff.

There is a second exposure of the same strata on the east fork of Thatcher creek just below the wagon bridge and a short distance above the junction with the west fork. Beds 1 and 2 of the preceding section are represented here by a continuous bed of sandstone with an exposed thickness of twelve and one-half feet.

At the Price quarry on Price creek in the southwest quarter of section 20, T. 69 N., R. 10 W., the Lower St. Louis shows evidence of its shallow water origin in the form of strongly developed cross-bedding and contemporaneous erosion phenomena.

Section in the Price quarry.

		Feet	Inches
6.	Drift, yellowish, sandy, oxidized. Maximum thickness	10	
Upper St. Louis			
5.	Limestone, buff, dolomitic, in rather thin layers	2	
4.	Limestone, buff, dolomitic, compact, disturbed, brecciated and conglomeratic. At one point this member bears at the top a bed of medium-grained gray sandstone one foot thick. Resting irregularly on bed below	5	8
Lower St. Louis			
3.	Limestone, compact, gray, tough, unaltered. Preserved as a small lens at one point only	0 to 10	
2.	Limestone, fossiliferous; in places cherty; imperfectly dolomitized. Represented at some points by compact gray limestone with molds of fossils and at others by dense bluish magnesian limestone weathering buff. Locally this bed appears to fill small channels in the bed below. One such channel is three feet deep and about twenty-four feet wide. This member is evenly bedded while the member below is cross-bedded	0 to 2½	
1.	Limestone, in the form of one massive ledge in quarry face, arenaceous, magnesian; filled with rather coarse sand grains; bluish when fresh but weathering buff, cross-bedded; locally exhibiting a tendency towards thin lamination	7	

The cross-bedding in bed 1 is on a large scale. The heavy sloping massive layers are truncated by the bed above. A short distance down the creek, in the south bank, twelve feet of cross-bedded limestone is shown at the horizon of bed 1. It is overlain by drift. The upper two feet is fossiliferous and more thinly laminated. Below these inclined layers is a blue soft limestone with fucoid markings resembling worm castings. It has an exposed thickness of two feet.

In the quarry at the mouth of Price creek, in the eastern part of section 20, the Upper St. Louis is thicker than usual and is somewhat different lithologically from other exposures in this part of the state.

Section in quarry at mouth of Price creek.

		Feet	Inches
8.	Drift.		
Pella			
7.	Limestone, gray, fractured	6	
6.	Sandstone, soft, fine-grained; resting upon the irregular surface of the bed below	6	8
Upper St. Louis			
5.	Limestone, gray, rather soft, in two massive ledges, fractured, stylolytic; with thin shaly seams near the middle which bear a few fossils such as *Syringopora* sp., *Orthotetes* sp., *Zaphrentis* sp.	11	9

4.	Limestone, buff, magnesian, dense and massive above but softer and thin-bedded below	3½ to 5	
3.	Limestone, consisting of interbedded layers of compact and granular gray limestone	4 1/3 to 5 1/3	
2.	Limestone, brecciated, buff, magnesian; shaly in upper part; poorly exposed	8	
LOWER ST. LOUIS			
1.	Limestone, buff, magnesian, bluish when fresh; fucoid markings in a zone about six inches below the top. Lower three feet arenaceous and cross-bedded. Upper part massive. To bed of creek	8	6

The Upper St. Louis is exposed in the south bank of Chequest creek at the bend about one-half mile above its mouth (NE.¼ of SW.¼ sec. 27, T. 69 N., R. 10 W.). It is here represented in part by sandstone as in the Thatcher creek section.

Section on Chequest creek.

		FEET	INCHES
PELLA			
6.	Limestone, gray, slightly brecciated	7	6
5.	Sandstone, massive, fine-grained; bluish when fresh but weathering yellowish; with occasional angular and subangular blocks of compact gray limestone which bear pelecypods resembling Pella types	6 to 7½	
UPPER ST. LOUIS			
4.	Limestone, compact, gray, with a tendency to cleave; locally mashed	1 to 3½	
3.	Sandstone, massive, bluish; in places filled with rounded and subangular pebbles of compact gray limestone	3 to 7	
2.	Limestone, fine-grained, gray, rather soft, massive, structureless, stylolytic; with occasional small dark colored rounded chert concretions; tending to flake off parallel to face of bluff. Total thickness exposed only at one point where a small anticline brings it above the level of the creek. Locally slightly brecciated	8	6
1.	Sandstone, fine-grained, bluish, soft, some layers calcareous; exposed in a small anticlinal flexure	2	

Beds ranging from the Lower St. Louis limestone to the Des Moines sandstone are exposed in the Kilbourne bluff, in the east bank of Lick creek near its mouth, in the southwest quarter of section 1, T. 69 N., R. 10 W. The section is as follows:

Section in Kilbourne bluff.

		FEET
7.	Drift.	
DES MOINES		
6.	Shale, drab in basal part and carbonaceous above	28
PELLA		
5.	Slope, strewn with blocks of limestone	5
4.	Limestone, gray, resting on the uneven surface of the bed below	3
UPPER ST. LOUIS		
3.	Limestone, granular to compact, thin-bedded, much fractured; contact with bed below irregular	6 to 8½
2.	Limestone, dense, compact, gray, brecciated, no semblance of original structure preserved. Resting on the irregular surface of the bed beneath	3½ to 8½
LOWER ST. LOUIS		
1.	Limestone, buff, magnesian, massive. Exposed	16¼

The upper surface of bed 2 is very irregular. Mounds of conglomerate limestone locally extend several feet up into bed 3. Inasmuch as bed 3 does not arch up over these mounds but tends to fill in the depressions between them and is not itself conglomeratic it is believed that the disturbed character of bed 2 is original.

A bed resembling closely bed 3 of the preceding section is exposed in the east bluff of Des Moines river one and one-half miles southeast of Kilbourne. This bed rests directly upon the Lower St. Louis. It is possible that bed 2 of the Kilbourne bluff section is absent here, but this cannot be proven definitely. See the following section:

Section southeast of Kilbourne.

	FEET
5. Concealed to brow of hill.	
PELLA ?	
4. Sandstone, fine-grained	2 to 3
3. Concealed	1
UPPER ST. LOUIS	
2. Limestone, gray, granular to compact. Lower portion consisting of thin-bedded, granular and compact limestone which is somewhat cross-bedded where it is undisturbed. Upper portion consisting of a breccia of compact gray limestone in a calcareous matrix. Maximum measured thickness	14 2/3
LOWER ST. LOUIS	
1. Limestone, buff, magnesian. Exposed	20

Des Moines County.—In the report on the geology of Des Moines county Keyes[16] describes the distribution and character of the St. Louis as follows:

"The chief exposures of this formation are in the extreme southwestern corner of the county where it underlies an area of perhaps thirty square miles. It covers most of the uplands of Augusta township and probably nearly one-half of Danville township. A small area also occurs in the western part of Union township. The outcrops are principally on Long and Cedar creeks and on the Skunk river."

The exposures are small and the formation is similar in development in all respects to that in the adjacent counties of Lee and Van Buren.

Henry County.—The St. Louis limestone constitutes the bed rock over a much larger area in Henry than in any other county in Iowa. In the extreme western and southern borders there are narrow, irregular strips of Des Moines sandstones with oc-

16 Iowa Geol. Survey, vol. III p. 447; 1895.

casional small adjacent outliers. Small outliers of this formation occur also in Center township near the middle of the county and in the extreme southeastern part. The Keokuk limestone and Lower Warsaw shale outcrop along Skunk river in the south-central part of the county and along Mud creek, a tributary of this stream in the southwestern part. These are the only important known exceptions to the universal extent of the St. Louis as the surface rock of Henry county.

Nearly all of the important exposures of the formation are in the southern part of the county, the more typical outcrops being along Big Cedar, Little Cedar, Brush and Big creeks.

The most complete section observed by the writer in Henry county occurs along Big creek in section 7 of Baltimore township. Both divisions of the St. Louis appear in a high bluff just above the wagon bridge in the southwest quarter of this section. The Croton member is very much mashed and brecciated and is imperfectly dolomitized. It has a thickness of about thirty-five feet. The lower part is shaly and at the base of the section there are carbonaceous seams. At both the east and west ends of the bluff there appears more evenly bedded and less disturbed brownish dolomitic limestone, which abuts into the disturbed phase. Near the east end of the bluff the Upper St. Louis is exposed in the form of two beds of gray limestone. The lower bed is three to four feet thick and consists of fine-grained, dense much brecciated and partly dolomitized limestone. It has a rough upper surface and rests on the irregular surface of a soft brownish dolomitic limestone layer of Croton age containing silicified specimens of *Lithostrotion canadensis*. The upper bed consists of granular to compact thin-bedded slightly fractured limestone seven feet in thickness.

A few rods upstream from the above described bluff section the following succession is shown near the mouth of a small ravine:

Section on Big creek.

	FEET
PELLA	
7. Concealed; slope to top of hill overspread with blocks of Pella limestone	3
6. Limestone, exposed	1/3
5. Concealed; upper part of slope strewn with blocks of Pella limestone; lower part with blocks of fine-grained sandstone	9½
UPPER ST. LOUIS	
4. Limestone, granular to compact, no fossils noted	7½

	3. Limestone, fine-grained, compact, gray to buff; imperfectly dolomitized; little disturbed; contacts above and below poorly shown	3
LOWER ST. LOUIS		
	2. Limestone, buff, massive, dolomitic, probably the *Lithostrotion canadensis* zone	4
	1. Limestone, buff, massive, dolomitic	5

A third important exposure is shown above the bend of the creek near the center of section 7. The Lower St. Louis has an exposed thickness of thirty-five feet at one point. The lower part is mashed and deformed but the higher layers are only slightly brecciated. The Upper St. Louis is twelve feet thick and consists of two members very similar in character to those in the above described bluff section farther down stream.

A good exposure of the St. Louis is present in a meander scarp of Big creek, near the center of section 6 of Center township.

Section of St. Louis limestone on Big creek.

		FEET	INCHES
	8. Drift, yellowish brown clay containing gravel	2	
UPPER ST. LOUIS			
	7. Limestone, compact, gray, slightly brecciated; massive below but thin-bedded and nodular above; with rounded limestone pebbles in upper part	4	6
	6. Sandstone, gray, fine-grained, soft	8	
	5. Limestone, light gray, granular, bearing *Lithostrotion proliferum, Composita trinuclea, Spirifer* sp. and *Girtyella indianensis*	1	8
	4. Limestone, buff, dolomitic, soft, rather thin-bedded; weathering to thin irregular chips. A layer near the top is filled with worm castings	7	6
LOWER ST. LOUIS			
	3. Limestone, dolomitic, buff, in one massive ledge. The *Lithostrotion canadensis* zone	3	6
	2. Limestone, buff, dolomitic, in rather thin layers; resting on the irregular hummocky surface of the bed beneath	3	
	1. Limestone, gray, brecciated. The lower part is locally evenly bedded, buff and dolomitic	15	

The following beds of the St. Louis are exposed in the Winter quarry, located near the railway bridge over a branch of Big creek, in the southeast quarter of section 17, Center township:

Section of St. Louis limestone in the Winter quarry.

		FEET
	9. Drift	4
UPPER ST. LOUIS		
	8. Limestone, soft, shaly; mostly concealed at present	6
	7. Limestone, fine-grained, compact, gray; breaking with subconchoidal fracture; slightly brecciated	10
	6. Sandstone, fine-grained, bluish, shaly	4 to 5
	5. Limestone, fine-grained, dense, gray; in some places arenace-	

	ous; with nodules and bands of dark flint	½	to 1½
4.	Sandstone; in part fine-grained, gray, calcareous, massive; with irregular stratification lines; in part shaly and laminated; resting on the uneven, eroded surface of the bed below	1½	to 2½
3.	Limestone, light gray, compact, fine-grained, dense; usually badly mashed and brecciated but in places little disturbed; with occasional reddish chert nodules; resting on the uneven surface of the bed beneath	3	to 3½
LOWER ST. LOUIS			
2.	Limestone, buff, dolomitic; weathering into rather thin irregular layers; with small irregular patches of unaltered gray limestone and an occasional nonsilicified specimen of *Lithostrotion canadensis*	2½	
1.	Limestone, buff, dolomitic, in rather thin layers; obscure worm tubes noted at one point in upper part; bearing occasional rounded chert nodules: containing *Brachythyris altonensis*, *Aviculopecten* sp. and other fossils. Exposed	5	

Another excellent exposure of the Croton limestone is located approximately one mile east of the town of Lowell, in the west bluff of Mud creek, near the wagon bridge. This division is less disturbed at this locality than usual and consists of massive buff to brownish dolomitic limestone about thirty-five feet in thickness. It is underlain by shales of Lower Warsaw age.

The character of the St. Louis limestone in the northeastern part of Henry county is well brought out by the following description by Savage[17] of a quarry exposure in Scott township.

"Twenty miles directly north of the Lowell exposure and separated from it by almost the length of the county, there is an interesting quarry in the Se.¼ of section 4, of Scott township, about one mile northeast of the town of Winfield. At this place an exposure just north of the road on land owned by Mr. G. W. Wilson shows the following succession of layers:

Section.

		FEET
5.	Clay of a reddish brown color containing gravel	5
4.	Bed of fine-grained, fissile limestone, light gray in color, the layers one to three inches in thickness, and containing but few fossils	4
3.	Bed of rather soft, fine-grained standstone	6½
2.	Bed of bluish gray limestone, the layers three to eight inches in thickness near the top, but increasing to as much as twelve inches near the base. The layers are separated by shaly partings which contain numerous fossils	10
1.	Yellowish brown magnesian limestone perforated with irregularly shaped cavities; to the base of the exposure	2

Number 1 in the above section is of a stronger yellow color than the magnesian limestone usually met with over the county. It is less compact and contains a greater number of cavities which resemble water worn passages. No traces of fossils were

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17 Iowa Geol. Survey, vol. XII, pp. 277, 278; 1902.

found in the rocks of this member. Number 2 is a bed of gray limestone. The narrower layers are somewhat shaly and weather easily into thin fragments, but the thicker portions are compact and durable. The shaly bands are very fossiliferous and among them the following forms are abundant:

Zaphrentis spinulosa E. and H.	Fenestella sp.
Lithostrotion canadensis var. proliferum Hall	Dielasma formosa ? Hall
Syringopora sp. undet.	Spirifer keokuk Hall
Archaeocidaris sp. spines and plates	Eumetria marcyi Shumard
	Athyris subquadrata ? Hall''

Beds 1 and 2 of the above section probably represent the Croton while the overlying beds are believed to be of Verdi age.

Another section of interest, located in the northwestern part of the county, two miles west of Wayland, also is described by Savage.[18]

Section of St. Louis limestone west of Wayland (after Savage).

		FEET	INCHES
6.	Bed of brown sandstone, rather hard and coarsely granular	4	
5.	Layer of white fine-grained nonfossiliferous limestone	1	2
4.	Soft fine-grained sandstone	12	
3.	Layers of light colored limestone, eight to ten inches in thickness, containing no fossils	1	6
2.	Band of clay or marl containing very numerous casts of a fossil which somewhat resembles a species of *Athyris*	4	
1.	Layers of light gray nonfossiliferous limestone down to the level of the stream	2	

Jefferson County.—The mantle rock is underlain over the greater part of Jefferson county by the Des Moines formation. The St. Louis as mapped by Udden,[19] appears in the northeastern part of the county where it has been uncovered by Skunk river and its tributaries; over a small area in the extreme northwestern part of the county; as small inliers in the eastern, south-central, and southwestern parts; and as ribbon-like areas along Cedar creek and its tributaries in the southeastern part.

One of the most complete sections in the entire county may be studied in the Cedar Bluff of Skunk river just southeast of the mouth of Rattlesnake creek and one-fourth mile east of the southeast corner of section 12, Lockridge township. The St. Louis is underlain here by fine-grained, bluish sandstone of Spergen age with an exposed thickness of twenty-one feet.

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18 Idem, p. 276.

19 Iowa Geol. Survey, vol. XII, pp. 355-437; 1901.

Section of St. Louis limestone on Skunk river.

		FEET	INCHES
14.	Drift	1	
UPPER ST. LOUIS			
13.	Limestone, gray to light gray, less brittle and dense than the bed below, containing *Productus ovatus, Composita trinuclea, Allorisma sinuata*	2	6
12.	Sandstone, soft, fine-grained, bluish, incoherent	2	
11.	Sandstone, gray, calcareous, fine-grained, in a single layer		6
10.	Limestone, gray, compact, fine-grained, brittle, middle and upper parts with ribbon-like stratification	3	6
9.	Shaly parting		4
8.	Limestone, compact, dark gray, fine-grained; rather heavily bedded; slightly disturbed in upper part	1	6
7.	Limestone, compact, gray, nodular; in the form of rounded pellets, ranging from size of pea up to size of walnut, in a shaly matrix. Filled with *Composita trinuclea*		6
6.	Limestone, gray, compact, fine-grained, brittle; weathering into thin flakes; locally brecciated and mashed down into the bed below; with stylolytic seams. Lower contact poorly exposed but appears to be irregular where mashing has not taken place. *Spirifer* cf. *S. pellaensis* and *Composita trinuclea* ....5 to	6	
LOWER ST. LOUIS			
5.	Limestone, yellowish to brownish, dolomitic, much decayed: shale in lower and upper parts; of differing thickness due to mashing down of limestone above ....4½ to	7½	
4.	Limestone, brownish, tough, massive, dolomitic; with small fragments and nodules of chert; indistinctly stratified; contact with bed below is an irregular wavy line; slightly vesicular; in one massive layer	3	6
3.	Limestone, gray, tough, dolomitic, hard; weathering buff and soft; in layers 2 to 18 inches thick; receding slightly beneath bed above. Upper surface irregular. Top layer thickens and thins from above; shaly and arenaceous in lower part and grading down into the bed below	4	6
2.	Shale, bluish, argillaceous, with seams of light gray more calcareous shale	3	
1.	Limestone, compact, buff, dolomitic; in a single layer. Probably the base of the Lower St. Louis		8

An excellent section of the Lower St. Louis occurs in an old quarry opening in the north bank of Turkey creek near the center of the northeast quarter of section 11, Lockridge township. It is here underlain by fifteen and one-half feet of Spergen sandstone.

Section of Lower St. Louis limestone on Turkey creek.

		FEET
UPPER ST. LOUIS		
9.	Slope, covered with loose blocks of gray nondolomitic limestone.	
LOWER ST. LOUIS		
8.	Limestone, gray, dolomitic, weathering brownish, poorly exposed	3
7.	Limestone, gray weathering buff, soft, dolomitic, much rotted, structureless	4
6.	Limestone, dark gray weathering buff; tough; massive below but thin-bedded above; projecting	2¼
5.	Shale, bluish, weathering buff; arenaceous and dolomitic above but calcareous below	4 1/6
4.	Limestone, compact, dense, dove-colored, brittle; with fine	

	lines of stratification; upper and lower surfaces uneven; brecciated; mashed down at one point 2 or 3 feet into bed below; bearing many small irregular areas of calcite and a few buff patches of dolomite. Pinches out at east end of quarry, probably owing to dolomitization. Probably bed 8 of Cedar Bluff section	0 to 1¾
3.	Limestone, gray weathering slightly yellowish, soft, dolomitic; massive below but laminated above; of variable thickness owing to mashing down of bed above	3 to 4 1/3
2.	Shale, bluish, calcareous, weathering slightly yellowish; of variable thickness owing to mashing	1½ to 3
1.	Limestone, gray, subcrystalline; mottled with yellowish dolomitic patches above, but shaly, buff and dolomitic below; resting on the slightly undulating surface of the Spergen sandstone	1

The following section is exposed in a quarry and in the ravine nearby in the southwest one-fourth of the southeast quarter of section 3, Lockridge township.

Section of St. Louis limestone in section 3, Lockridge township.

		FEET	INCHES
UPPER ST. LOUIS			
12.	Sandstone, gray, calcareous	1	6
11.	Sandstone, fine-grained, soft, shaly	3	
10.	Limestone, gray, compact	1 to 2½	
9.	Limestone, compact, gray, nodular; filled with a *Composita*		6
8.	Limestone, gray, compact, brecciated	3 to 5½	
7.	Shale, bluish, calcareous; of variable thickness owing to mashing	1 to 3	
6.	Limestone, brownish, dolomitic, tough; with reddish, quartzose masses		6
LOWER ST. LOUIS			
5.	Limestone, gray, compact, containing *Lithostrotion proliferum, Syringopora* sp. and *Composita trinuclea*	2	6
4.	Limestone, gray, dolomitic, slightly vesicular, massive; worm burrows in 6 inch zone at top	5	6
3.	Shaly parting		8
2.	Limestone, gray weathering yellowish, dolomitic, tough, massive; irregularly bedded owing to mashing and deformation	7	6
1.	Shale, bluish, dolomitic, weathering buff. Exposed	4	

Other characteristic exposures appear in Round Prairie township. The accompanying section is exposed in the bluff at the south end of the bridge over Cedar creek, near the middle of the south line of section 33.

Section of St. Louis limestone on Cedar creek.

		FEET	INCHES
10.	Drift, to brow of hill	6	
UPPER ST. LOUIS			
9.	Limestone, gray, fine-grained, compact	1	6
8.	Concealed	1	3
7.	Sandstone, gray weathering buff; massive in middle but thin-bedded above and below	7	
6.	Shale, soft, buff, dolomitic	8	8
LOWER ST. LOUIS			
5.	Limestone, gray, fine-grained, compact, brittle, nondolomitic;		

		FEET	INCHES
	containing *Lithostrotion proliferum*, *Spirifer* sp., and other fossils	1	7 to
		2	
4.	Limestone, gray weathering buff, dolomitic, with occasional rounded chert nodules; rather soft above. Bears the following fossils: *Girtyella indianensis*, *Spirifer* sp., *S. pellaensis*, *Composita trinuclea* and *Straparollus* sp.	4	
3.	Limestone, gray, dolomitic, weathering buff; in two heavy layers	2	8
2.	Limestone, gray, arenaceous, thin-bedded; cross-bedded below; bearing *Lithostrotion proliferum*	4	2
1.	Limestone, gray, subcrystalline, nondolomitic. Exposed to level of water in creek	1	6

A good exposure of the St. Louis occurs in the north bank of Cedar creek a short distance east of the southwest corner of section 34 of the same township.

Section of St. Louis limestone on Cedar creek in section 34.

		FEET	INCHES
UPPER ST. LOUIS			
5.	Limestone and sandstone interbedded, the sandstone predominating below and the limestone above. Sandstone soft, fine-grained and gray; limestone gray, compact, dense and slightly brecciated. At the top no sandstone appears and the limestone is filled with small sinuous tubes of calcite. Some of the limestone layers exhibit a tendency towards lamination	23	
4.	Limestone, gray, fine-grained; filled with dark brecciated chert	1	6
3.	Sandstone, gray, calcareous, weathering yellowish, very iregularly bedded. Locally filled with small angular fragments of whitish chert	4	
LOWER ST. LOUIS			
2.	Limestone, light gray, fine-grained; weathering to irregular angular blocks. Bears *Lithostrotion canadensis* in calcareous form. This and the bed below are undulating and much disturbed	1	9
1.	Limestone, dark gray, dense, compact, tough, brecciated. Exposed to water level	4	6

At the meander scarp of the large meander, a short distance east of this point, in the northeast quarter of the southwest quarter of section 34, the Pella limestone, with a basal sandstone three to four feet in thickness, rests upon bed 5 of the preceding section.

Numerous other outcrops of the St. Louis limestone in Jefferson county have been described by Udden[20] but inasmuch as the general character of the formation is much the same as in the exposures described above further space will not be given to them here.

Wapello County.—The beds in Wapello county which were mapped and described as St. Louis by Leonard[21] are believed

20 Iowa Geol. Survey, vol. XII, pp. 368-386; 1901.

21 Iowa Geol. Survey, vol. XII, pp. 439-499; 1901.

to be everywhere of Pella age. They were so identified by him with the exception of a layer of soft sandstone, which was seen below the limestones at two localities, and which he referred to the Verdi. According to the observations of the writer this sandstone is more probably of basal Pella age and it is so regarded in this report.

Louisa County.—In the report on Louisa county submitted by Udden[22] reference is made to only one locality where rocks believed to be of St. Louis age outcrop. I quote from his description:

"On the left bank of Honey creek in the Se.¼ of the Sw.¼ of Sec. 32, Tp. 73 N., R. 3 W., some twenty rods north of the boundary of the county, there is a limestone breccia of greenish gray color composed of fragments of varying sizes, interbedded in a calcareous matrix of the same color. Some of the limestone blocks contain fragments of crinoid stems and other unrecognizable fossils. There are also seen in them some small cavities filled with a bright green clay. The breccia is only three or four feet high in the bank and rests on an uneven surface of the lower formation, which is yellow and weathered. An unconformity is here indicated. The rock extends only a few rods along the stream. A little farther down some reddish shaly beds appear on the same side of the creek. These are apparently continuous with the geode-bearing horizon of the Augusta (Osage), exposed nearby. The limestone breccia on this creek is entirely unlike anything else seen in the county. Doctor Bain, who visited the locality in company with the author, inclines to the opinion that it represents the St. Louis stage. If such is the case there are possibly some more outliers of the same formation under the drift in the southwest part of the county, where the bed rock occurs in wells at a considerably higher level than that of the Burlington limestone in the nearest outcrops".

Washington County.—Beds of St. Louis age cover the southern part of the county with the exception of small areas in the southwestern part which are buried by the Des Moines formation.

The type section of the Verdi member is located in this county at an abandoned quarry one-half mile south of Verdi station, in the eastern part of section 9 of Brighton township. The succession of beds there is as follows:

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22 Iowa Geol. Survey, vol. XI, pp. 55-126; 1901.

Section one-half mile south of Verdi.

		FEET
6.	Drift, reddish, with decayed granite bowlders	4½ to 11
DES MOINES		
5.	Sandstone, coarse-grained, yellowish, soft	0 to 6½
VERDI		
4.	Limestone, compact, gray, finely brecciated	1/3
3.	Limestone, ash-gray, fine-grained, rather soft, brecciated; thin-bedded and laminated above; locally little disturbed and heavily bedded below. Filled with stylolytic structure along fractures. Small pelecypods and *Leperditia* abundant in laminated layer at very top	9½
2.	Sandstone, gray, fine-grained, soft, incoherent, shaly; thickens and thins owing to mashing down of limestone above	1 to 2½
1.	Sandstone, massive, fine-grained, gray, soft, weathering yellowish; with mashed irregular lentils of compact gray limestone. Exposed	7

In an exposure two hundred yards north of the preceding section in the west bluff of a small creek which parallels the railroad the Lower St. Louis appears. It consists of twenty feet of sandstone, dolomitic and shaly below, with a large lentil of compact gray limestone, about five feet thick in the middle and fifty feet long, in the upper part. A thin seam of finely brecciated limestone near the top of the lens is filled with a small brachiopod resembling *Girtyella.* Below the dolomitic shales comes four feet of thin-bedded, laminated buff dolomitic limestone with thin light gray to whitish chert bands.

The following fossils were collected from bed 3 of the above described quarry section.

Orthotetes ? sp.
Pustula alternata (N. and P.)
Girtyella indianensis (Girty)
Spirifer cf. S. pellaensis Weller
Composita trinuclea (Hall)
Edmondia ? sp.
Aviculopecten sp.
Aviculopecten sp.
Allorisma sinuata McChesney ?
Laevidentalium ? sp.
Bellerophon sp.
Leperditia carbonaria Hall

The Lower St. Louis is exposed in the vicinity of Brighton mill, one mile slightly east of north of the town of Brighton, in the southwest quarter of section 20, Brighton township. The following section appears in the Skunk river bluff at the mill and in the banks of a small creek just south of the mill.

Section at and near Brighton mill.

		FEET
7.	Drift to brow of hill	3
UPPER ST. LOUIS		
6.	Limestone, gray, compact, brecciated; not well exposed	8
5.	Sandstone, gray, fine-grained, massive, calcareous	5
4.	Sandstone, yellowish, soft, incoherent; filled with small angular fragments of whitish chert	2 to 3

LOWER ST. LOUIS		
3.	Concealed	3
2.	Shale and limestone; thin layers of dark gray compact, dense limestone weathering buff, intercalated with layers of shale....	1¾
1.	Shale, bluish, argillaceous, with thin sandy seams	14

In a quarry one-half mile south of the Brighton mill a bed believed to represent an upward continuation of number 6 of the preceding section is overlain unevenly by sandstone and shale, viz.:

Section one-half mile south of Brighton mill.

		FEET
4.	Drift	4
3.	Shale, bluish, argillaceous	1
2.	Sandstone, gray, fine-grained, thin-bedded, calcareous; weathering yellowish on surface; slightly cross-bedded; with thin seams and lenses of compact gray limestone in lower part. Resting on the uneven surface of the bed beneath	5
1.	Limestone, gray, fine-grained, compact, dense, brittle; breaking with subconchoidal to splintery fracture; in heavy, massive layers. Lower part slightly brecciated locally; with occasional small nodules of chert. *Leperditia* zone at top 4 to 6 inches thick. Bed 6 of preceding section. Exposed	5

The fossils listed below are from bed 1:

Zaphrentis sp.
Syringopora sp.
Orthotetes ? sp.
Productus ovatus Hall ?
Girtyella indianensis (Girty)
Spirifer sp.
Composita trinuclea (Hall)
Allorisma sp.
Sphenotus sp.
Myalina ? sp.
Straparollus sp.
Leperditia carbonaria Hall ?

An exposure in a ravine one hundred yards south of the quarry section shows the shale bed, number 3, to be overlain by five and one-half feet of interbedded shales and limestones filled with characteristic Pella fossils. It is probable therefore that the sandstone bed, number 2, of the quarry section represents the basal member of the Pella formation. Bed 1 undoubtedly represents bed 3 of the Verdi section.

An exposure in an abandoned quarry along the Chicago, Burlington and Quincy railway one-half mile northeast of Coppock probably represents a shaly facies of the Lower St. Louis. No fossils were found.

Section northeast of Coppock.

		FEET
3.	Limestone, brownish, dolomitic, with shaly and sandy seams; much decayed and rotted, and with solution cavities	8
2.	Shale, dolomitic and arenaceous, buff, poorly exposed	12
1.	Sandstone, fine-grained, gray weathering yellowish. Exposed	3

Bain[23] has described other exposures of the St. Louis along

[23] Iowa Geol. Survey, vol. V, p. 143 ff; 1896.

Crooked creek in the southeastern part of the county and on Skunk river between the Brighton mill and the west county line.

Keokuk County.—The St. Louis limestone underlies the greater part of Keokuk county. Osage formations appear in the northeastern part and as isolated inliers in the St. Louis in the southern half of the county. Areas of Pennsylvanian project into the county on the west and southeast and there are small scattered outliers in the interior. Elsewhere the St. Louis is the bed rock.

The St. Louis as developed in Keokuk county has been subdivided by Bain[24] into three members designated as the Springvale, the Verdi, and the Pella. He reports the Pella beds as being sparingly present.

His type section of the Springvale is at the old Springvale mill on South Skunk river in section 34, Warren township. The writer has pointed out on an earlier page (p. 181) that the shaly beds exposed here are more probably of Keokuk age, as are the shaly beds in the "granite" quarry northwest of Ollie, which were referred by him to the Springvale. It is apparent, however, that in a few instances, the beds elsewhere in the county designated by him as Springvale are of true Lower St. Louis age.

One of the most typical sections of the Upper St. Louis appears in a cut of the Minneapolis and Saint Louis railway one and one-half miles west of Ollie, in Jackson township. The following description of this is modified after Bain.[25]

Section of Upper St. Louis limestone west of Ollie.

		FEET	INCHES
8.	Drift, reddish	6	
7.	Limestone, gray, compact, with subconchoidal fracture, laminated; in the form of large lenses in the upper part of the sandstone member below	2	6
6.	Sandstone, fine-grained, yellowish, of differing thickness due to limestone lenses in upper part. With rounded blocks of limestone in lower part	2½ to 6	
5.	Limestone, compact, gray, not everywhere present		8
4.	Limestone, brecciated, with shaly and sandy matrix		6
3.	Limestone, gray, fine-grained		4
2.	Limestone, gray, compact, finely brecciated; upper part locally undisturbed	2	
1.	Limestone, gray, compact; locally slightly brecciated. Exposed	6	

24 Iowa Geol. Survey, vol. IV, p. 277 ff; 1895.
25 Idem, p. 281.

A layer of limestone at the very top of bed 1 is filled with a small species of a Pelecypod and a small *Leperditia.* The fossils of this bed and of bed 7 are as follows:

List of fossils from bed 1 of above section.

Stenopora sp.
Productus ovatus Hall
Spirifer cf. S. pellaensis Weller
Schizodus sp.
Modiomorpha sp.
Allorisma sp.
Allorisma sp.
Laevidentalium sp.
Bellerophon sp.
Bellerophon sp.
Bucanopsis sp.
Straparollus sp.
Leperditia cf. L. carbonaria Hall.

List of fossils from bed 7 of above section.

Orthotetes kaskaskiensis Weller
Spirifer pellaensis Weller
Composita trinuclea (Hall)

Ninety yards east of the above section, twenty-one feet of Lower St. Louis limestone is exposed in the bluff of a small creek which parallels the railway on the north.

Section ninety yards east of the preceding section.

	Feet
4. Drift.	
Lower St. Louis	
3. Limestone, brownish, soft, dolomitic, a thin-bedded chipstone; with occasional chert nodules and a few poorly preserved fossils	12
2. Limestone, brownish, dolomitic; massive above, but thinner bedded and rotted below	4
1. Limestone, shaly and arenaceous, bluish to buff; massive in lower part. Exposed	5

About one hundred yards east of this point another bluff on this branch shows Lower St. Louis in contact with the Upper. Twenty and one-half feet of dolomitic limestone, which is poorly exposed in its upper part, is succeeded by six feet of massive basal Verdi sandstone. This is overlain by two and one-half feet of shaly sandstone which is succeeded in turn by three feet of gray limestone.

Another interesting section appears one-fourth mile farther east in the north bank of the branch a short distance north of the railroad and about one and one-fourth miles west of Ollie.

Section in creek bed west of Ollie.

	Feet	Inches
9. Drift, with loose blocks of gray limestone	2	
Upper St. Louis		
8. Limestone, gray, compact, fine-grained, brecciated. Bed 1 of railway cut section	7	

		Feet	Inches
7.	Sandstone, very soft, incoherent, shaly	2	
6.	Sandstone, gray weathering buff, in one massive ledge; calcareous and irregularly stratified in lower part	5	
Lower St. Louis			
5.	Limestone, buff, dolomitic; with occasional seams and lenses of gray compact limestone. Contact with bed above irregular and undulating	1/3 to 1	
4.	Limestone, buff, fine-grained, dolomitic; soft and shaly in middle part; flaking off obliquely; with zone of worm borings four inches thick in lower part	2	6
3.	Limestone, gray, shaly, laminated		3 to 5
2.	Limestone, dark gray, fine-grained, dense		8 to 12
1.	Limestone, soft, buff, dolomitic. Exposed	1	3

Additional exposures in which the Verdi member of the St. Louis appears prominently are described by Bain (1) in a quarry located in the northeast quarter of section 12, T. 74 N., R. 12 W.; (2) in the bank of Cedar creek south of Sigourney (T. 75 N., R. 12 W., sec. 10, Se.¼ Sw.¼); (3) in a railway cut north of Hedrick and near Showman station; and (4) in the Atwood quarry (T. 75 N., R. 13 W., sec. 8, Ne.¼).

The best evidence at hand supports the view that the Lower St. Louis limestone rests upon shaly beds of Keokuk age in this part of the state although the writer has not observed any direct contacts.

In the "granite" quarry, which is located in the southeast quarter of section 10, Jackson township, typical Keokuk limestone is overlain by cherty dolomitic shale ten feet in thickness. The fauna of this shaly member indicates that it also is of Keokuk age, although Bain[26] referred it to the St. Louis. The following beds of Verdi limestone are exposed three hundred yards south of this quarry.

Section of Verdi limestone near the "granite" quarry.

		Feet	Inches
5.	Drift	1	
Upper St. Louis			
4.	Sandstone, fine-grained, gray, massive	3	
3.	Limestone, gray, compact, in single layer		6
2.	Limestone, gray, fine-grained, finely brecciated		10
1.	Limestone, gray, compact. Exposed	7	

Barometric measurements indicate that bed 1 of this section lies about twenty-two feet above the top of the highest member of the Keokuk in the "granite" quarry. It is believed that this interval is occupied by the Lower St. Louis limestone.

Bain[27] reports the occurrence of St. Louis limestone in con-

[26] Iowa Geol. Survey, vol. IV, p. 278; 1894.

[27] Idem, p. 273.

tact with the Augusta limestone (presumably Keokuk) in the Connor quarry, in the southeast quarter of section 15, Sigourney township.

His section is given below:

Section in the Connor quarry (After Bain).

		FEET
2.	Limestone, yellow, soft, magnesian; apparently arenaceous in part. Exposed	10
1.	Limestone, coarse, subcrystalline. Exposed at water's edge	4

Bed 2 was referred by Bain to the St. Louis and bed 1 to the Augusta. At the time of the writer's visit bed 1 was not exposed. Bed 2 is partly concealed but it resembles the Lower St. Louis limestone. Bain[28] says further:

"About two and one-half miles west of Connor's quarry (Tp. 75 N., R. 12 W., sec. 18, Se.¼ Se.¼), the Augusta limestone, having its usual characteristics, rises above the water four feet. Both above and below this point the St. Louis limestone is well developed."

Mahaska County.—According to Bain[29] the Verdi member of the St. Louis and the Pella beds are the only Mississippian formations exposed in Mahaska county. They outcrop at intervals along the valleys of North Skunk, South Skunk and Des Moines rivers, which flow in a southeasterly direction across the county in the northeastern, middle and southwestern parts respectively. Both the Verdi and the Pella members were mapped by Bain as St. Louis without differentiation. The Verdi in this area contains a large proportion of sandstone.

At Roberts mill, on North Skunk river, (T. 76 N., R. 14 W., sec. 4, Nw.¼ Ne.¼) Bain[30] found twelve feet of poorly exposed interbedded sandstone and limestone of Verdi age. He also reports six feet of interbedded Verdi limestone and sandstone as being exposed at McBride's mill in the southwest quarter of section 15 of the same township. These beds are overlain by fossiliferous marls and limestones of Pella age.

The Verdi beds as shown in the valley of Des Moines river in the southwest quarter of section 14, T. 75 N., R. 14 W., have an

28 Iowa Geol. Survey, vol. IV, p. 273.
29 Idem, p. 333 ff.
30 Idem, p. 325.

exposed thickness of thirty-five feet and consist of soft yellow cross-bedded sandstones which are capped locally by limestone. An exposure showing the Verdi limestone and sandstone overlain by the Pella beds appears in the valley of Spring creek and in the Des Moines river bluff nearby in the northwest quarter of section 4, T. 75 N., R. 15 W.

Other interesting exposures of the Verdi along Des Moines river are described by Bain[31] as being present at and above Bellefountaine in the western part of Scott township. In section 18 he found eight feet of white calcareous sandstone overlain by twelve feet of fine-grained bluish sandstone. Southward, in section 19, fifteen feet of limestone with irregular, cross-bedded sandstone layers of Verdi age is overlain by more than one hundred feet of Des Moines sandstones and shales.

Marion County.—The Verdi beds are the lowest member of the St. Louis exposed in Marion county. So far as the writer is aware outcrops of these beds are confined to the valleys of South Skunk river and its tributary, Thunder creek, in the northeastern part of the county.

The following section is typical of the Thunder creek exposures. It is located in the east bluff of an old meander in the creek which is now abandoned as a result of an artificial cut-off in the northeast quarter of section 26, T. 77 N., R. 18 W.

Section of Verdi beds on Thunder creek.

		FEET	INCHES
5.	Drift	3	
4.	Shale, marly; with thin irregular layers of fine-grained gray limestone. Exposed	4	
3.	Limestone, gray; with included rounded pebbles and grains of compact gray limestone and dark flint	1	6
2.	Shale, bluish, argillaceous, weathering buff	4	6
1.	Sandstone, yellowish, massive; with thin interbedded layers of compact gray limestone which weather in relief	27	6

Poweshiek County.—The geological map which accompanies Stookey's[32] report on the geology of Poweshiek county shows an area of St. Louis limestone in the southeastern part of the county. Inasmuch as no descriptions of outcrops in this area are given it is not known whether this represents the true St. Louis or the Pella since both were mapped as St. Louis in the reports issued at that time.

31 Iowa Geol. Survey, vol. IV, p. 330.
32 Iowa Geol. Survey, vol. XX, pp. 237-270; 1910.

Descriptions are given of exposures of both Pella and Verdi limestones in Sugar Creek township in the southwestern part of the county. Stookey's statements regarding the Verdi are as follows:

"In the northwest quarter of the southwest quarter of section 36, Sugar Creek township, in the east bank of the river near the Stilwell bridge, eight feet of rather heavily bedded, compact limestone is exposed. It represents the middle phase of the Saint Louis stage, known from the typical exposures at Verdi in Washington county, as the Verdi beds. No fossils were noticed. Above the limestone exposure the drift is intermingled with fragments of limestone, indicating the extension of these beds upwards. Elsewhere, as in Washington county, the Verdi beds are characteristically brecciated, and in Keokuk county they alternate with beds of sandstone. The phase represented here is the compact cherty form of the limestone which to the southeast is found associated with sandstone."

The stratigraphic relations of the St. Louis in this county are not entirely clear, owing apparently to the lack of outcrops showing this formation in contact with underlying deposits. It is possible that it rests upon the Kinderhook locally as indicated by Stookey's geological map of the county. However, Norton[33] identifies strata below the St. Louis as Osage in his records of deep wells at Grinnell.

Marshall County.—With the exception of one small exposure in Bangor township, provisionally referred to the St. Louis by Beyer,[34] the bed rock over Marshall county is of Des Moines and Kinderhook age. Beyer's description of the doubtful beds follows:

"In Bangor township in the SW.¼ SW.¼ of sec. 16, a heavily bedded, close-textured limestone is quarried in the bottom of Honey creek. The rock is of a dark, ash-gray color and contains some small, cherty concretions. Iron pyrites occur in bands and sheets in certain layers. The rock breaks with an uneven or hackley fracture, and some blocks give a metallic chink when struck with a hammer. No fossils could be found. Lithologically, these beds have a very close resemblance to the lithographic facies of the Saint Louis limestone as exhibited at the quarries north of Ames on the Skunk river, and at Web-

33 Iowa Geol. Survey, vol. XXI, p. 580 ff.; 1912.

34 Iowa Geol. Survey, vol. VII, p. 227.

ster City on the Boone river. The area is mapped as Kinderhook, but probably should be referred to the Saint Louis. Coal Measures overlie these beds at this point."

Story County.—The highest consolidated rocks in Story county are everywhere of Des Moines age except for an irregular inlier in the vicinity of Ames, in the western part. This owes its development to a local doming of the rocks and subsequent erosion.

In the report on the Geology of Story county, Beyer[35] says:

"The chief outcrops occur along the Skunk and its immediate tributaries between Ames and Soper's mill, and along Onion creek, in Franklin township. The beds exposed consist, in the main, of impure limestone, but arenaceous layers and calcareous shales are usually also present."

One of the most typical exposures of the St. Louis in this area is in the southwest quarter of section 25, Franklin township. Beyer's description of this follows:

Section of St. Louis limestone on Skunk river (After Beyer).

		FEET
5.	Drift	5–10
4.	Limestone, earthy, yellow; very much disintegrated and rubbly; bedding planes almost eliminated	4
3.	Limestone, fossiliferous	1
2.	Limestone, similar to 4; bedding planes apparent, but showing tendency to become marly and assume a fissile structure in places	3
1.	Limestone, buff to gray-buff when unweathered and massive; layers from ten to twenty inches in thickness; compact, lithographic in texture, fracture conchoidal to uneven; and earthy when weathered (exposed)	6

He reports that a fenestelloid bryozoan and a syringoporid coral occur in the upper half of the exposure. From the fossiliferous bed he identified a cyathophylloid coral and several brachiopods.

Additional exposures of the St. Louis are to be found in the banks of Skunk river at Hannom's mill in the southwest quarter of section 23, Franklin township. The following section of an escarpment in the south bank was described by Beyer:

35 Iowa Geol. Survey, vol. IX, pp. 155-245: 1899.

Section on Skunk river at Hannom's mill (After Beyer).

		FEET
6.	Soil and bowldery wash	3
5.	Limestone, residual and concretionary	½
4.	Limestone, arenaceous, yellowish gray to blue-gray, thinly-bedded and much fractured; in places argillaceous, while in others tends towards the massive; and fissility is apparently a function of weathering; small cherty concretions present	6
3.	Sandstone, grayish blue, friable; shaly below	2
2.	Limestone, impure, grayish buff; uneven to earthy fracture; compact and heavy-bedded	4
1.	Limestone, gray-buff, compact, almost lithographic in character	5

The fossiliferous zone of the preceding section occurs in bed 1 at this locality and is at an elevation nearly twenty-five feet lower. The latter relationship probably is due to the arch which exists in the Ames area.

Beyer states that north of Hannom's mill the St. Louis is concealed by Pleistocene deposits as far as Soper's mill, in the southeast quarter of section 6, Milford township, where he found the following section:

Section on Skunk river at Soper's mill (After Beyer).

		FEET
4.	Drift, pale yellow, bluish below, unoxidized and unleached	10
3.	Limestone, rubbly, with occasional heavy ledges	10
2.	Limestone, cherty, concretionary, cavernous; some of the larger caverns coated with calcite crystals, which consist of complicated combinations of the scalenohedron and rhombohedron; also smaller quartz-decorated caverns	5
1.	Limestone, gray-buff, compact; heavy, but irregularly bedded; some of the layers two feet in thickness	10

No fossils were found in these exposures but the strata were regarded as representing the St. Louis.

The following beds are exposed near the mouth of Onion creek. The section is revised from Beyer's by the writer.

Section of St. Louis limestone near the mouth of Onion creek.

		FEET
6.	Limestone, brownish, dolomitic, impure	6
5.	Limestone, brownish, heavy bedded; forming a projecting ledge	1½
4.	Limestone, shaly, containing *Productus ovatus* and *Fenestella multispinosa*	1
3.	Sandstone, yellowish, buff to gray buff; close textured, and bedding planes not apparent; the upper 15 inch layer more indurated than the lower part; nonfossiliferous	7
2.	Sandstone, bluish gray to yellowish gray; irregularly bedded; containing *Modiomorpha* sp.	4
1.	Sandstone intermixed with shale, thinly and evenly bedded; exposed	2

A similar exposure showing the same layers appears a short distance farther up the creek.

Webster County.—The Pella beds were included with the St. Louis in the geological report on Webster county,[36] therefore the areal distribution of the St. Louis as now delimited cannot be definitely determined without additional field work. The areas mapped as St. Louis by Wilder are small isolated patches chiefly along Des Moines river and its tributaries and in the valleys of Soldier creek and Lizard creek, in the central and north-central parts of the county. A small inlier in the east-central part also is indicated on the map. Elsewhere the country rock is of Pennsylvanian and Permian age.

The more important exposures in which St. Louis beds appear are located in the abandoned Miller quarry on Soldier creek; in the east bluff of Des Moines river in the southeast quarter of section 7 and across section 18, Cooper township; and along Lizard creek west of Fort Dodge. All of these sections have been described by Wilder[37] but they were revisited and examined by the writer.

The Miller quarry is located just below the stone bridge over Soldier creek in Fort Dodge. The revised section follows:

Section in the Miller quarry.

	FEET	INCHES
7. Drift	1	
UPPER ST. LOUIS		
6. Limestone, lenticular, gray, compact, brecciated, fossils scarce and poorly preserved	0 to 1	6
5. Sandstone, fine-grained	3 to 6	
4. Sandstone, fine, calcareous, in a single layer	1	6
LOWER ST. LOUIS		
3. Limestone, massive, dolomitic in lower part; less disturbed than the beds below	3	6
2. Concealed	7	6
1. Limestone, yellowish, tough, dolomitic, in mashed undulating layers. Exposed in bed and bank of creek near by	4	

The beds are arched up in the quarry. The contact of beds 3 and 4 is irregular, indicating a disconformity. The exposure gives evidence of small cavities in the limestone which are filled with sandstone.

Wilder[38] states that "a little above Miller's quarry, on Soldier creek, the St. Louis limestone gives place to Coal Measure shales. One-half mile farther up Soldier creek in Cooper town-

36 Wilder, F. A., Iowa Geol. Survey, vol. XII, pp. 63-235; 1902.
37 Idem, p. 78. See also vol. XXVIII, map in pocket and pp. 139-147, 163, 164; 1918.
38 Idem, p. 79.

ship, section 19, NE.¼, the limestone again comes to the surface and appears for 200 feet in the creek bed''.

Still farther up Soldier creek in the southwest quarter of section 17, the St. Louis is overlain by gypsum beds which are believed to be of Permian age.

At one point seven feet of massive gypsum overlain by thirty feet of red sandy shale appears in the bank of the creek. The gypsum comes down to the water's edge. ''One hundred yards farther down stream, at the water level and for three feet above it, the St. Louis limestone is exposed''. Within another hundred yards the limestone gives way to Coal Measure shale.

The east bluff of Des Moines river in section 7 of Cooper township shows the following beds:

Section on Des Moines river in section 7, Cooper township.

	Feet	Inches
Upper St. Louis		
4. Sandstone, fine-grained, soft, incoherent, marly above	10	
3. Sandstone, fine-grained, gray, calcareous, in one heavy layer	1	2
Lower St. Louis		
2. Limestone, gray weathering buff, massive, zone of worm burrows in lower and middle parts. A thin flint layer near the top	8	
1. Concealed to level of water in the river	3	6

A few yards down stream a massive layer of finely brecciated compact gray limestone three feet thick comes above the level of bed 4. Drift overlies the limestone. Farther up the river, around the bend Wilder found Coal Measure shales resting upon ten feet of St. Louis limestone. Several other exposures of limestone along the river between this point and the north boundary of the county are described by the same writer.[39] He says: ''The striking peculiarity of the limestone in the northern part of the county is the great amount of drusy quartz and flint that it carries, most of it in the upper brecciated layers. Frequently the masses weigh 200 pounds. Calcite is also abundant.''

Small exposures of the St. Louis along Des Moines river below Fort Dodge are described by Wilder from sections 5, 8 and 16 of Pleasant Valley township. Elsewhere the Coal Measures appear along the valley.

The Lizard creek sections are most important from the stand-

39 Idem, p. 82.

point of Pella stratigraphy but the St. Louis beds outcrop at a few points at the base of the exposures.

In a bluff section near the center of section 24, Douglas township, approximately thirteen feet of limestone, sandstone and shale of this age is overlain by more than fifty feet of strata referred to the Pella. A description of the individual beds is given below:

Section on Lizard creek.

		FEET
PELLA		
9.	Marl. Like bed below but free from red areas	6
8.	Gray marl blotched with red. Bears *Spirifer pellaensis, Pugnoides ottumwa, Composita trinuclea* and other fossils	34
UPPER ST. LOUIS		
7.	Limestone, drab, compact, shaly and laminated	3
6.	Shale, drab, argillaceous	3
5.	Sandstone	2
LOWER ST. LOUIS		
4.	Limestone as in bed 2	0 to 2/3
3.	Shaly parting	½
2.	Limestone, gray, dolomitic, tough; undulating owing to mashing. Bearing impressions of *Sigillaria*	2/3
1.	Sandstone, fine-grained, gray, thin-bedded. Exposed	3

Lees and Thomas[40] found thirty feet of St. Louis limestone exposed in the bluff of South Lizard creek just above the junction of the two branches of the Lizard, one mile west of the above section. The beds dip eastward, that is, downstream. One hundred feet upstream ten feet of green sandy marl grading up into gray sandstone underlies the limestone. Below a gap of six feet they found a two foot bed of limestone.

Humboldt County.—So far as the writer is aware only the Lower St. Louis is represented in these northernmost exposures of the formation in Iowa. It apparently rests everywhere on the Kinderhook formation, all of the pre-St. Louis Mississippian formations except the basal deposits having wedged out to the south of this area. The exposures are all in the form of small isolated patches along Des Moines river and its east and west forks.

An excellent opportunity of observing the contact of the St. Louis and Kinderhook limestones is afforded in the banks of a small creek a short distance southwest of the creamery at Rutland, in section 29, Rutland township.

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[40] Iowa Acad. Sci., vol. XXV, p. 602; 1918.

Section southwest of the creamery at Rutland.

		Feet
	4. Drift	2
St. Louis		
	3. Limestone, brecciated, dense, gray, imperfectly dolomitized; lower surface irregular and undulating	3
	2. Limestone, dense, gray, tough, in the form of one undulating layer which fills irregular depressions in the limestone beneath	½ to 1
Kinderhook		
	1. Limestone, light gray; stratification very imperfect; finely oölitic except in middle part where there is a thin seam of coarse oölite	2 to 3½

The contact of the Kinderhook and St. Louis is again shown at the point where this small creek joins the west fork of Des Moines river, just above the dam at the old mill site. At this point about four feet of the Kinderhook oölite is exposed above the bed of the creek. This is overlain by three feet of gray tough St. Louis dolomite which weathers yellowish. At one point in the exposure this dolomite grades laterally, in part at least, into unaltered gray brecciated limestone.

This contact is again shown in the river bank about seventy-five yards below the dam. Three feet of Kinderhook oölite is succeeded by two feet of yellowish St. Louis limestone in undulating layers, and this again by four feet of dense gray thin-bedded unaltered limestone of the same formation, which locally is mashed into mounds of breccia.

Where the St. Louis is disturbed the Kinderhook also shows considerable fracturing and slight brecciation.

Several other exposures between this point and the bridge show a similar relationship. The upper light gray limestone is five and one-half feet thick at one point. Where it is only slightly brecciated it tends to assume a massive appearance and in places is almost lithographic in fineness.

In the abandoned quarry and in the bank of a creek twenty yards west of the creamery at Rutland eight feet of St. Louis limestone is exposed. The lower two feet consists of disturbed, hummocky limestone but the upper six feet is made up of mashed layers of yellowish dolomitic limestone with seams and patches of gray dense unaltered limestone.

A small isolated exposure occurs along the West Fork of Des Moines river near the center of section 23, Avery township. Here the St. Louis is represented by undulating, slightly brecciated layers of gray dense limestone. A moundlike mass of structureless brownish dolomite which occupies the middle part of the outcrop contains small remnants of gray limestone.

Macbride shows on his geological map of Humboldt county a small area of St. Louis in the valley of the Des Moines in the northern part of section 17, Avery township. The limestone in the vicinity of Gilmore City in western Humboldt and eastern Pocahontas counties which was referred to the St. Louis by Macbride[41] is believed to be of Kinderhook age.

A small exposure of the St. Louis appears south of the town of Humboldt in the east bank of the West Fork of Des Moines river. In an abandoned quarry back of the slaughter house, south of the center of section 12, Corinth township, two feet of yellowish dolomitic limestone is succeeded above by two feet of gray to drab calcareous shale and this in turn by two feet of dense gray slightly brecciated limestone. A short distance farther downstream massive yellowish dolomitic St. Louis limestone rises ten feet above the water's edge.

The most complete section of the St. Louis in the county appears at the mill in the east bluff of the East Fork of Des Moines river at Dakota City. The section is as follows:

Section at Dakota City.

		FEET
5.	Drift	1
4.	Limestone, soft, brownish, dolomitic; massive and structureless and showing evidences of brecciation	8
3.	Limestone, brownish, soft, dolomitic; in layers 2 inches to 1 foot in thickness	3¼
2.	Thin interbedded layers of fine-grained gray sandstone and limestone	2
1.	Limestone, dolomitic, dense; gray when fresh but weathering yellowish or brownish: Exposed above level of water	2

No fossils were noted in any of the beds.

A very sharp flexure is shown in the strata near the middle of the exposure. The beds are bent down three feet in the space of six feet although they are essentially horizontal on each side. The axis of the flexure trends approximately northwest-southeast. Similar beds are exposed in the Welch quarry and in the river bank near by in the west bluff of the same stream in the southeast quarter of section 31, Grove township.

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41 Iowa Geol. Survey, vol. IX, pp. 131, 132; 1898.

Section in and near the Welch quarry.

		Feet	Inches
4.	Limestone, gray and medium-grained		8
3.	Sandstone, soft, incoherent, fine-grained, drab weathering yellowish	2	
2.	Limestone, buff, dolomitic; thin-bedded and arenaceous below, but more calcareous and massive above	5	
1.	Shale, drab when fresh but weathering yellowish, with thin layers of fine-grained drab sandstone also weathering yellowish. Exposed above water	3	6

The following section is modified after Macbride's description of an outcrop of St. Louis which appears in the east bank of Des Moines river, near the south line of the county.

Section in east bank of Des Moines river.

		Feet
8.	Limestone, soft, buff, dolomitic	6 to 10
7.	Limestone, yellowish, dolomitic, brecciated	5 to 7
6.	Shale seam with pockets of clay	
5.	Limestone, compact, gray	4
4.	Limestone, gray, dolomitic, weathering yellowish	2
3.	Limestone, gray, fine-grained	2
2.	Concealed	4
1.	Limestone, gray, weathering yellowish, in bed of river	

The quarry section in the city of Humboldt which Macbride describes as showing the St. Louis overlying the Kinderhook is concealed at present. But mounds of gray St. Louis limestone are exposed along the streets in the northwest part of the town. A particularly good outcrop may be studied three blocks north of Main street and one block west of the high school.

The Ste. Genevieve Formation

NOMENCLATURE

The name Ste. Genevieve was given by Shumard[42] to a limestone formation typically developed in the Mississippi river bluffs near Ste. Genevieve, Missouri. This formation is represented in Iowa by the Pella beds of earlier reports. The Pella formation, so named by Bain[43] because of its exposure near the town of Pella in Marion county, was formerly regarded as the topmost member of the St. Louis limestone. In the year 1900, however, Nickles and Bassler[44] correlated the Pella beds with the Ste. Genevieve formation upon the basis of the bryozoan element of their fauna. The Ste. Genevieve affinities of the

42 Trans. St. Louis Acad. Sci., vol. I, p. 406;1859.
43 Iowa Geol Survey, vol. IV, p. 282; 1894.
44 U. S. Geol. Survey Bull. 173, pp. 166 and 180.

fauna were later pointed out by Weller,[45] and the correlation was definitely established by Weller and Van Tuyl,[46] as a result of further field and faunal studies.

AREAL DISTRIBUTION

The formation has a limited areal distribution due in part to erosion in late Mississippian time prior to the deposition of the Pennsylvanian beds and in part to post-Pennsylvanian denudation. The most representative sections are along the tributaries of Des Moines river in Lee, Van Buren, Wapello, Mahaska and Marion counties. These deposits have also been recognized locally in southeastern Iowa in Henry, Jefferson, Washington, Keokuk and Poweshiek counties. To the northwest of the last named county the Pella beds, if present, are concealed by Des Moines sandstone as far as Webster county where several exposures of the formation appear.

On the areal geology map of the state of Iowa the Pella formation is grouped with the St. Louis limestone and the Spergen formation under the name of "St. Louis limestone."

LITHOLOGIC CHARACTER AND THICKNESS

The Pella formation is most typically developed in southeastern Iowa where it normally consists of a thin basal sandstone followed by a bed of shale about five feet in thickness, and this again by approximately twenty-five feet of compact thinly bedded limestone. To the northwest the limestones give way to shale. In Webster county, in north-central Iowa, the formation is represented almost entirely by shale, which is there about fifty feet in thickness.

STRATIGRAPHIC RELATIONS

The Pella beds rest disconformably upon the St. Louis limestone wherever their contact has been observed in Iowa. In most of the exposures where the contact is shown the basal sandstone of the formation succeeds the Verdi limestone member but at a few localities it overlies the Croton, or Lower St. Louis limestone. The formation is overlain disconformably by either Des Moines sandstone or Pleistocene deposits.

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45 Journal of Geology, vol. XVII, p. 278; 1909.
46 Proc. Iowa Acad. Sci., vol. XXII, p. 241 ff.; 1915.

CHANGES AT CLOSE OF STE. GENEVIEVE TIME

At the close of Pella time the sea withdrew from the Upper Mississippi Valley again and this region remained a land area until the close of the Mississippian period. A great warping began to the north at the time of this emergence and continued probably to the end of the Mississippian. This resulted in a tilting of the Mississippian and earlier formations to the southwest and was accompanied by the development of small northwest-southeast anticlines and synclines and by extensive brecciation of the hard, brittle St. Louis limestone.

Consequent upon this uplift erosion proceeded rapidly during the remainder of Mississippian time and the tilted beds were partly truncated, thus giving rise to a series of northwest-southeast belts of formational outcrops in Iowa, some of which were later buried by the Coal Measures.

This southwestward tilting of the beds in Iowa was related to a widespread late Mississippian deformation which involved also eastern Nebraska, eastern Kansas and Missouri, and outlined a great southwestwardly pitching geosyncline which was later occupied by the early Pennsylvanian sea as it advanced along a narrow trough from the southwest and gradually spread to the margin of the basin.

AREAL DESCRIPTION BY COUNTIES

Lee County.—The Pella formation is exposed at few localities in this county, although the underlying St. Louis limestone outcrops over large areas.

The section in the banks of a small creek emptying into Des Moines river in the lower part of the town of Croton is typical.

Section along creek near Croton.

	FEET
PENNSYLVANIAN	
3. Sandstone, yellowish, soft.	
PELLA	
2. Limestone, compact, light gray above but dark gray below; near the middle is a bed of calcareous shale 2½ feet thick....	9
1. Sandstone, yellowish, fine-grained; in some places soft and shaly in lower part; contact with bed below uneven; bearing large fucoid-like markings on surface of layers	4¼
UPPER ST. LOUIS	

The limestone member yields the following species:

BRACHIOPODA—
- Productus ovatus Hall
- Pugnoides ottumwa (White)
- Girtyella indianensis (Girty)
- Spirifer pellaensis Weller
- Composita trinuclea (Hall) ?

PELECYPODA—
- Edmondia sp.
- Schizodus sp.
- Schizodus sp.
- Allorisma sp.

TRILOBITA—
- Phillipsia ? sp.

Van Buren County.—The most important exposures of the Pella beds in Van Buren county appear along Des Moines river and its tributaries, especially on Indian and Reed creeks.

The following section was measured in an abandoned quarry on the south bank of Indian creek (NE.¼ of NW.¼, sec. 5, T. 67 N., R. 8 W.).

Section of Pella beds on Indian creek.

		FEET	INCHES
5.	Drift, yellowish, sandy	0–8	
PELLA			
4.	Limestone, light gray, dense, breaking with conchoidal fracture; coarser-grained and slightly crinoidal in the upper part; in rather heavy layers separated by thin partings of shaly limestone; locally seamed with calcite veinlets following fractures; some layers exhibiting stylolytic structure	8	6
3.	Shale, bluish, argillaceous, bearing many pelecypods in calcareous seams near top	3	5
2.	Limestone, gray, subcrystalline, with discontinuous seams of fine-grained sandstone in thin undulating layers; bearing a few small pelecypods		9
1.	Sandstone, fine-grained, rather soft; light gray when fresh but weathering yellowish; in some places with angular chert fragments in basal part	0–2	
UPPER ST. LOUIS			

The shale bed (bed 3) and the overlying limestone (bed 4) contain numerous fossils, as is shown by the following lists:

List of fossils from bed 3 of above section.

BRACHIOPODA—
- Pugnoides ottumwa (White)

PELECYPODA—
- Sphenotus (several species)
- Nucula illinoisensis
- Leda curta M. and W. ?
- Myalina sp.
- Schizodus (several species)
- Aviculopecten sp.
- Modiola sp.
- Allorisma sp.

GASTROPODA—
- Solenospira sp.

CRUSTACEA—
- Leperditia sp.

List of fossils from bed 4 of above section.

BRYOZOA—
- Rhombopora sp.

BRACHIOPODA—
- Productus ovatus Hall
- Pugnoides ottumwa (White)
- Girtyella indianensis (Girty)
- Spirifer pellaensis Weller
- Composita trinuclea (Hall) ?

PELECYPODA—
- Allorisma sp.

GASTROPODA—
- Bellerophon sp.

TRILOBITA—
- Phillipsia ? sp.

A remarkable section exhibiting both the Pella and the whole of the St. Louis appears in the south bluff of Reed creek about three-fourths of a mile above its mouth (near middle of north line, sec. 14, T. 68 N., R. 8 W.). The succession, as measured near the middle of the bluff, is as follows:

Section of Pella beds on Reed creek.

		FEET	INCHES
11.	Drift.		
PELLA			
10.	Limestone, light gray, compact to subcrystalline; some layers lithographic-like and breaking with conchoidal fracture; layers 1 inch to 1½ feet thick, separated by shaly partings some of which are highly fossiliferous; exhibiting much stylolytic structure; increasingly shaly in lower part and grading downwards into the bed below; locally brecciated in part	21	6
9.	Shale, bluish, argillaceous to calcareous, of variable thickness owing to mashing	3 to 6	
8.	Limestone, light gray, compact, in thin irregular layers with shaly partings		9
7.	Sandstone, bluish, fine-grained, rather soft, bearing rounded and subangular pebbles of compact gray limestone	6	
6.	Limestone, gray, compact in middle but subcrystalline above and below		4
5.	Sandstone, bluish, fine-grained, calcareous, massive, bearing rolled chert fragments	3	
UPPER ST. LOUIS			
4.	Limestone, buff, magnesian, arenaceous	6	
3.	Limestone, buff, dolomitic, massive	2	9
2.	Limestone, buff, dolomitic with small irregular remnants and blocks of compact gray limestone; slightly brecciated	9	
LOWER ST. LOUIS			
1.	Limestone, buff, dolomitic, mashed and brecciated, shaly in lower part	28	

Beds 9 and 10 of this section, which are to be correlated with beds 3 and 4 of the preceding Indian creek section, are fossiliferous.

List of fossils from bed 9 of above section.

BRACHIOPODA—
- Pugnoides ottumwa (White)

PELECYPODA—
- Solenomya ? iowensis Worthen ?
- Sphenotus (several undescribed species)
- Glossites (species undescribed)
- Edmondia (species undescribed)
- Nucula ? sp.
- Leda curta M. and W. ?
- Pinna (species undetermined)
- Myalina ? sp.
- Myalina (species undetermined)
- Schizodus (several undescribed species)
- Aviculopecten (species undetermined)
- Allorisma (species undescribed)

CRUSTACEA—
- Leperditia (species undetermined)

List of fossils from bed 10 of above section.

BRACHIOPODA—
- Productus ovatus Hall
- Girtyella indianensis (Girty)
- Pugnoides ottumwa (White)
- Spirifer pellaensis Weller
- Composita trinuclea (Hall) ?

PELECYPODA—
- Schizodus sp.

Other sections measured nearby in the same bluff showed considerable variation from that given, owing to differential erosion of the St. Louis prior to the deposition of the Pella and to the variable character of the basal beds of the Pella itself. The section presented, however, may be regarded as typical.

In another bluff on the opposite side of Reed creek about two hundred yards above the location of the preceding section the Pella beds are seen to rest upon somewhat lower beds of the Upper St. Louis. At this point, bed 10 of the foregoing section is represented by eighteen feet of limestone; bed 9 by three and one-half feet of shale; and beds 5, 6, 7 and 8 collectively by a continuous bed of sandstone ranging from twenty-four to thirty-four feet in thickness. The underlying St. Louis limestone is mashed here for the most part, and towards the top the matrix of the brecciated limestone is filled with sand grains probably derived from the overlying formation. The basal sandstone of the Pella attains a similar development in the vicinity of Keosauqua, whence the name Keosauqua sandstone as applied by Gordon.[47]

A very interesting and instructive exposure appears along a small branch of Des Moines river one and one-half miles north of Farmington, near the middle of the north line of the northeast quarter of section 26, T. 68 N., R. 8 W. Near the Yargus coal bank about fifteen feet of Pella beds is overlain by Des Moines sandstone. At the base of the exposure there is shown three to four feet of fine-grained Pella limestone. Overlying this member is eleven feet of fine-grained thin-bedded shaly sandstone also of Pella age. Des Moines sandstone caps the section. At one point in the bluff a shear zone appears in the Pella beds but does not traverse the Des Moines formation, which shows no disturbance whatever. Where this shear zone crosses the Pella sandstone there are numerous angular blocks of limestone resembling in every way the limestone which normally comes at the top of the Pella formation in this region. It is believed that the shearing took place directly after the deposition of the Pella and before erosion stripped off the limestone member which normally comes above the sandstone. After the shearing of fragments of this bed down into the sandstone a period of

47 Jour. Geol., vol. III, p. 304; 1895.

erosion, representing the disconformity between the Mississippian and Pennsylvanian systems, followed. It is believed that the shearing was contemporaneous, in part at least, with the local brecciation of the St. Louis limestone and that it was related to the regional uplift which caused a retreat of the Mississippian sea to the southward at the close of Pella time.

An exposure of the Pella beds appears approximately midway between the towns of Farmington and Bonaparte, on Slaughters branch (NW.¼ sec. 23, T. 68N., R. 8 W.).

Section of Pella beds on Slaughters branch.

		FEET	INCHES
4.	Limestone, formerly quarried on a small scale	13	6
3.	Shale	4	
2.	Limestone, compact, gray, dense		9
1.	Sandstone, fine-grained, light gray, soft and shaly in upper part. Exposed	2	10

The capping limestone contains several typical Pella brachiopods, viz.:

Productus ovatus Hall
Girtyella indianensis (Girty)
Pugnoides ottumwa (White)
Spirifer pellaensis Weller

At the southeast end of the bridge over Des Moines river at Keosauqua an exposure shows three to four feet of Pella limestone underlain by thirteen feet of sandstone. Blocks of the Pella limestone are mashed down several feet into the sandstone at one point.

Davis County.—In the report on the geology of Davis county, M. F. Arey[48] describes exposures of limestone along Des Moines river and its tributaries in the extreme northeastern part of the county. He refers these to the Pella but in the absence of lists of diagnostic fossils it is possible that they represent the St. Louis.

Henry County.—The most representative sections of the Pella formation in Henry county occur along Brush creek in the eastern part of section 6 of Baltimore township. The following beds appear in the east bank of the stream just north of the wagon road at the point where it crosses the creek.

48 Iowa Geol. Survey, vol. XX, p. 501 ff.

Section of Pella beds along Brush creek.

		FEET
PELLA		
3.	Limestone, gray, fine-grained, thin-bedded; shaly partings between the layers filled with fossils	8½
2.	Sandstone, fine-grained, gray, massive, weathering yellowish	21
LOWER ST. LOUIS		
1.	Limestone, buff, dolomitic, massive; *Lithostrotion* zone at the top	2

A well defined synclinal flexure is developed in the beds of this locality. In a quarry in the opposite bank of the creek, directly west of this exposure, bed 3 has an exposed thickness of six and one-half feet and is followed by the same thickness of highly fossiliferous calcareous shale with intercalated limestone layers. The shale is gray when fresh but weathers yellowish. About six feet of drift comes above.

The following species characterize the limestone (bed 3):

BRYOZOA—
Fenestella sp.
BRACHIOPODA—
Productus ovatus Hall
Pugnoides ottumwa (White)
Girtyella indianensis (Girty)
Spirifer pellaensis Weller
Composita trinuclea (Hall)
PELECYPODA—
Allorisma marionensis White ?

The overlying shale contains a somewhat more diversified faunule, as the following list shows:

ANTHOZOA—
Zaphrentis pellaensis Worthen
CRINOIDEA—
Stems and fragments
BRYOZOA—
Anisotrypa fistulosa Ulrich
Anisotrypa ramulosa Ulrich
Fenestella sp.
BRACHIOPODA—
Orthotetes kaskaskiensis (McChesney)
Productus ovatus Hall
Productus parvus M. and W.
Pugnoides ottumwa (White)
Spirifer pellaensis Weller
Composita trinuclea (Hall)
Cliothyridina sp.
PELECYPODA—
Allorisma sp.
VERTEBRATA—
Fish teeth

Jefferson County.—A number of exposures of the Pella beds in Jefferson county have been carefully described by J. A. Udden[49]. These occur on the north and middle branches of Walnut creek in sections 21 and 23 of Penn township; in the south bank of Brush creek, near the northeast corner of section 36, Lockridge township; in the bed of Wolf creek, south of the center of section 5, Round Prairie township; in the banks of Cedar creek in the southwest one-fourth of the southeast quarter of section 34, Round Prairie township; in the south bank of Rock creek in the northeast one-fourth of the northeast quarter of section 32, Round Prairie township; in a ravine about one-

49 Iowa Geol. Survey, vol. XII, pp. 373-386; 1902.

sixth mile southwest of the center of section 23, Round Prairie township; in the south bank of Cedar creek in the northeast quarter of section 34, Cedar township; in an old quarry in the east bank of Cedar creek, northeast of the center of section 10, Liberty township; near the Chicago, Rock Island and Pacific railway in the northwest one-fourth of the southeast quarter of section 9, Liberty township, and in the bed of Lick creek near the center of section 25, Des Moines township.

The section in the south bank of Rock creek, which was visited by the writer, is typical for the entire area. Udden's description is copied without change.

Section in the south bank of Rock creek (After Udden).

		FEET
10.	Gray marl	1/3
9.	Limestone	1/2
8.	Gray marl	1/2
7.	Limestone	1 1/3
6.	Marl	1/8
5.	Limestone	1
4.	Yellow marl containing *Productus ovatus, Productus marginicinctus, Pugnoides ottumwa, Spirifer keokuk, Seminula trinuclea,* (?) *Fenestella serratula, Anisotrypa fistulata,* cyathophylloids and stems of crinoids	5
3.	Limestone	1
2.	Marl with some of the same fossils as those above	1/8
1.	Quite evenly bedded ledges of bluish gray limestone	7½

The thickness of the formation in this county is given by him as seventeen feet. The above section therefore contains all the members of the Pella represented in this part of the state.

The fauna of the formation in this county as listed by Udden, but now subject to some revision in the light of more recent paleontological studies, is as follows:

List of fossils from the Pella beds in Jefferson county (after Udden).

PROTOZOA—
- Endothyra baileyi (Hall)
- Other rhizopods not identified

ANTHOZOA—
- Zaphrentis pellaensis Worthen

ECHINODERMATA—
- Pentremites koninckiana Hall
- Archaeocidaris (spines and separate plates, small)
- Crinoids (stems)

VERMES—
- Spirorbis ?

BRYOZOA—
- Anisotrypa fistulosa Ulrich
- Fenestella serratula Ulrich

BRACHIOPODA—
- Cleiothyris roissyi (Leveille)
- Derbya keokuk (Hall)
- Dielasma formosa (Hall)
- Dielasma turgida Hall
- Eumetria marcyi (Shumard)
- Productus marginicinctus Prout
- Productus ovatus Hall
- Camarotoechia grosvenori (Hall)
- Pugnoides ottumwa (White)
- Seminula trinuclea (Hall)
- Seminula sp. undt.
- Spirifer keokuk Hall

PELECYPODA—
- Allorisma marionensis White

Astartella sp.
Lithophaga pertenuis M. and W. (?)
Pinna ? (fragment)
ARTHROPODA—
Cytherellina glandella Whitfield
Leperditia carbonaria Hall
Phillipsia ? (pygidium)
VERTEBRATA—
Deltodopsis stludovici St. J. and W.

Wapello County.—Exposures of the Pella formation in Wapello county are confined to the valleys of Des Moines river and its larger tributaries in the central and northwestern parts. But rocks of this age are believed to underlie the mantle rock over small areas in the northeastern and southeastern corners of the county also.

It is probable that all the rocks in this county mapped and described by Leonard[50] as St. Louis are of Pella age. The sandstone below the Pella limestone which he referred to the Verdi is believed to be a basal sandstone of Pella age.

One of the most instructive and complete exposures of the formation in this county is in an abandoned quarry on Harrows branch, one-fourth mile above Second street, in the northwest part of the city of Ottumwa. The succession is as follows:

Section on Harrows branch.

	FEET	INCHES
8. Drift, yellowish	5	
DES MOINES		
7. Shale, dark, carbonaceous, contact with shale below obscure	4	
PELLA		
6. Shale, drab, marly, with harder calcareous seams in lower part; blotched and streaked with reddish patches	9	
5. Limestone, drab, fine-grained; massive when fresh but weathering shaly; grading into shale above and below	2	
4. Shale, like bed 6 but free from reddish patches; locally grading laterally into limestone	1	9
3. Limestone, like bed 5		6
2. Shale, like bed 4	3	2
1. Limestone, drab, fine-grained. Exposed	2	6

The following fossils were collected from the Pella beds at this locality:

ANTHOZOA—
Zaphrentis pellaensis Worthen
CRINOIDEA—
Crinoid stems
BRYOZOA—
Anisotrypa ramulosa Ulrich
Anisotrypa fistulosa Ulrich
Fenestella sp.
BRACHIOPODA—
Orthotetes kaskaskiensis (McChesney)
Productus parvus M. and W.
Productus ovatus Hall
Pugnoides ottumwa (White)
Girtyella indianensis (Girty)
Spirifer pellaensis Weller
Composita trinuclea (Hall)
Cliothyridina hirsuta (Hall)
PELECYPODA—
Allorisma marionensis White

50 Iowa Geol. Survey, vol. XII, pp. 439-499; 1901.

Other important exposures appear in the vicinity of the town of Dudley. The accompanying section is shown in a quarry opening on South Avery creek (SW.¼ of SE.¼, sec. 35, T. 73 N., R. 15 W.).

Section of Pella beds on South Avery creek.

		Feet
4.	Drift	1 to 2
3.	Limestone, shaly. Exposed	1
2.	Shale, marly, with a six inch layer of shaly limestone in middle	6½
1.	Limestone, gray, massive when fresh but weathering to thin layers, fine-grained. Exposed	6½

Bed 1 yields only a few species, namely: *Productus ovatus* Hall, *Pugnoides ottumwa* (White), *Spirifer pellaensis* Weller, *Composita trinuclea* (Hall) and *Allorisma* sp. The fossils of bed 2 are much more varied.

List of fossils from bed 2 of Pella formation on South Avery creek.

ANTHOZOA—
Zaphrentis pellaensis Worthen
CRINOIDEA—
Crinoid stems
BRYOZOA—
Anisotrypa ramulosa Ulrich
Anisotrypa fistulosa Ulrich
Fenestella sp.
BRACHIOPODA—
Orthotetes kaskaskiensis (McChesney)
Productus ovatus Hall
Productus parvus M. and W.
Pugnoides ottumwa (White)
Girtyella indianensis (Girty)
Spirifer pellaensis Weller
Composita trinuclea (Hall)
PELECYPODA—
Allorisma marionensis White
GASTROPODA—
Gastropod sp.

Two hundred yards south of the above exposure the following layers are exposed in the opposite bank of the creek.

Section of Pella beds two hundred yards south of the preceding one.

		Feet
4.	Drift	10
3.	Limestone, gray, fine-grained, thin-bedded	5½
2.	Concealed	2¼
1.	Sandstone, fine-grained, gray to buff, massive below but in thin cross-bedded layers above. Exposed	10

Several feet of the Pella are exposed in an abandoned quarry just west of the Chicago, Burlington and Quincy railway station at Dudley.

Section of Pella beds in quarry at Dudley.

		Feet
6.	Drift	10
5.	Limestone, gray, fine-grained, shaly	1½
4.	Shale, gray, marly	2
3.	Limestone like bed 5	½
2.	Shale, like bed 4	3
1.	Limestone, dove-colored, very compact, thin-bedded; coarser-grained and crinoidal in lower part. Exposed	6

The fauna of the formation at this place is very similar to that of the foregoing exposures.

Fauna of the Pella beds in quarry at Dudley.

ANTHOZOA—
- Zaphrentis pellaensis Worthen

CRINOIDEA—
- Crinoid stems

BRYOZOA—
- Anisotrypa fistulosa Ulrich
- Anisotrypa ramulosa Ulrich

BRACHIOPODA—
- Orthotetes kaskaskiensis (McChesney)
- Productus ovatus Hall
- Productus parvus M. and W.
- Pugnoides ottumwa (White)
- Girtyella indianensis (Girty)
- Spirifer pellaensis Weller
- Composita trinuclea (Hall)

PELECYPODA—
- Schizodus sp.
- Allorisma marionensis White
- Allorisma sp.

GASTROPODA—
- Bellerophon sp.

TRILOBITA—
- Phillipsia sp.

OSTRACODA—
- Leperditia sp.

An excellent exposure of the Pella beds in disconformable contact with the Des Moines formation may be seen half a mile east of Dudley where an artificial channel for North Avery creek has been cut in order to shorten its course. The following section was measured near the west end of the cut:

Section east of Dudley.

		FEET
7.	Drift.	
6.	Limestone, light gray, compact, fine-grained, thin-bedded above but in heavier layers below; with a coarser-grained crinoidal layer 20 inches thick in lower part	7
5.	Sandstone, fine-grained, soft, bluish, resting on the irregular surface of the bed beneath	1/6–½
4.	Limestone, dark gray, fine-grained, compact, locally coarser-grained and crinoidal in part, very irregular owing to extreme brecciation and mashing; lower boundary irregular owing to mashing down into soft sandstone below	3
3.	Sandstone, fine-grained, bluish, soft	1 to 1½
2.	Limestone, compact, dark gray, brecciated, with a sandy matrix	1 to 2
1.	Sandstone, gray, fine-grained, soft, irregularly and imperfectly stratified. Exposed	4½

A short distance east of this point a black carbonaceous laminated shale of Des Moines age occupies a broad shallow valley cut into the Pella formation.

On North Avery creek, nearby, a bed of sandstone with an exposed thickness of ten feet is followed above by Pella limestone like bed 6 of the above section, a concealed interval of two and one-half feet intervening.

Washington County.—The Pella beds extend northward from Jefferson county a short distance into southern Washington county. Bain[51] says:

[51] Iowa Geol. Survey, vol. V, p. 150; 1896.

"They have only been preserved from erosion in the immediate neighborhood of Brighton, in the bottom of what is probably a broad, shallow syncline."

The most representative exposures are in the western part of section 29 of Brighton township. The following succession is shown in the bank of a small ravine half a mile south of the Brighton mill.

Section of Pella beds near Brighton mill.

		FEET	INCHES
4.	Drift	3	
3.	Limestone, gray, fine-grained, in one heavy layer, containing *Spirifer pellaensis*, *Pugnoides ottumwa* and *Straparollus* sp.	1	6
2.	Limestone, drab, fine-grained, in layers 2 to 3 inches thick, separated by shaly layers 1 to 8 inches thick. *Pugnoides ottumwa* abundant	4	2
1.	Shale, bluish, arenaceous, with lenses and seams of compact gray brecciated limestone. Exposed	3	6

Bed 1 of the preceding section has a thickness of one foot in a quarry opening one hundred yards north of the ravine. It is underlain by five feet of gray fine-grained thin-bedded basal Pella sandstone which rests unevenly on the St. Louis limestone.

Keokuk County.—Exposures of the Pella beds in Keokuk county apparently are confined to its western half. Bain[52] refers to several quarries east and south of What Cheer in Washington township which derive stone from this formation. The more important of these are in the southeast quarter of section 11 and the northwest quarter of section 24. At the last locality *Pugnoides ottumwa* and other characteristic fossils were collected by him. Bain states that the quarries north of Sigourney, the county seat, are in both the Verdi and Pella limestones.

Mahaska County.—The distribution of the Pella beds in Mahaska county is similar to that of the St. Louis limestone, although they are not so extensive. Bain[53] describes scattered outcrops of the formation along the north and south forks of Skunk river and in the valley of Des Moines river.

On the north fork of Skunk river exposures appear (1) in the Meyer's section (T. 77 N., R. 16 W., sec. 1, NW.¼ SE.¼) where six feet of limestone is overlain by Des Moines shales and sandstones; (2) in the Union mills sections in the east half of

52 Iowa Geol. Survey, vol. IV, p. 305; 1895.
53 Idem, p. 324 ff.

section 23 (T. 77 N., R. 15 W.); and (3) in the McBride mill section (T. 76 N., R. 14 W., sec. 15, SW.¼). At the last named locality Bain measured the following section:

Section at the McBride mill.

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

Beds 1 to 4, which he refers to the Verdi, outcrop under the east pier of the bridge. Bed 6, the Pella, appears in a small quarry opening about two hundred yards west of the mill.

Bain identified the Pella on South Skunk river in (1) the Ballinger branch section (T. 76 N., R. 17 W., sec. 11, NW.¼), (2) in the waterworks section (T. 76 N., R. 16 W., sec. 25, SW.¼ SE.¼), and (3) in the Spring creek section (T. 75 N., R. 15 W., sec. 4, NW.¼). He also reports the presence of the Pella along Des Moines river in the Given (T. 74 N., R. 16 W., sec. 10, SW.¼) and Bluff creek (T. 74 N., R. 16 W., sec. 23, NW.¼) sections.

Poweshiek County.—The only exposure of the Pella beds recorded by Stookey[54] in his report on the geology of Poweshiek county is located in the southeast one-fourth of the northwest quarter of section 35, Sugar Creek township, where seven feet of interbedded shale and limestone of this age is overlain by Des Moines sandstone. The fauna listed by Stookey is very similar to that of the Pella in adjoining counties.

Marion County.—The type section of the Pella formation is near the town of Pella in Marion county. The nearest exposure of the beds to the town is in an abandoned quarry one-half mile southwest of the city limits (T. 76 N., R. 18 W., sec. 9, SE.¼). Other quarry openings are located a short distance south in the northeast quarter of section 16. The limestone which was formerly quarried no longer outcrops, but the overlying fossiliferous shales have an exposed thickness of eight feet. The following species were collected from these shales:

54 Iowa Geol. Survey, vol. XX, p. 255; 1909.

List of fossils from Pella shales near Pella.

ANTHOZOA—
Zaphrentis pellaensis Worthen
BLASTOIDEA—
Pentremites conoideus Shumard
CRINOIDEA—
Crinoid stems
BRYOZOA—
Anisotrypa fistulosa Ulrich
Anisotrypa ramulosa Ulrich
Fenestella sp.
Polypora sp.
BRACHIOPODA—
Orthotetes kaskaskiensis (McChesney)
Productus ovatus Hall
Productus parvus M. and W.
Pugnoides ottumwa (White)
Girtyella indianensis (Girty)
Spirifer pellaensis Weller
Composita trinuclea (Hall)
Cliothyridina hirsuta (Hall)
PELECYPODA—
Allorisma marionensis White
Schizodus sp.
TRILOBITA—
Phillipsia sp.

The limestone member of the Pella is exposed below the fossiliferous marls in the quarries southwest of the town of Tracy (T. 75 N., R. 18 W., sec. 35, NE.¼ of SE.¼). Near the middle of the quarry face the succession is as follows:

Section southwest of Tracy.

	FEET
DES MOINES	
5. Shale, dark, impregnated with carbonaceous material, arenaceous above	8
PELLA	
4. Shale, fossiliferous	4½
3. Limestone, gray, fine-grained, in a single layer	1
2. Limestone, gray, fine-grained, thin-bedded, rather soft and shaly	5
1. Limestone, similar to bed 3	2

The characteristic fossils of the limestone members are: *Pugnoides ottumwa*, *Spirifer pellaensis*, *Composita trinuclea* and *Allorisma* sp.

The assemblage in the shale is considerably more diversified, viz.:

List of fossils from shale bed at top of Pella in above section.

ANTHOZOA—
Zaphrentis pellaensis Worthen
CRINOIDEA—
Crinoid stems
BRYOZOA—
Anisotrypa fistulosa Ulrich
Anisotrypa ramulosa Ulrich
Fenestella cf. F. multispinosa Ulrich
BRACHIOPODA—
Orthotetes kaskaskiensis (McChesney)
Productus ovatus Hall
Productus parvus M. and W.
Pugnoides ottumwa (White)
Girtyella indianensis (Girty)
Spirifer pellaensis Weller
Composita trinuclea (Hall)
PELECYPODA—
Schizodus sp.
Schizodus sp.
Allorisma sp.
GASTROPODA—
Bellerophon sp.
VERTEBRATA—
Fish teeth

Webster County.—No exposures of the Pella formation are known northwestward from southwestern Poweshiek county until Webster county is reached. Except for a small inlier of

St. Louis limestone in Story county the intervening area is covered everywhere by the Des Moines formation.

Fossils now known as characteristic Pella species were reported from the St. Louis limestone of this area by White[55] as early as 1870. Many years later Wilder[56] described fossiliferous marls on Lizard creek, one mile west of Fort Dodge, which he also referred to the St. Louis. Upon the basis of the fossils listed by Wilder, the beds were asigned to the Pella by Weller and Van Tuyl in 1915.[57] More recent studies by Lees and Thomas[58] have demonstrated the presence of a typical Pella fauna in the marls.

Lees and Thomas state that all the known exposures of the formation in Webster county are, with two exceptions, located in the valley of Lizard creek west of Fort Dodge. One of these exceptional localities "is in a ravine which opens into Des Moines valley from the northwest opposite the dam and about one-third mile above the railroad and wagon bridges over the river at the mouth of Lizard creek." Twenty to twenty-five feet of fossiliferous Pella shales is overlain here by the Coal Measures. The other locality is in the northwest quarter of section 6, Cooper township, in a small ravine on the east side of Des Moines river, about five miles above Fort Dodge. Two small outcrops here show a few inches of sandy shale at water level, above which is two feet of marl. Over this is a foot of clay shale in which were found a few specimens of *Spirifer pellaensis* and *Pugnoides ottumwa.* A bluff section on Lizard creek near the center of section 24, Douglas township, shows forty feet of Pella shales underlain by thirteen feet of interbedded sandstone and limestone of St. Louis age. The lower thirty-four feet of the Pella shale is mottled with red areas and contains *Spirifer pellaensis, Pugnoides ottumwa, Composita trinuclea* and other fossils. (See also page 284.)

Several other exposures of Pella shales on Lizard creek are described by Lees and Thomas.[59] In an exposure about one-fourth mile up the valley from the above mentioned section they found three feet of nodular gray limestone overlain by

55 Report on the Geol. Survey, Iowa, vol. I, p. 221 ff.

56 Iowa Geol. Survey, vol. XII, p. 78; 1901. See also Wilder's statements in vol. XXVIII, pp. 146, 154, 164; 1918.

57 Proc. Iowa Acad. Sci., vol. XXII, p. 241 ff.

58 Proc. Iowa Acad. Sci, vol. XXV, p. 599 ff.

59 Idem, p. 600 ff.

thirty or more feet of fossiliferous gray-green shale which is followed in turn by five feet of red clay shale barren of life forms. Regarding other outcrops they say:

"About four hundred yards above the junction of North and South Lizard creeks, on the east bank of North Lizard there is an exposure of the gray-green shale which rises twenty-five or thirty feet above the stream. Over this shale lies fifteen to twenty feet of red shale. At several horizons in the gray-green shale there are harder limy bands which contain large numbers of fossil brachiopods. The contact of the red shale with the gray is quite sharp and lies just above a layer of fossiliferous yellow limestone.

The next exposures on this fork, and so far as known to the writers the last ones, are a group five miles up the valley and in the southeast quarter of section 8, Douglas township, about one-fourth mile below the Minneapolis and Saint Louis railroad bridge on the north bank of the stream. Here a small tributary ravine has been cut through six feet of yellow and green shale, below this through five feet of red and green shale, beneath which is exposed two feet of gray sandstone or sandy limestone, then five feet of shaly material beneath which in turn two feet of green shale is seen above the stream level."

None of the beds at this locality yielded any fossils.

Regarding the exposures on South Lizard creek Lees and Thomas have the following to say:

"In the lower one-half mile of South Lizard valley there are several exposures of the red and green shales. Only one of these, the southernmost, need be described here. This one shows beneath twenty or thirty feet of till a body of red clay shale twelve feet thick. Under it is eight feet of gray sandstone and below this bed a green and red shale extends fifteen feet to water level. Some of the shale near the base of this exposure is finely sandy. All the other outcrops are similar in the character of the beds exposed and it is noteworthy that none of the beds carry any fossils."

The fauna of the Pella beds of Webster county as reported by Lees and Thomas[60] is as follows:

SPONGIAE—.
- Clinolithes lizardensis Lees and Thomas

VERMES—
- Spirorbis fortdodgensis Lees and Thomas

CRINOIDEA—
- Crinoid stems

BRYOZOA—
- Batostomella interstincta Ulrich
- Batostomella (species undescribed)
- Anisotrypa fistulosa Ulrich

BRACHIOPODA—
- Orthotetes kaskaskiensis (McChesney)
- Pugnoides ottumwa (White)
- Girtyella indianensis (Girty)
- Spirifer pellaensis Weller
- Composita trinuclea (Hall)

TRILOBITA—
- Phillipsia sp.

60 Op. cit., p. 605 ff.

CHAPTER V

THE GEODES OF THE KEOKUK AND LOWER WARSAW BEDS

Introduction

In no other area in North America do geodes attain such an exceptional development as in the Keokuk and Lower Warsaw beds of the central Mississippi Valley. Representative specimens of geodes from this region are now found in the mineral cabinets of many of the museums of the world. Apart from Professor Brush's[1] preliminary examination and description of a few select specimens submitted to him in 1865 by A. H. Worthen, then director of the Geological Survey of Illinois, no study of these remarkable geodes has ever been made, in spite of the fact that they bear a variety of metallic sulphides and promise to throw some light upon the origin of more important deposits of these materials in sedimentary rocks which show no signs of igneous influence. The following report on their characteristics is therefore considered justified.

Definition of Geode

The term geode is derived from the Greek word meaning earthlike. The following definition of geode is given in Webster's International Dictionary:

a "A nodule of stone containing a cavity lined with crystals or mineral matter:"
b "The cavity in such a nodule."

Geodes are described in Dana's Manual of Geology as "Spheres or irregular spheroids, or balls in rock, hollow within and lined with crystals."

Chamberlin and Salisbury[2] in their text books on Geology state that geodes are formed by the partial filling of cavities by the inward growth of crytsals.

1 Geol. Survey Illinois, vol. I, pp. 90-96; 1866.
2 Geology, vol. I, pp. 416, 417; 1904.

Bassler,[3] who has recently made a study of geodes, defines them thus:

"Spheroidal or irregular spheroidal, concretion-like masses, hollow and lined with crystals pointing inwardly are known to geologists as geodes."

The following definition is given by O'Hara in Bulletin 9 of the South Dakota School of Mines:

"Geodes are spheroidal masses of mineral matter formed by deposition of crystals from mineral solution on the walls of a rock cavity. The growth is constantly inward toward the center. If the process of deposition has continued sufficiently long, the crystals reach across the depositional space, interlock with each other and the geodes become solid. Often the crystals project only part way, leaving a considerable cavity and then the geodes when broken present a crystal lining of much beauty and interest."

In all but the last of these definitions the impression is given that geodes are always hollow and that they are formed by the partial filling of pre-existing cavities by the inward growth of crystals. Such a view, however, is incorrect, for the growth of crystals toward the interior has in many cases proceeded sufficiently for them to meet and coalesce, thus giving rise to solid geodes.

Furthermore geodes are not always spheroidal. Some of them do not even distantly approach the spheroidal form. Many are very irregular and nodular in shape. A more comprehensive definition is as follows: Geodes are rounded or nodular masses formed by the inward growth of mineral matter upon the walls of pre-existing cavities. They may be either solid or hollow, depending upon whether or not the process of filling has been carried to completion.

The origin of the cavities need not enter into the definition. They may be either original, as in amygdaloidal lava, or they may be due to solution. Solution cavities are characteristic of sedimentary rocks. In their most typical development, geodes possess siliceous or calcareous shells and in this respect they should be distinguished from geodic cavities which are inseparable from the enclosing rock.

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3 U. S. Nat. Museum Proc. vol. 35, p. 133 ff; 1908.

Agates have a method of development analogous to that of geodes but they always consist of banded chalcedonic quartz. Also they are normally limited to igneous rocks while geodes are typically confined to shales and limestones.

Nodules and concretions differ in their origin from geodes and agates in that they grow from a nucleus outward by the segregation of like material originally disseminated through the surrounding rocks.

Other Occurrences of Geodes

Some of the more important occurrences of geodes in this country are as follows: (1) In the Keokuk limestone and the Lower Warsaw beds of the Central Mississippi Valley; (2) in the Little Falls dolomite of New York; (3) in the Lockport limestone at Lockport and Rochester, New York; (4) in the Knobstone shales of Indiana and Kentucky; (5) in the Tertiary beds of the Big Bad Lands of South Dakota; and (6) in Tertiary shales at Yaquima Bay on the coast of Oregon.

In England geodes occur in the marls and dolomitic conglomerate of the Keuper formation and in a basalt at Tortworth.

Geodes of the Keokuk Beds

Geodes attain their most typical development in the Lower Warsaw beds. But geodes and calcareo-siliceous masses are locally found in the Keokuk. These will be considered briefly before passing to a more detailed discussion of the geodes of the Lower Warsaw.

In this subdivision the masses are confined invariably to unfossiliferous calcareous shale beds and impure magnesian limestone layers which are interstratified with the bluish fossiliferous crystalline limestone. They are present at only a few localities in the area. The best known of these are (1) along the bed of a small intermittent stream two miles northwest of Denmark in Lee county; (2) in a quarry along Long creek in the northern part of section 18 of Union township, Des Moines county; and (3) at the mouth of Soap creek in the city of Keokuk.

The occurrence near Denmark is typical. Imperfect calcareous geodes and calcareo-siliceous masses appear in several layers separated from each other by bluish fossiliferous limestone. The most productive layer, however, is an impure buff magnesian limestone about two and one-half feet in thickness. Rounded and lenticular masses, some of which exceed two feet in greatest diameter, are common at this level. The relation of such masses to the surrounding rock is not such as to indicate appreciable expansion during their growth. The maximum arching of the overlying layers noted was less than two inches for a mass two feet in diameter. The majority of these masses are solid, and although they possess chalcedonic shells, in part at least, as do the typical geodes of the area, and may have a similar method of origin, many of them cannot be regarded strictly as geodes. Rather they should be described as segregations. The interiors of such masses are characterized by no definite structural arrangement and many of them contain layers or smaller inclusions of material resembling the surrounding rock. They are usually occupied in large part, however, by crystalline calcite and fine-grained quartzose material. The calcite and massive quartz may be indiscriminately mixed but usually the calcite either occupies the entire interior or is limited to isolated pockets in the included limestone. In the latter case the calcite of some masses contains small inclusions of buff calcareous material and in some others is associated with masses of sphalerite, some of which are as large as a man's fist. In still other cases it bears many fibrous inclusions of pyrite or small sphenoids of chalcopyrite. All three sulphides may occur in the same mass but not more than two have been found in any one calcite pocket. The chalcopyrite found in some masses has a zonal arrangement, the small sphenoids generally being most abundant about the periphery of the calcite clusters.

Such segregations are usually surrounded, either wholly or in large part, by a shell of chalcedony which may differ in thickness from a thin film to several centimeters. The outer surfaces of most shells are marked by numerous ridges, protuberances and rounded depressions, and in some cases they show a blistered appearance.

An impure soft magnesian limestone layer which is exposed in the quarry in section 18, Union township, Des Moines county, and which belongs in the upper part of the Keokuk limestone, is geode-bearing. Well formed hollow calcareous geodes are common at this place. Their shells consist commonly of buff calcareous material which is more indurated than the surrounding rock. But in some cases incomplete siliceous shells envelop a portion of the masses. Besides the rhombohedrons of calcite which line the interiors of these masses, crystals of sphalerite are abundant. In several instances this mineral was found to be associated with smithsonite, one of its decomposition products.

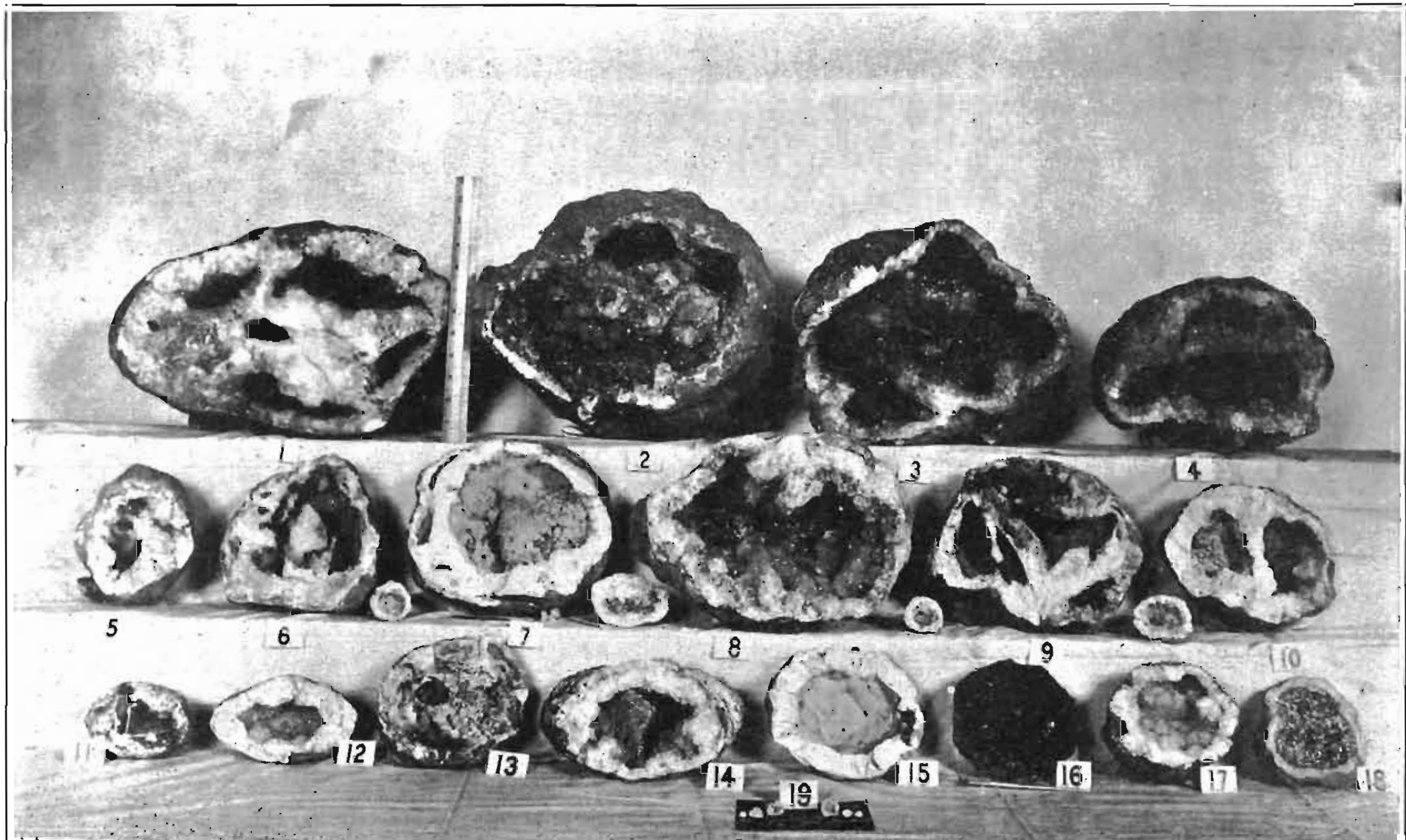
Well formed calcareous geodes occur in an impure limestone bed near the middle of the Keokuk at the mouth of Soap creek in the city of Keokuk. This geodiferous layer is six feet in thickness. It bears hollow calcareous geodes ranging up to ten or twelve inches in diameter. The interiors of these are lined with transparent rhombohedrons of calcite to which are attached numerous hairlike tufts and fibers of millerite, the sulphide of nickel. These tufts and fibers are intergrown with the calcite and in some cases they are entirely included by it.

Small geodic cavities have likewise been noted in the cherty limestone layers of the Montrose chert which was exposed in the excavation for the Mississippi river dam at Keokuk. These have no true shells and usually occur in compact chert bands. They are almost all lined with quartz crystals, but upon these are frequently superimposed rhombohedrons of calcite. Some of these rhombohedrons carry fibrous inclusions or needle-like projections of millerite. The nickel mineral, however, is not always confined to calcite, for in one instance its filaments were found implanted upon the crystals of a pure quartz geode.

Geodes of the Lower Warsaw Beds

OCCURRENCE AND SIZE

The geodes of the Lower Warsaw are remarkable for their abundance as well as for their beauty. Geodes occur in great profusion in the geodiferous phases of this horizon and many of the outcrops are thickly set with these rounded masses. The weathering of such outcrops releases large numbers of specimens and the stream beds at some localities are strewn with many geodes. (See Plate II.)



Group of geodes from the Lower Warsaw beds.

The geodes from this horizon range in size from about 0.2 centimeter up to 75 centimeters in diameter. Well developed geodes, however, of either extreme are very rarely found. Many of the smallest specimens consists of solid chalcedony, but well formed geodes no larger than a pea occur. The greater number of the largest examples, on the other hand, are either lenticular and poorly developed, or compound, in which case they consist of several individuals intergrown. Well formed geodes, however, ranging up to 60 centimeters in diameter are found, but most of these are chambered in their interiors.

Large and small geodes are not found intimately associated in any given layer, but there may be considerable range in size at different levels in the same exposure. Moreover, there may be marked differences in their dimensions at the same level at different localities.

In abundance the geodes of the geodiferous phase of the Lower Warsaw have a wide range both laterally and vertically. In places they are so numerous in a given layer that their freedom of growth has been interfered with and they are thus of very irregular shape. In other places, geodes are very sparingly distributed throughout the rock and none are present in an outcrop embracing an area of several square feet. In the non-geodiferous phase no trace of geodes may be found.

The proportion of well-developed geodes in the beds differs greatly at different localities. At some places well formed geodes do not constitute more than ten per cent of the total, but at others the great majority of those broken may be of typical character. The same relationship holds for different levels in the Lower Warsaw at the same locality.

MINERALOGICAL CHARACTER

Mineralogically the geodes are almost all siliceous but a few calcareous geodes and geodic calcareous nodules have been found. The siliceous types are without exception characterized by an outer shell of chalcedony. In most geodes this is followed by crystalline quarts, but calcite occasionally succeeds the chalcedony. In some instances, however, the interior is lined with botryoidal chalcedony and no crystalline quartz nor calcite appears. Many of these chalcedonic types bear cubes of pyrite, and one specimen was found which contained sphalerite, partly decomposed to smithsonite. This geode bore also a slight incrustation and a few minute crystals of gypsum, but the same mineral has been found in normal quartz geodes. Some of the quartz geodes are solid. In many of those which are hollow the quartz crystals of the interior are studded with crystals of calcite, dolomite, ankerite, sphalerite, or pyrite. More rarely elongated crystals of magnetite or the red powder of hematite are found. Some of these quartz types, on account of their imperviousness, contain water, although the surrounding rocks may be dry.

Many hollow siliceous geodes in the vicinity of Niota, Illinois, are filled with a black viscous bitumen, and those from the upper argillaceous half of the Lower Warsaw, particularly at Keokuk and Warsaw, commonly contain kaolin in the form of a flocculent white powder.

Calcite geodes and geodic calcareous nodules with or without siliceous shells are much less common than the quartz variety. A few calcite geodes from the Denmark locality bear small sphenoids of chalcopyrite. The geodic calcareous nodules, however, are characterized in general by calcite of two periods of growth and many of them contain elongated crystals of pyrite. Calcareous nodules without geodic cavities and inclosed by siliceous shells identical with those of perfect geodes have been found at several localities.

RELATION TO THE CONTAINING ROCK

It has been stated previously that the Lower Warsaw is represented by geodiferous and nongeodiferous phases which may grade into each other laterally within short distances. The only apparent physical difference between the two phases is that the member where it bears no geodes is in most cases, although not in all, fossiliferous, while the geodiferous phase is, except for occasional limited seams of limestone, nearly destitute of fossil remains.

The Lower Warsaw, in its typical development, is roughly divisible into two halves. The lower of these is massive and has the composition of an impure magnesian limestone. Bands or seams of fossiliferous nonmagnesian limestone are sometimes found interbedded with this type. Where it is geodiferous this limestone tends to bear large and well developed geodes which are distributed irrregularly throughout the rock mass. The upper part, however, is much more argillaceous and in some exposures is laminated. The geodes in this part are much more numerous than in the lower part but they are much smaller and more imperfectly developed. In general, it may be said that the degree of development of the geodes varies directly with the amount of calcareous matter in the rocks. In this part of the Lower Warsaw most of the geodes are found in productive layers or bands parallel to the stratification and ranging from a few inches to several feet in thickness. These bands are as a rule separated from each other by layers of barren shales of differing thickness. Such bands, interbedded with unproductive shale, and in some localities thickly set with geodes, are in many cases traceable along the entire width of an outcrop.

The relationship of the geodes of the Lower Warsaw to the containing rock, as in the case of the masses in the Keokuk limestone, does not suggest appreciable expansion during their formation. At no place was the inclosing rock found to be under any strain at the contact, nor was there any evidence of flexing consequent upon lateral pressure. Some thin seams of limestone, however, which overlie the geodes are slightly arched upward. But such archings are no greater than would result if masses analogous in size to the geodes were imbedded in the sediment at the time of its accumulation, and this seems to be the true condition. This idea is further strengthened by the occurrence of a few limestone layers which exhibit a thinning where they pass over the upper surface of the geodes. This is the usual relationship. An excellent example of such thinning is found in the lower part of the Lower Warsaw at the outcrop along Fox river, near Fox City, Missouri.

A close study of geodes in place in the rocks reveals the fact that their greatest diameter invariably lies in a horizontal plane, provided their development has not been interfered with. Calcareous nodules when found exhibit a similar relationship.

Many of the geodes have been deformed and crushed in place by the pressure of the superincumbent strata. The imperfect development of such geodes indicates that the crushing must have taken place while the process of geodization was yet in progress. Additional evidence of the settling of the rocks is found in the slickensided structure which characterizes much of the shaly material adhering to the siliceous shells of the geodes, and which, in some instances is even impressed upon the surface of the chalcedonic shells.

The extent of the geodes in the rock back from the outcrops is worthy of some consideration. Bassler[4] in his discussion of the geodes of the Knobstone shales of Kentucky and Indiana calls attention to the impervious nature of shale and inclines to the view that the geodes of that formation, which are of fossil origin, are confined to the immediate neighborhood of joint planes or rifts in the strata through which water had easy access. In speaking of their occurrence he says:

> "Usually the geodes were lying on the surface itself, free or partially covered with soil, and digging in the compact shale immediately beneath would reveal no trace of other specimens. In other cases they were apparently buried in the shale, but, in every instance of this kind, closer examination showed these examples to lie on the edge or very near to joint planes or rifts in the strata through which the water had easy access."

Such a relationship does not appear to hold for the geodes of the Lower Warsaw beds. They do accumulate along ravines as residual material, but they are found also in appreciable numbers in the unweathered shale. Blasting many feet into the bluff of the Lower Warsaw at Keokuk, Iowa, did not reveal any discontinuity of its geodiferous character. Geodes occur in a clay pit in the beds at Hamilton, and the sinking of a well into this division near Bentonsport revealed the presence of perfect geodes well down within the formation.

The mineralogical relationships of the geodes to the containing rock received some attention in this study. The general conclusion drawn from this investigation is that at any given locality each geodiferous layer or band, as a rule, bears geodes which are closely related among themselves but which may be mineralogically unlike those from other bands. Such differences, however, may be trivial, and one series may possess only a greater and more constant amount of one mineral than the other. Also the geodes from the same level may differ in general character

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[4] U. S. Nat. Museum Proc. vol. 35, p. 133 ff.

at different localities. In this respect it has been found that there are characteristic geode provinces.

To illustrate the diversity of character of the geodes from different bands, specimens from several levels in the Lower Warsaw, at Warsaw, Illinois, were studied and classified upon the basis of their development and mineral content. The following tables represent the types found in three productive bands in the lower ten feet of the upper argillaceous half of the formation at that place. The bands are designated as band A, band B, and band C, respectively, A being the highest band.

BAND A.

Geodes dominantly of the quartz type.

	Number
I. Geodes having well developed chalcedonic shells.	
A. Hollow geodes.	
1. Interior lined in part with drusy quartz and in part with granular quartz coated with chalcedony	16
2. Geodes similar to those of I A 1, but containing kaolin	25
3. Geodes like I A 1, but with fine crystals of quartz occurring upon the chalcedonized grains.	
(a) Without flakes of pyrite	12
(b) With flakes of pyrite	2
B. Geodes solid or nearly so.	
(a) Like I A 3a but iron stained	2
II. Geodes with imperfect shells.	
A. Otherwise like I A 2	2
B. Otherwise like I A 3	3

BAND B.

Geodes dominantly of calcite type.

	Number
I. Geodes with well developed shells.	
A. Hollow geodes.	
1. Interior of chalcedonic shells lined with rhombs of calcite.	
(a) Without kaolin	9
(b) Bearing kaolin	10
B. Solid geodes (quartzose)	1
II. Geodes with imperfect shells.	
A. Hollow specimens.	
1. Bearing calcite, kaolin, clay and sphalerite	1
B. Geodes solid or nearly so.	
1. Otherwise like II A 1	1
2. Otherwise like II B 1 but containing no sphalerite	3

BAND C.

Geodes dominantly of calcite type.

	Number
I. Geodes with well developed shells.	
A. Hollow geodes.	
1. Interior of shell studded with transparent crystals of calcite	9
2. Like I A 1 but bearing kaolin	1
3. Like I A 1 but bearing a few flakes of pyrite	1
B. Solid geodes.	
1. Interior filled with impure calcite	8
2. Like I B 1 but containing kaolin	7
3. Like I B 1 but containing blende and kaolin	1
4. Like I B 1 but containing only blende	1

Another band a few feet above A yielded very imperfectly developed and nodular geodes. Many specimens from this level have only incomplete chalcedonic shells while their interiors are occupied by clay intermixed with kaolin. The greatest diameter of these nodular geodes is about three inches.

The lower part of the Lower Warsaw at this place bears much larger but less numerous geodes than does the upper division. The lower four and one-half feet is by far the most productive part of the seven and one-half feet of this division which is exposed. The geodes taken at this level from an area four and one-half feet high and ten feet wide were studied. The results of this study are given in the following table:

	Number
I. Well formed geodes with chalcedonic shells.	
A. Solid quartz geodes	9
B. Hollow quartz geodes.	
1. Interior lined with pure quartz crystals.	
(a) Crystals not bearing flakes of pyrite	3
(b) Crystals bearing flakes of pyrite	6
2. Interior lined with quartz crystals which are coated with chalcedony.	
(a) Without flakes of pyrite	2
(b) With flakes of pyrite	5
II. Imperfect geodes; either broken or possessing brittle defective shells; interiors hollow but occupied by granular and finely crystalline quartz.	
A. Already broken	29
B. Broken with hammer	9
	63

At this locality the geodes from any one layer were not found to differ greatly in their mineralogical character, and this is the general rule. Instances have been found, however, in which there is considerable range in the mineral content of the geodes from the same level. This feature is illustrated by the following table prepared from the study of geodes taken from a band in the upper part of the Lower Warsaw, which is exposed along a small stream on the east side of Mud creek, about one mile above its mouth, in Henry county, Iowa.

	Number
I. Well formed geodes with chalcedonic shells.	
A. Hollow geodes.	
1. Interior lined with crystalline quartz	2
2. Like I A 1 but quartz crystals bearing elongated crystals of magnetite upon their surfaces	1
3. Like I A 2 but containing calcite also	1
4. Like I A 1 but with quartz bearing flakes and crystals of pyrite	3
5. Like I A 4 but containing calcite	7
II. Solid and imperfectly developed geodes;	
A. Interior partly filled with shaly material	8

The same feature is illustrated even more forcibly by the mineralogical nature of the geodes which occur in a band along a ravine which cuts into the Lower Warsaw in the vicinity of the Fort Madison and Appanoose Stone Company's quarry near Niota, Illinois. The geodes obtained from this band were as follows:

	Number
I. Well formed geodes with siliceous shells.	
A. Hollow geodes.	
1. Interior lined with mammillated chalcedony.	
(a) Metallic sulphides wanting	6
(b) Chalcedony bearing pyrite.	
1. Without calcite	3
2. With calcite	1
(c) Chalcedony bearing sphalerite	1
2. Interior lined with quartz crystals.	
(a) With pyrite	1
(b) Without pyrite	1
3. Interior lined with crystals of calcite.	
(a) With pyrite	2
(b) Without pyrite	2
B. Solid geodes.	
1. Solid chalcedony	1
2. Solid calcite	3
II. Imperfectly developed geodes; containing shaly matter.	
A. Without kaolin	3
B. With kaolin	1

The formations overlying the Lower Warsaw do not appear to have influenced geode development, for geodes occur at localities where the overlying strata are still preserved, as well as at localities where they have been completely eroded. Thus, at Warsaw the geodiferous beds are succeeded above by the Upper Warsaw formation, but at Lowell the beds are overlain at the most productive point only by drift.

The presence or absence of unconformities between the Lower Warsaw and the overlying formations, however, may have had some influence, but it is believed that the effect, if there was any, had to do with the time of origin rather than with the mode of development.

IMPORTANT LOCALITIES

Some of the most typical localities for studying the Lower Warsaw and its geodes have already been mentioned in connection with the discussion of the stratigraphy of the beds. But reference is again made to these localities with greater emphasis

The best known localities, without a doubt, are Keokuk, Iowa, placed on the geodes.

and Warsaw, Illinois. It was from these places that A. H. Worthen collected many specimens to distribute among the museums of the world. The same localitites have, in more recent years, afforded most of the geodes taken from the region for museum and ornamental purposes.

The Lower Warsaw is most typically developed at Keokuk along Soap creek near the end of Fourteenth Street, but it is exposed also along the west bluff of Mississippi river from the Union station southward for a distance of at least two miles. The Soap creek exposure is most satisfactory for the study of geodes. A section of the beds at this locality has been recorded earlier in this report. (See page 193.)

The most characteristic geodes at this locality are the thin-shelled siliceous types which bear crystals of dolomite and ankerite. These are best developed in the lower part of the formation but on account of the fragile nature of their siliceous shells they have been broken in most instances by the scaling off of large flakes of the containing rock which adheres tightly to the geodes.

The geodes of the upper part of the beds are much smaller than those from the lower part, and like those from Warsaw at this horizon, many of them contain the white powder of kaolin. The subjoined table will indicate the general character of the geodes occurring in a persistent band near the middle of the upper part of the beds.

		Number
1.	Geodes well developed and hollow.	
	A. Interior lined with drusy quartz	1
	B. Interior lined with drusy quartz which bears small crystals of pyrite	2
	C. Interior occupied by drusy quartz, pyrite, dolomite and calcite	1
	D. Interior lined with drusy quartz studded with dolomite	3
	E. Interior lined with drusy quartz, dolomite and pyrite	1
	F. Interior occupied by drusy quartz, dolomite and kaolin	1
	G. Interior lined with coarse crystals of quartz	2
	H. Coarse crystals of quartz and pyrite	1
2.	Geodes well developed but solid	2
3.	Geodes imperfectly developed; interior nearly filled.	
	A. Lined with drusy quartz and dolomite and bearing kaolin	7
	B. Interior consisting of drusy quartz, dolomite, kaolin and blende	1

Another excellent place for studying geodes is along the east bluff of a creek just northeast of the town of Warsaw (fig. 16), where the Lower Warsaw is well exposed. A detailed section of the rocks at this point has been given on page 190. The nature of the geodes at this place is indicated by the tables presented under the discussion of the mineralogical relationship of the geodes to the containing rock. (See pages 315 to 317.) One of the most striking features in connection with the geodes at this locality is that although they are otherwise quite similar to the Keokuk specimens, they were not found to bear dolomite, which is a very characteristic mineral in the geodes at Keokuk.

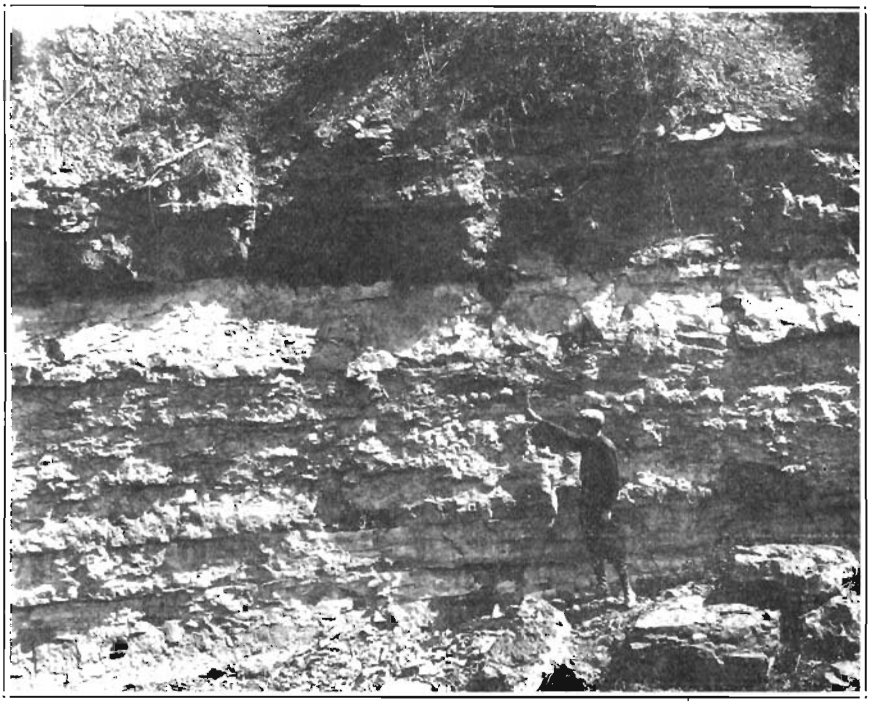

FIG. 16.—Geodes in place in Geode bed along creek just northeast of Warsaw, Illinois.

Geodes occur also at Soap Factory Hollow, a creek two miles south of Warsaw, and along the beds of creeks tributary to the Mississippi between Warsaw and Hamilton. Of these creeks Crystal Glen, whose mouth is about two miles above Warsaw, is the most important. Many geodes are strewn along the bed of this stream and about a mile up the valley an outcrop of the lower part of the geodiferous phase of the Lower Warsaw may be seen. The exposure at this point is about eight feet high and is made up of highly calcareous shale interstratified with layers of limestone. The geodes occur both in the limestone and in the shale. They are dominantly of the quartz, calcite and quartz-calcite varieties. Metallic sulphides are rare.

At Hamilton geodes are common along Railroad creek but conditions are the most favorable for studying them at the clay pits of the Hamilton Clay Company, situated about one-half mile southeast of town. The bluish nonfossiliferous shales of the upper part of the Lower Warsaw are here used for the manufacture of brick and tile and have been exposed to a maximum thickness of about eight feet. Many geodes which have been picked from the shale in the process of excavation are now scattered over the floors of the pits. More than one hundred of these were broken. Of this number about one-fourth were of the solid quartz variety and the remainder consisted chiefly of hollow quartz geodes whose interiors were in most cases studded with rhombs of calcite or crystals of dolomite or ankerite. A few, however, were found to contain pyrite and an occasional one contained sphalerite. The ankerite is in many cases partly decomposed to limonite. The interior linings of nearly all of the geodes at this place are incrusted, in part at least, with lime carbonate.

Many of the hollow geodes have been fractured transversely and recemented by calcareous material. These are for the most part much discolored in their interiors. The rupture of these is believed to have been caused by the freezing of included water when they were not far below the surface. A few deformed geodes also were observed. Most of these contained kaolin and included clay but a few were found to contain dolomite or ankerite.

The exposure of the Lower Warsaw at Fox City, Missouri, is very interesting from many standpoints. Reference has already been made to the excellent opportunities at this place for studying the relation of the geodes to the containing rock. Many geodes have been collected at this locality and considerable blasting has been done along the face of the bluff to facilitate their removal from the rock. The upper part of the formation at this place furnishes the greatest number of specimens, but they are small and most of them are poorly developed. In size they range from about 0.2 centimeter to 20 centimeters in diameter. Many of the smallest geodes consists of solid chalcedony.

But the larger geodes are usually of the quartz type and many are nearly or quite solid. Other varieties of subordinate importance are the quartz-pyrite, quartz-calcite, quartz-calcite-pyrite and the kaolinitic types.

The geodes from the lower part of the shale are of far greater importance than those from the upper part. At no other known locality in the area can such large and well developed geodes be so satisfactorily studied in place in the rocks. Numerous well formed quartz geodes ranging up to 45 centimeters in greatest diameter may be seen dotting the face of the bluff. They reach their maximum development, however, in a layer six feet in thickness near the base of the exposure. The geodes from this layer may be classified as follows:

	Number
A. Geodes exceeding six inches in diameter.	
1. Interior hollow.	
(a) Interior lined with quartz crystals which bear small flakes of pyrite upon their surfaces	2
2. Solid geodes.	
(a) Interior filled with crystalline quartz	1
B. Geodes less than six inches in diameter.	
1. Interior hollow.	
(a) Pure quartz type	4
(b) Interior lined with quartz crystals bearing flakes of pyrite	26
2. Solid or almost solid geodes.	
(a) Pure quartz filling the interior	2
(b) Interior filled with quartz which bears pyrite	2

The widespread occurrence of pyrite and the paucity of calcite are the most characteristic features of the geodes at this place.

Another Missouri locality for collecting geodes is near Wayland. A few feet of the Lower Warsaw are exposed about one-half mile southwest of this place, in the east bank of Fox river. Here many of the geodes contain calcite. St. Francisville, Missouri, also is said to be a good locality for quartz geodes.

The geodes from the lower part of the Lower Warsaw at several localities near Niota, Illinois, are strikingly contrasted to those in other occurrences in that many of them are partly or completely filled with a black viscous bitumen. The fact that such bituminous geodes occur in a non-bituminous shale and may be found in close proximity to ordinary geodes which show no trace of bitumen, lends to this feature still greater interest. As a general rule, however, the regular hollow geodes which occur in the same layers with bituminous types show at least a black stain in their chalcedonic shells.

Such bituminous geodes occur along a small creek in the southern limits of Niota. But the most satisfactory place to study them is two miles south of Niota along the north and south forks of a small creek a short distance back from their confluence. At the more northerly of these places bituminous geodes occur only in a layer a few feet in thickness near the base of the Lower Warsaw. Above this layer occur thin-shelled geodes lined with drusy quartz studded with ankerite. These show no traces of petroleum.

The geodes which bear oil are, so far as could be ascertained, no different from the geodes which normally occur at this horizon. Most of them are of either the calcite or the quartz types but some geodes lined with botryoidal chalcedony also contain bitumen. Furthermore, the thickness of the wall seems to have had no great influence, for almost solid quartz geodes have been found to contain a small amount of the crude oil in their centers. No bitumen or carbonaceous material has ever been found included in the quartz. The bitumen, then, must have been introduced at some time subsequent to the development of the geodes. It certainly has not interfered with their development. The source of the oil is not positively known. It may have migrated into the basal part of the Lower Warsaw from the underlying formations. When it penetrated the geodes it must have been in a much more fluid condition than it now is.

Other outcrops of the Lower Warsaw occur along a small creek which empties into the Mississippi about three miles below Niota. Near the sources of this creek many rounded calcareous nodules occur in a layer of shale exposed along the bed of the stream. One of these masses was found when broken to bear a geodic cavity lined with calcite.

Toward the mouth of the same stream, however, the geodiferous shales are exposed in their usual facies. They are capped with drift at this point and are underlain by the upper ledges of the Keokuk limestone. The maximum exposure of the Lower Warsaw is about thirty feet. The geodes at this place have nearly all been deformed by the weight of the overlying sediments and in consequence of such deformation the upper or lower sides of many of the geodes were crushed inward before geodization was complete. Their interiors are now occupied by impure clay and kaolin. No bitumen was found in any of the geodes at this locality, although conditions were favorable for its retention. A similar condition prevails at the outcrops above Niota. Thus in the ravine near the Fort Madison and Appanoose Stone Company's quarry, no trace of oil was found, although well developed geodes occur at that place.

The most famous, and in fact the only known, locality for collecting geodes in Henry county, Iowa, is east of Lowell, in Baltimore township, along Mud creek, a tributary of Skunk river. Many geodes occur along the bed of this stream and several outcrops of the Lower Warsaw appear. The first outcrop of the Lower Warsaw to be seen in following up this creek from its mouth is one in the southern part of section 27 at the west end of the iron bridge on the Lowell road. The beds are succeeded above by St. Louis limestone. The exposure of the Lower Warsaw at this place, however, is largely concealed and cannot be satisfactorily studied. But a few rods farther upstream a low bluff capped with drift on the east side of the stream furnishes a section sixteen feet in thickness. The upper ten feet of the beds at this place is very argillaceous, but the lower six feet is calcareous and some of the layers approach in composition an impure magnesian limestone.

The geodes of the more shaly part are small, imperfectly developed and nodular. The siliceous shells of these are of a reddish color and in some specimens the red tint shows through the transparent druses of quartz which line the interior. The lower part, on the other hand, bears more perfectly developed geodes which are dominantly of the quartz type. These have a maximum diameter of more than ten inches. Flakes of pyrite or single crystals of sphalerite occur in the interiors of some of these geodes while a few were found which were filled with water. A short distance above this point and just west of the second wagon bridge which spans Mud creek appears a third outcrop of the beds. At the base of this section appears a layer which was not exposed at the above described section. At the top of the basal layer there occurs a band which is thickly set with rounded nodules which appear to be more calcareous than the containing rock.

Still farther up the creek the uppermost ledges of the Keokuk beds appear in the bed of the stream, a fact which suggests that an anticlinal arch exists at this place. No other exposures of the Lower Warsaw appear until the northern limit of section 27 is reached. Here on the east bank of the stream is a bluff of shale thirty feet in height, without any indurated rocks above the shale beds. Parts of the formation are exposed also a few rods north of this point in the southern part of section 22 in an extension of the same bluff and along the ravines emptying into Mud creek above this place on the same side of the stream. These are the most northerly outcrops of the Lower Warsaw. Beyond this point only the limestones of the Keokuk appear.

The upper part of the Lower Warsaw which is exposed at the bluff in the northern part of section 27 consists of argillaceous shale. The lower part is made up of calcareous shale interstratified with bands of impure magnesian limestone. The upper argillaceous portion is twelve feet in thickness and bears many geodes, but most of them are very small. In character they are dominantly of the quartz type. The surfaces of many of the specimens from this level are partly coated with mamillary pyrites and many of their shells are of the red variety of chalcedony. These geodes differ from those from other localities at the same level in that they do not bear kaolin. Many of the imperfect specimens, however, contain impure clay.

Just below the argillaceous member there occurs a band of soft impure buff magnesian limestone which bears large quartz geodes. A few of these have a maximum diameter of two feet. They are usually somewhat lenticular in shape and are chambered within. The walls of some of the geodes from this level are quite thin but others possess very strong shells and can be broken only with great difficulty. In some of the geodes from this layer characteristic twinned crystals of calcite are found.

The formation is poorly exposed at the bluff in the southern part of section 22 but many geodes similar in character to those in the magnesian layer of the above exposure are strewn over the surface of the slope. In addition to the types described from the foregoing locality there are found at this place a few geodes whose interiors are partly or completely occupied by a soft white gritty variety of silica which in some cases is intersected by a network of veins of transparent quartz. In some chambered specimens this material is limited to one of several chambers but in simple geodes it may occupy the entire interior. In some instances cavities lined with small transparent crystals of quartz appear in the interior of masses of this material.

One small quartz geode from this exposure was found to bear small slender crystals of magnetite and the red powder of hematite. Along the bed of one of the ravines a few rods north of this point there appear many large quartz geodes whose interiors are stained with limonite as the result of the decomposition of small flakes of pyrite which they formerly contained. Several of these geodes have a maximum diameter of two feet, but specimens of such size were invariably found to be of the compound type. None of these large geodes was found in place but judging from the material adhering to their shells they were derived from a layer of impure magnesian limestone.

A short distance farther up the creek many geodes are to be found in the drift on the west side of the creek. Beyond this point a few appear along the bed of the creek as far north as the bridge crossing the stream in the northern part of section 22.

Satisfactory outcrops of the Lower Warsaw in Des Moines county are rare and apparently the typical geodiferous phase of the subdivision is lacking, for well developed geodes were not found.

Near Denmark in Lee county an interesting exposure of the Lower Warsaw is to be found along a small stream flowing through the old Leverett estate, two miles northwest of the town. In the bed of this creek there appears at one point a layer of calcareous shale which bears many siliceous and calcareous nodules some of which are geodic. Some of the calcareous nodules are inclosed by chalcedonic shells and the resemblance of these to the siliceous masses strongly suggests that the latter have been formed by the replacement of their calcareous content by silica. Furthermore the similarity of the geodes to such calcareous and siliceous nodules is striking. The surfaces of many of the nodules and geodes at this place are partly encrusted with pyrite. Well developed geodes are not common and the majority of those found are of the calcite or chalcedony types. Of the calcite geodes some are lined with rhombohedral calcite but others bear dog tooth spar. Some of the latter variety bear sphenoids of chalcopyrite. Many of the chalcedony geodes, on the other hand, lack characteristic mamillary structure. Some of the hollow specimens bear perfect cubes of unaltered pyrite in their interiors.

Other interesting localities for studying geodes occur in Van Buren county. The most important of these are: along Indian creek across the river from the town of Farmington; along Bear creek one-half mile south of Vernon; and along Copperas creek about two miles northwest of Bentonsport. At the Farmington and Vernon localities rounded calcareous nodules, some with and some without inclosing shells of chalcedony, are common in the shale. Some of these are hollow and lined with crystals. Exteriorly most of such masses are indistinguishable from the typical geodes with which they are occasionally associated, but when they are broken their true character is revealed. Many of those which are hollow bear a brownish variety of calcite upon which in some cases there are superimposed bright transparent rhombohedrons of the same mineral of a later period of growth. Elongated crystals of pyrite are frequently found in association with this last variety of calcite.

In many of the solid nodules there is considerable evidence of the partial replacement of original calcareous material by silica. This replacement product commonly assumes the form of irregular patches of reddish chalcedony but in some specimens rounded masses of bluish chalcedony occupy part of the interior. In addition some specimens bear many radiating groups of small quartz crystals imbedded in the mass.

The Copperas creek locality is noted mainly for the deformed condition and the irregular surfaces of the geodes. But the occurrence of bands and lenticular masses of reddish siliceous material intermixed with calcite also is of considerable interest. The upper and lower surfaces of such bands and masses are thickly set with small nodular elevations which generally are blended together and many of which are geodic.

Over seventy-five per cent of the geodes at this place are either crushed or of a very irregular shape, and only a fraction of the well rounded specimens attain a normal state of development. Among the few well formed specimens one geode of the quartz type was found to bear slender elongated crystals of magnetite partly decomposed to limonite.

DESCRIPTION OF TYPICAL GEODES

The mineralogical variations of the geodes are such that it is impossible to give a general description of their characters which is satisfactory. In order that the many mineralogical relationships may be fully presented a number of typical geodes are described below.

Geode No. 1.—Shape roughly oblong. Surface bearing minute concretionary masses of chalcedony and in places exhibiting faint slickensided structure. Dimensions[5] 23.1 by 18.2 by 15.6 cms. Interior hollow; wall 0.5 cm. to 5. cms. thick. Chalcedonic shell 0.1 to 0.7 cm. in thickness. Cavity lined with transparent terminations of quartz crystals. When it was broken this geode was partly filled with water.

Position and locality: In place in an exposure of the Lower Warsaw along the east bank of Mud creek, just above the iron bridge east of Lowell, Henry county.

Geode No. 2.—Shape lenticular; surface fairly smooth but showing minute concretionary protuberances. Dimensions 15.1 by 14.1 by 8.8 cms. Interior hollow; wall 0.85 cm. to 2.8 cms. in thickness; chalcedonic shell not distinctly marked off; outer part consisting in large part of fine-grained calcareous material partly replaced by concretionary silica; inner part occupied by an irregular band of bluish chalcedony. Upon this band there occurs a perfect lining of small transparent quartz crystals to which the underlying chalcedony imparts a bluish tint.

Position and locality: Basal part of Lower Warsaw two miles northwest of Denmark, Lee county.

Geode No. 3.—Shape approximately spheroidal with slight compression at one point. Surface exhibiting many small

[5] The dimensions given are the greatest in each of the three directions. Statements made regarding the thickness of the wall or of the chalcedonic shell are based only upon the section obtained in breaking the geodes.

rounded elevations of chalcedony. Adhering shale showing slight slickensided structure in direction of greatest diameter. Dimensions 18.6 by 17.3 by 15.8 cms. Interior hollow; separated by a perforated partition into two almost equal chambers. Outer wall 2.2 to 3.75 cms. in thickness, outer shell of chalcedony averaging 0.35 cm. in thickness. Inner part of wall occupied by crystalline quartz. Chambers lined with pointed quartz crystals. In one chamber there is superimposed upon this quartz a thin layer of bluish chalcedony. No trace of this mineral is to be found in the other chamber. Both chambers slightly iron stained. Close study of this geode shows that it is compound in character, having resulted from the union of two individuals. The presence of the chalcedony in only one chamber, however, when the intervening wall offers no resistance to passage of solutions, is difficult to explain.

Position and locality: Along the bed of Mud creek in section 27 of Baltimore township, Henry county.

Geode No. 4.—Shape lenticular, with lower side compressed, upper surface corraded in places, bearing the usual concretionary elevations and marked with several gougelike depressions; lower surface smooth but irregular. Dimensions 29 by 28.2 by 17.25 cms. Interior nearly solid. Outer shell of chalcedony ranging from practically nothing to 0.8 cm. in thickness; bearing a single minute crystal of sphalerite. Succeeding this shell inwardly there is a band of unequal thickness of solid crystalline quartz analogous to that which lines ordinary quartz geodes. Resting upon this and coating the quartz crystals there appears a layer of banded chalcedony averaging 0.8 cm. in thickness. Following this there occurs a second layer of quartz more finely crystalline than the first. In a part of the cavity there is a thin coating of chalcedony on the terminations of the crystals of this layer. Implanted on this coating are a few cubes of pyrite, and in the lower part of the cavity there is a slight incrustation of calcium carbonate. A large part of the cavity is occupied by a mass of crystalline calcite, which bears included flakes of pyrite. About the periphery of this mass are crystals consisting of a combination of hexagonal prisms of the first order with the negative rhombohedon.

Position and locality: Along the bed of a ravine tributary to Mud creek in the southern part of section 22, Baltimore township, Henry county.

Geode No. 5—Shape globular. Surface fairly smooth and regular. Dimensions 16.5 by 14.8 by 13.9 cms. Interior hollow, lined with botryoidal chalcedony. Width of lining 0.35 cm. to 2.7 cms. Outer chalcedonic shell 0.2 cm. to 1.3 cms. thick; bearing a trace of calcareous material. Line of contact with inner layer of chalcedony in general very irregular. Lining of botryoidal chalcedony showing faint evidence of banding and marked by numerous rounded pits which extend out to the crust. One such pit of irregular shape is filled with crystalline sphalerite which is decomposing to smithsonite. The latter mineral forms an incomplete crust over the unaltered sulphide. A slight deposit of the same mineral forms a coating in the bottom of the cavity of the geode. In addition there are a few flakes of gypsum.

Position and locality: In place in the Lower Warsaw along a ravine near the Fort Madison-Appanoose stone quarry, near Niota, Illinois.

Geode No. 6.—Shape subglobose. Surface with many small rounded concretionary protuberances of chalcedony. Dimensions 8.3 by 8.1 by 7.1 cms. Interior hollow; wall siliceous; thickness 0.4 cm. to 2.1 cms. Outer shell of chalcedony 0.3 to 0.5 cm. thick. Cavity lined with terminations of small quartz crystals bearing slender prismatic crystals of magnetite, and stained with the reddish powder of hematite. The hematite is later than the magnetite for it forms a coating on some of the crystals of that mineral.

Position and locality: From an exposure in the east bank of Mud creek in the southern part of section 22, Baltimore township, Henry county.

Geode No. 7.—Shape roughly spheroidal. Outer surface with irregular elevations. Dimensions 17 by 14 by 13.5 cms. Interior hollow; walls chalcedonic, 1.2 to 3 cms. thick, showing no trace of banding. Shell not distinct. Cavity lined with drusy quartz which possesses a sufficient coating of chalcedony to give it a milky white appearance. Thickly implanted upon this material are small, slightly tarnished cubes of pyrite. In one part of the cavity there also are one large and several small crystals of calcite. The large crystal is of the same form as that found in geode No. 4. It envelops pyritiferous drusy quartz and is clearly younger than that mineral. In one part of the wall there occurs a pocket of calcite which bears inclusions of pyrite.

Position and locality: In place in lower part of Lower Warsaw two miles northwest of Denmark.

Geode No. 8.—Vertical section subcircular, horizontal section subquadrangular. Surface with minute elevations. Dimensions 9.15 by 8 by 6.6 cms. Interior hollow; wall siliceous, averaging about 1.6 cms. in thickness. Chalcedonic shell 0.25 to 0.5 cm. thick, bearing small pockets of kaolin. Succeeding the shell there is a band of crystalline quartz, which is again followed by a coating of chalcedony of differing thickness. Many small bright cubes of pyrite occur on this coating and a few minute crystals and a thin incrustation of gypsum occur in a part of the cavity. A few stains of limonite were observed on the chalcedonic lining.

Position and locality: In place in Lower Warsaw bed along Soap creek, Keokuk.

Geode No. 9.—Geode large, sub-ovate; longer and wider than high. Surface smooth but marked by irregular elevations and depressions. Dimensions 39 by 37 by 25.3 cms. Interior occupied for the most part by a large rounded mass of cryptocrystalline silica coated with crystalline quartz. Several quartz-lined cavities intervene between this mass and the wall of the geode.

Position and locality: In Lower Warsaw beds along Mud creek, south part of section 22, near Lowell.

Geode No. 10.—Shape spheroidal; surface with small irregular protuberances and minute rounded elevations. Dimensions 13.8 by 12.3 by 10.7 cms. Wall siliceous; interior hollow, lined with quartz crystals, and almost completely filled with black viscous bitumen.

Position and locality: Along bed of creek south of Niota, Illinois.

Geode No. 11.—Shape, nodular; flattened upon one side by contact with another specimen; surface smooth. Dimensions

9.8 by 7.8 by 6.6 cms. Interior hollow; wall about 1.1 cms. in thickness; outer part consisting of a thin shell of chalcedony; inner part made up of fine-grained impure calcareous material. Lining this wall are small scalenohedrons of calcite on which are numerous flakes and sphenoids of chalcopyrite.

Position and locality: In place in lower part of Lower Warsaw, two miles northwest of Denmark.

Geode No. 12.—Shape nodular; surface irregular. Dimensions 12.5 by 11.2 by 8 cms. Interior hollow; wall 0.55 cm. to 1.5 cms. thick, consisting of finely crystalline calcareous material; no trace of a chalcedonic shell. Brownish rhombs of calcite, some which are much elongated, line the wall, and implanted on them are small tarnished crystals of pyrite which exhibit the faces of the pyritohedron. Superimposed upon both minerals are many clear, transparent rhombs of Iceland spar with which are associated acicular crystals of unaltered pyrite either as inclusions or as freely projecting needles which upon superficial examination might be mistaken for millerite. Two periods of mineralization are indicated by this geode.

Position and locality: In place in the upper part of the Lower Warsaw beds along Indian creek near Farmington, Van Buren county.

Geode No. 13.—Shape lenticular. Surface rough and irregular, partly coated with mammillary pyrites. Dimensions 21 by 19.1 by 11.4 cms. Interior hollow; wall siliceous, 0.8 cm. to 3 cms. thick. Outer shell of chalcedony distinct; showing concretionary structure; partly replaced by pyrite 0.2 cm. to 1.1 cms. in thickness. Cavity lined with quartz and occupied in part by a large mass and smaller aggregates of calcite which are thickly set with included flakes of pyrite. Small crystals of pyrite are implanted upon the quartz also and the latter mineral is partly coated with an incrustation of calcium carbonate.

Position and locality: Along bed of ravine emptying into Mud creek near Lowell.

Geode No. 14.—Shape irregular and nodular, surface with concretionary elevations of chalcedony. Dimension 8.5 by 7 by 6.5 cms. Wall siliceous, averaging about 0.6 cm. in thickness. Outer shell of chalcedony 0.1 to 0.5 cm. thick; concretionary;

bearing a few small cavities filled with kaolin. Interior of wall thickly set with small pointed quartz crystals beyond which occur aggregates of dolomite crystals, which possess characteristic curved surfaces. Remainder of cavity almost filled with white fluffy powder of kaolin. Solution of several dolomite crystals from different places in the cavity showed that some contained inclusions of kaolin, for a cloudy liquid resulted in a few instances. Microscopic examination of the quartz, however, did not reveal any inclusions of the powder in it.

Position and locality: In place in bluff back of Harrison lumber mills two miles below the Union Station at Keokuk.

Geode No. 15.—Shape subglobose; surface rough and irregular. Dimensions 11.3 by 9.9 by 9.3 cms. Interior hollow; wall 1.8 to 5.1 cms. in thickness; outer part siliceous; inner part dolomite. Chalcedonic shell concretionary, 0.5 cm. to 2 cms. thick, containing small cavities and irregular pockets of limonite and kaolin. Inner lining of dolomite continuous. Shell succeeded by massive dolomite in lower part on which are superimposed crystals of the same mineral. But in the upper part crystals of dolomite succeed the siliceous shell directly. The crystals are rhombohedrons with characteristic curved surfaces.

Position and locality: In upper part of fossiliferous phase of the Lower Warsaw, two miles below the Union Station at Keokuk.

Geode No. 16.—Geode small, globular; surface bearing minute rounded elevations of chalcedony. Dimensions 7 by 7 by 6.3 cms. Interior hollow; wall thin, consisting of a shell of chalcedony, averaging 0.5 cm. in thickness, succeeded in all but what seems to be the lower part, by a thin layer of drusy quartz. In the part excepted, a layer of the massive quartz containing one large and several small pockets of limonite intervenes between the shell and the drusy coating. Superimposed upon the quartz lining are a few rhombs of calcite, the largest of which measures 1.3 cms. in diameter, and several aggregates of ankerite crystals. A whitish efflorescent-like coating of calcium carbonate is present as an incrustation on these minerals and on the drusy quartz.

Position and locality: From the Lower Warsaw in the clay pit of the Hamilton Clay Company, Hamilton, Illinois.

Geode No. 17.—Geode small, nodular; surface rough. Dimensions 6.0 by 5.5 by 38.0 cms. Wall thin, averaging 0.5 cm., consisting of an outer shell of chalcedony lined with a thin layer of whitish granular calcite upon which appear numerous minute crystals of pyrite. Interior almost completely filled with flaky kaolin. The calcite crystals contain minute flakes of this mineral.

Position and locality: Lower Warsaw along bluff back of Harrison lumber mills two miles below Keokuk Union Station.

Geode No. 18.—Geode large; shape very irregular; surface rough and uneven. Dimensions 37.3 by 29.0 by 28.5 cms. Entirely siliceous. Wall averaging about two centimeters in thickness; lined with crystals; chalcedonic shell distinct. Interior occupied by a large mass of chalcedonic silica which is covered by a coating of crystalline quartz, some of the crystals of which are united with those of the wall. The whole interior is strongly stained with limonite, and locally it is incrusted with calcium carbonate.

Position and locality: Along bed of a ravine in southern part of section 22 of Baltimore township, Henry county.

Geode No. 19.—Geode of medium size, subglobose; surface rough, irregularly pitted. Dimensions 11.5 by 10.8 by 8.5 cms. Interior hollow; wall averaging about 2.5 cms. in thickness; chalcedonic shell distinct, bearing minute cavities, some of which are filled with kaolin. Following this is a layer of crystalline quartz, the interstices of which are filled with chalcedony. Superimposed upon the quartz layer and lining the interior of the geode is a band of chalcedony about three-tenths centimeter thick which bears botryoidal prominences. A few bright untarnished flakes of pyrite rest upon the surface of the chalcedony. In the lower part of the cavity there is a yellowish stain of limonite.

Position and locality: In place in Lower Warsaw, along Soap creek, Keokuk.

Geode No. 20.—Shape nodular and very irregular; surface bearing many rounded elevations, as if formed by the coalescence of many small nodules. Dimensions 14.8 by 13.1 by 9.1 cms. Interior hollow; wall siliceous, averaging about 2.4 cms. in thickness. Outer shell of calcedony exhibiting faint traces of banding; about 0.4 cm. thick. Inner part of wall consisting of massive crystalline quartz. Cavity lined with closely intergrown crystals of quartz. In one part of the cavity there occurs a small mass of crystalline calcite about two centimeters long and one centimeter wide, and implanted upon both the quartz and calcite are slender prismatic crystals of magnetite. There is a slight incrustation of calcium carbonate in what seems to be the lower part of the cavity.

Position and locality: In Lower Warsaw, along Copperas creek two miles northwest of Bentonsport, Van Buren county.

Geode No. 21.—Size small; bun-shaped; surface fairly smooth. Dimensions 9.4 by 8.4 by 4.7 cms. Interior hollow; wall about 0.7 cm. thick; outer half consisting of reddish chalcedony which has a concretionary structure; inner part consisting of discolored crystalline calcite. Cavity lined with imperfect scalenohedrons of brownish discolored calcite.

Position and locality: In place in Lower Warsaw, along Bear creek near Vernon, Van Buren county.

Geode No. 22.—Shape approaching lenticular but laterally compressed. Surface with minute elevations of chalcedony. Dimensions 11.0 by 10.8 by 8.3 cms. Interior hollow; wall siliceous; outer shell distinct, showing a reddish tint. Interior of wall lined with drusy quartz which, for the most part, is iron stained. Implanted upon this quartz occur many small cubes of pyrite which are decomposing to limonite. Superimposed indiscriminately upon quartz and pyrite there are, in some parts of the cavity, small twinned rhombohedrons of calcite. Related to all three minerals and obviously subsequent to them are a few slender projecting crystals of gypsum of the usual form. One elongated crystal has a length of 1.5 cms., its greatest width being not more than 0.1 cm.

Position and locality: In place in Lower Warsaw beds along bluff of Mud creek in southern part of section 22 of Baltimore township, Henry county.

Minerals of the Geodes and the Inclosing Rocks

Quartz (Rock Crystal), SiO_2.—This is the most common mineral found in the geodes. The majority of specimens are either lined or completely filled with crystalline quartz. The crystals almost without exception consist of the first order hexagonal prism terminated with positive and negative rhombohedrons. Usually only the pyramidal terminations line the cavities of the quartz geodes, but doubly terminated crystals are found loose in the interiors of some specimens.

Chert, SiO_2.—Discontinuous bands and irregular nodules of chert occur in the Keokuk limestone and in the limestone layers of the Lower Warsaw. The relation of the material to the limestone suggests that it has resulted from the replacement of that rock.

Chalcedony, SiO_2.—The outer siliceous shell which covers almost all geodes is of the variety of quartz known as chalcedony. the same mineral also occurs as a bluish lining with botryoidal prominences in the interior of some geodes and it appears commonly as a coating on the surfaces of the quartz crystals which line the cavities. In the first mode of occurrence the chalcedony in most cases has a concretionary structure, but in the last two modes it may show only faint evidence of banding.

Calcite, $CaCO_3$.—This is a common constituent of the geodes and its relationships are such as to indicate at least two periods of formation. This mineral is most commonly found as isolated crystals or crystal aggregates on the quartz of quartz geodes. But calcite in some instances succeeds the siliceous shell directly. In all geodes not characterized by chalcedonic shells and in the geodic calcareous nodules this mineral lines the interior. The calcite of the Keokuk limestone in some cases includes crystals of metallic sulphides such as hairlike tufts of millerite, sphenoids of chalcopyrite and slender elongated crystals of pyrite. In the Lower Warsaw, on the other hand, some of the crystals include the white powder of kaolin and a few of them contain flakes of pyrite. But in many of the geodes from this horizon the calcite was deposited subsequently to the pyrite. The crystals of the earlier period of formation exhibit a variety of forms and some of them show a brownish discoloration. The most common forms of the calcite of this age are the rhombohedron, the scalenohedron, and the scalenohedron modified by the rhombohedron.

Much of the calcite of later growth consists of bright, transparent rhombohedrons of Iceland spar, some of which rest on calcite of earlier growth. Other forms assumed by the calcite of this age are the rhombohedron, the hexagonal prism of the first order in combination with the rhombohedron, and a twinned rhombohedron.

Dolomite, $CaCO_3 . MgCO_3$.—Rhombohedrons of this mineral exhibiting characteristic curved surfaces are commonly found in the geodes at Keokuk, Iowa, and Niota, Illinois. The dolomite appears as aggregates of crystals resting on the quartz of the geodes, or it follows the siliceous shell directly.

Ankerite, $(Ca.Mg.Fe)CO_3$.—Some of the crystals outwardly resembling dolomite possess a high iron content and undoubtedly they are to be classed as ankerite. The decomposition of these crystals generates a considerable amount of limonite. The limonite thus formed is in many instances a more or less perfect pseudomorph after the ankerite.

Magnetite, Fe_3O_4.—Slender elongated crystals of magnetite appear in the interiors of some of the geodes from the Lower Warsaw. In most cases the crystals of this substance are implanted on quartz, but in one instance they occur on both quartz and calcite. Microscopic examination shows that some of the magnetite crystals have been partly altered to limonite. This mineral has not been reported previously from the geodes.

Hematite, Fe_2O_3.—In a few of the geodes from the Mud creek locality the reddish powder of hematite is found staining the interior lining of quartz. Geode No. 6 exhibits such a relationship.

Pyrite, FeS_2.—Pyrite is by far the most abundant metallic mineral associated with the geodes. It occurs both in the geodes from the Keokuk limestone and in those from the Lower Warsaw. It is found also as free crystal aggregates in the shale and as a mammillary coating on the surface of some geodes of the Lower Warsaw.

Within the geodes, pyrite of at least two periods of growth appears. Geode No. 12 illustrates this feature excellently. This mineral favors no particular associations for its crystals. They occur implanted indiscriminately upon quartz, chalcedony, or calcite. In some specimens it is also included in calcite. The pyrite of such inclusions is almost invariably in a fibrous or flaky condition. This is especially true of the geodes of the Keokuk limestone. Geode No. 13 from the Lower Warsaw exhibits such a relationship. The majority of the uninclosed crystals of pyrite assume more or less well developed forms, but in a few geodes, of which No. 12 is the type, there are slender elongated crystals which might easily be mistaken for millerite. The hexahedron is the most common of the crystal forms which are normally found. Others which have been noted are the pyritohedron and the cube with octahedral modifications. Decomposition of the pyrite has taken place in many of the geodes and bright unaltered crystals are not often found. The alteration has been accompanied by the formation of limonite in each case and the interiors of many of the geodes are, as a consequence, strongly iron stained.

Millerite, NiS.—Millerite has been found in the geodes of the Keokuk limestone at Keokuk and in the geodic cavities of the Montrose chert exposed in the excavation for the dam at the same city. In both of these occurrences the millerite is closely associated with calcite. In but a single instance was it found on quartz. Many of the slender needles of this mineral are included in the calcite, but some freely projecting tufts are found. The inclusions resemble very much the flakes of pyrite found in the calcite of the geodes of the Lower Warsaw.

Chalcopyrite, $CuFeS_2$.—Small sphenoids of this mineral have been found in the geodes both from the Keokuk limestone and from the Lower Warsaw at the locality northwest of Denmark. At no other place in the area was this mineral found in these beds. The crystals of this substance are always associated with calcite. None has ever been found on quartz. In the Keokuk limestone the small sphenoids are entirely included by the calcite, but in the geodes of the Lower Warsaw crystals of chalcopyrite are implanted on the surface of rhombohedrons and scalenohedrons of this mineral.

Sphalerite, ZnS.—Sphalerite is commonly found in the geodes both from the Keokuk limestone and from the Lower Warsaw. It occurs as irregular crystalline masses which range in size from very small particles to those having a diameter of four inches. It is usually associated with calcite and the two minerals are in many instances so intergrown as to indicate a contemporaneous deposition. In some geodes, however, sphalerite is found with quartz.

In the Lower Warsaw the crystals of sphalerite attain their greatest development in those geodes which have been crushed, or which are otherwise imperfectly developed. Crystals of blende are not common in well formed specimens. This mineral is very common in the large rounded masses which occur in the Keokuk limestone two miles northwest of Denmark. At no other place in the region is sphalerite known to be so abundant.

Limonite, $2Fe_2O_3+3H_2O$.—Limonite is the most common alteration product of the geodes and the interiors of a large percentage of the specimens are discolored by this mineral. The hydrate of iron has two common modes of origin, namely, by the alteration of pyrite and by the decomposition of ankerite. It occurs either as a rusty stain or as small ocherous masses in the interiors or in the shells of the geodes.

Smithsonite, $ZnCO_3$.—The carbonate of zinc occurs in some geodes as an alteration product of sphalerite, with which it is closely related. It usually appears as an encrusting film over the unaltered sulphide.

Malachite, $CuCO_3+Cu(OH)_2$.—The green basic carbonate of copper is associated with the small sphenoids of chalcopyrite in some of the geodes which occur in the Keokuk and Lower Warsaw beds northwest of Denmark.

Kaolin, Al_2O_3, $2SiO_2+2H_2O$.—In some of the geodes there occurs the flocculent white powder of kaolin. This mineral is commonly found in the specimens from the upper argillaceous part of the Lower Warsaw at Keokuk, Iowa, and Warsaw, Illinois, but it also occurs in imperfectly developed geodes at other localities. Examination of the powder under the microscope shows it to be in the form of fine scales. The relation of this mineral to the argillaceous material in some of the specimens suggests that it may have been formed by a leaching process. Most of the geodes in which it occurs are poorly developed and the calcite found in some kaolinitic specimens includes the white powder of this mineral. In such cases the kaolin evidently was formed early in the history of the geodes.

Gypsum, $CaSO_4+2H_2O$.—Gypsum occurs in the shales of the Lower Warsaw as irregular flakes and in a few of the geodes from the same horizon as incrusting films and tabular monoclinic crystals.

Water, H_2O.—Some of the geodes, as has been stated, contain water. No analysis of this water was undertaken by the writer for it was thought that little emphasis could be placed upon the result, since circulation and diffusion must have continued long after the geodes were formed. Professor Brush, however, has made a chemical examination of the water contained in a geode from this region. His report follows:

"A portion of this water weighing 16.327 grammes, gave, on evaporation, a crystalline residue weighing .094 grammes, which on analysis, proves to consist of sulphate of lime and sulphate of magnsia, with minute traces of silica. Another sample was examined for carbonic acid with a negative result".

The character of this sample suggests that the water was introduced after the geode was formed.

Bitumen.—A hydrocarbon. In the vicinity of Niota, Illinois, many of the geodes from the Lower Warsaw are partly or completely filled with a black, viscous asphaltic bitumen. In a few specimens from this place a black solid hydrocarbon was found. This has resulted undoubtedly from the natural distillation of lighter hydrocarbon from the liquid bitumen commonly observed.

In many cases the rocks containing bituminous geodes show no evidence of bitumen but the shells of some of the geodes are strongly discolored with this material.

PARAGENESIS OF THE MINERALS

In the discussion of the order of deposition of the minerals only the primary ones are considered. With reference to these minerals, no constant order of succession holds for all geodes, and the same order of formation may not obtain in two adjacent specimens.

For the purpose of illustrating the variations in the succession of the minerals in the geodes the order of their deposition in a number of typical specimens is given. The chalcedony of the shells of the geodes is listed first for it must be conceded that this was formed prior to the deposition of the minerals now found in the interior of the geodes.

1. Chalcedony, quartz.
2. Chalcedony, quartz, chalcedony.
3. Chalcedony, chalcedony, quartz.
4. Chalcedony, quartz, chalcedony, pyrite.
5. Chalcedony, chalcedony, sphalerite.
6. Chalcedony, quartz, chalcedony, quartz, chalcedony, pyrite, calcite with included pyrite.
7. Chalcedony, quartz, chalcedony, pyrite, calcite.
8. Chalcedony, quartz, calcite with included pyrite.
9. Chalcedony, quartz, pyrite, calcite.
10. Chalcedony, quartz, pyrite, calcite with included pyrite.
11. Chalcedony, quartz, chalcedony, pyrite, sphalerite.
12. Chalcedony, quartz, dolomite, calcite.
13. Chalcedony, quartz, calcite, calcite.
14. Chalcedony, quartz, magnetite, hematite.
15. Chalcedony, quartz, pyrite, magnetite.
16. Chalcedony, quartz, pyrite, dolomite.
17. Chalcedony, quartz, dolomite.
18. Chalcedony, quartz, bitumen.
19. Chalcedony, quartz, calcite, bitumen.
20. Chalcedony, quartz, ankerite, calcite.
21. Chalcedony, quartz, pyrite, calcite.
22. Chalcedony, calcite, chalcopyrite.
23. Chalcedony, calcite, calcite and chalcopyrite.
24. Chalcedony, calcite, calcite.
25. Chalcedony, calcite.
26. Chalcedony, calcite, millerite.
27. Calcite and millerite.
28. Quartz, millerite.

First in the process of development of the siliceous geodes there was formed in nearly every case a thin chalcedonic shell. Upon this is superposed quartz, in either the crystalline or chalcedonic condition, or calcite. But where quartz is present in the specimens studied it always rests on the siliceous shell or on an inner layer of chalcedony.

The cause of the alternation of crystalline quartz and chalcedony in some of the geodes is not known. If the layers were all formed during one period of growth, as seems probable, changes in the condition and amount of silicia supplied may have given rise to the phenomenon. Changes in temperature or pressure cannot be appealed to because in many cases adjacent quartz geodes in the strata show no such alternations.

The position of calcite in the geodes is subject to even more variations. In some instances it succeeds the chalcedonic shell directly, but in more cases it rests upon a lining of quartz or chalcedony. Two distinct periods of growth of this mineral are indicated. In some of the geodes calcite of both generations appears. Geode number 12 illustrates this feature excellently. In some specimens the earlier calcite is discolored and in many cases it is contemporaneous with, or directly followed by sphalerite, millerite, chalcopyrite, or pyrite. Crystals of dolomite or ankerite are sometimes found intervening between the earlier calcite and that of later age. These crystals rest directly upon calcite or quartz or in some instances upon the pyrite which succeeds them. Much of the calcite of later formation is clear and transparent, and some of the crystals are characteristically twinned. Pyrite is commonly associated with this variety of calcite, either as included flakes or as implanted crystals. The occurrence of crystals of magnetite on calcite of this age in geode number 20 suggests that deposition of this mineral directly folowed.

The kaolin which occurs in some of the geodes has no constant relationship. In some instances it occupies the interior of well-formed geodes (see geode number 14) but in most cases it appears in imperfect specimens. In the latter condition the kaolin evidently is residual for it has interfered with the normal geode development. In the more perfectly formed kaolinitic types, however, the material may possibly have been introduced after the geodes were formed. But the evidence is in favor of the view that it is an original constituent.

Origin of the Geodes

The following discussion of the origin of the geodes is taken from an earlier paper by the writer:[6]

The origin of the geodes of the Keokuk and Lower Warsaw

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6 Am. Jour. Sci., 4th ser., vol. XLII, p. 38 ff.; 1916.

beds has long been a disputed question, and, although there has been considerable speculation upon the subject, no one theory of their development has, as yet, been widely held.

The existence of perfectly developed geodes in strata often very impervious to underground circulation furnishes a problem which is exceedingly difficult to solve. The containing rock is in many cases highly argillaceous and no structures which might serve as passage ways for mineralizing solutions are to be seen.

It was formerly believed that the geodes were formed by the deposition of mineral matter on the walls of cavities formed by the solution of sponges imbedded in the rocks. Thus, Dana states:[7]

> "They have been supposed to occupy the centers of sponges that were at some time hollowed out by siliceous solutions, like the hollowed corals of Florida, and then lined with crystals by deposition from the same or some other mineral solution."

This theory has had many followers and S. J. Wallace has even gone so far as to coin a generic name for the sponge whose solution is supposed to have afforded the cavities in which the geodes were developed.[8] To this genus, called *Biopalla,* eight species were referred upon the basis of difference in size, shape, and surface markings of the geodes. The sponge hypothesis, however, is not now widely held. No evidence of sponges capable of giving rise to geodes has ever been found in the Keokuk or Warsaw beds. Moreover, the geodes vary widely in size and shape, a fact which argues strongly against any theory which presupposes such an origin. Many specimens are nodular and irregularities of the greatest variety characterize their exterior form. It may safely be said that no two of them assume exactly the same proportions.

Professor Shaler, in a paper entitled "Formation of Dikes and Veins,"[9] also devotes some space to the development of geodes and, although his studies were based upon geodes known to be of fossil origin which occur in the Knobstone shales of Kentucky, his conclusions may well be considered at this point:

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7 Manual of Geology, 4th ed., pp. 97, 98; 1895.
8 Am. Jour. Sci. (3), vol. XV, p. 366 ff.: 1878.
9 Bull. Geol. Soc. Am., vol X, p. 253 ff.; 1899.

"Normal geodes are hollow spheroids and are generally found in shales. They clearly represent, in most cases, a segregation of silica, which has evidently taken place under conditions of no very great heat, brought about by deep burial beneath sediments or other sources of temperature. It is difficult in all cases to observe the circumstances of their origin, but in certain instructive instances this can be traced. It is there as follows: Where in a bed in which the conditions have permitted the formation of geodes the calyx of a crinoid occurs, the planes of junction of the several plates of which it is composed may become the seat of vein-building. As the process advances these plates are pushed apart and in course of time enwrapped by the silica until the original sphere may attain many times its original diameter and all trace of its origin lost to view, though it may be more or less clearly revealed by breaking the mass.

In the process of enlargement which the geodes undergo they evidently provide the space for their storage by compressing the rock in which they are formed. In the rare instances where I have been able to clearly observe them in their original position they were evidently cramped against the country rock, the layers of which they had condensed and more or less deformed. Although when found upon the talus slopes or the soil these spheres usually contain no water in their central cavities, these spaces are filled with the fluid while they are forming and so long as they are deeply buried. There can be no doubt that this water is under a considerable though variable pressure.

The conditions of formation of spheroidal veins or geodes clearly indicate that an apparently solid mass of crystalline structure may be in effect easily permeated by vein-building waters, and this when the temperature and pressure could not have been great. It is readily seen that the walls of these hollow spheres grow interstitially while at the same time the crystals projecting from the inner side of the shell grow toward the center. We, therefore, have to recognize the fact that the silex-bearing water penetrated through the dense wall. In many of these spherical veins we may note that the process of growth in the interior of the spheres has been from time to time interrupted and again resumed. These changes may be due to the variations in pressure to which the water in the cavities is necessarily subjected as the conditions of its passage through the geode-bearing zone are altered."

More recently Bassler has written[10] on the formation of the Knobstone geodes. He says:

"The majority of geodes in the Knobstone group may be

10 Proc. U. S. Nat. Mus., vol. XXXV, p. 133 ff.; 1908.

traced directly or indirectly to a crinoidal origin for the simple reason that these strata are often crowded with the fragments of this class of organisms. Probably next in order as a geode maker is the common brachiopod *Athyris lamellosa,* but no class of fossil is exempt from replacement by silica when the proper conditions obtain."

Bassler is of the opinion that the Keokuk and Lower Warsaw geodes may have the same mode of origin as those of the Knobstone. But he disagrees with Shaler as to the details of geode development. Thus:

"Returning to the suggestion in Dana's Manual of Geology that the Keokuk geodes are hollowed out sponges lined with crystals it seems more reasonable, in view of the absence of such sponges in that formation and the presence of numerous specimens indicating the origin described above, that the latter is nearer the truth. Prof. Shaler's idea that this class of geodes is formed when deeply buried is not in accord with the facts, nor does there appear to be any necessity for the water of formation to be under a considerable though variable pressure. Ordinary surface waters charged with silica seem to be sufficient."

This generalization in so far as it relates to the geodes of the region studied, would seem to be too broad. Out of several thousand geodes examined only one, which had plainly been formed by the enlargement of a specimen of the crinoid *Barycrinus,* showed evidence of this method of geodization.

The origin of the geodes in the region studied is believed by the writer to be related to the calcareous concretions which originally must have been very abundant in the beds and which are still preserved at some localities. These nodules, being more soluble than the inclosing rocks, have been in large part removed, thus affording cavities in which the geodes could be formed. Where they are still preserved, the concretions have exactly the same relationship to the containing rock as the geodes and possess analogous shapes. They were obviously formed on the sea-bottom while the strata were being deposited, since lines of stratification do not pass through them and no evidence of expansion is encountered about their borders. The process of solution seems to have started in the interior and proceeded outwards. That this was the method of removal is indicated by the occurrence in the beds of some geodic nodules whose interiors were only partly hollowed out when deposition began. Carbonic acid and sulphuric acid, the latter of which must have been generated by the decomposition of the pyrite so common in the beds, probably were the most active solvents.

The white powder of kaolin found in some of the geodes is thought to represent, at least in part, a residual product resulting from the leaching of the original argillaceous content of the nodules. That kaolin can be so formed is clearly indicated by the presence of this mineral so related to impurities in some of the nodules that its derivation cannot be questioned. The more common occurrence of kaolin in the geodes from the more argillaceous part of the beds is significant in this connection. Moreover, the great majority of the geodes which contain kaolin are imperfectly developed and the calcite of such specimens invariably includes the white powder of this mineral. These facts strongly support the idea that the kaolin must be a residual product.

Concerning the time of formation of the geodes, little is definitely known. The removal of the calcareous nodules which, it is assumed, preceded the geodes, implies an interval of solvent action during which the Keokuk and Lower Warsaw beds were above ground-water level. The growth of geodes, on the other hand, undoubtedly took place below ground-water level.

In the development of the geodes at least two periods of mineralization are involved. The first period of development was by far the most important. During this period of growth the quartz, chalcedony, dolomite, and a considerable amount of the calcite together with almost all of the metallic sulphides were deposited.

Of the minerals of the second period of growth, transparent crystals of calcite and slender untarnished flakes of pyrite are by far the most important. The minerals of this class are doubtless much younger than those of the former as suggested by the fact that in many instances the pyrite associated with the newer calcite is perfectly fresh while in the same geode the earlier pyrite is badly decomposed.

The secondary minerals of the geodes such as limonite, gypsum, smithsonite, and malachite are for the most part of much more recent origin. They have resulted from the alteration of the primary sulphides as is shown by their association with the partly decomposed members of this group.

The bitumen which occurs in some of the geodes must have been introduced sometime after their formation, since it has not interfered with the normal geode development.

The process of geodization evidently consisted of the inward growth of crystals upon the walls of cavities left by the solution of the imbedded concretions. The growth was necessarily accomplished by deposition from a solution which filled the interior completely. As this solution became depleted in its mineral content, more was introduced by some process of diffusion and a continuous deposition resulted. In some instances a very impervious wall was developed and growth must have been extremely slow. But in the majority of geodes numerous feeding channels in the walls afforded ready passage to the solutions after they penetrated the siliceous shells.

The mineralogical differences of geodes which occur in close proximity to each other are difficult to account for. It must be assumed either that the process of geodization was a very local one and that each individual geode possessed only a small sphere of attraction, or that a peculiar localization of conditions favored in some instances the deposition of mineral matter more widely diffused through the mineralizing solutions.

CHAPTER VI

GEOLOGIC HISTORY

Conditions at the Close of the Devonian

The character and distribution of the Upper Devonian deposits in Iowa are such as to suggest that they extended over a larger area in pre-Kinderhook time and it is believed that an erosion interval preceded the incursion of the first Mississippian sea. However, the data bearing on the stratigraphic relations of the Kinderhook and underlying Devonian deposits in Iowa are meagre, owing to the fact that no contact of these older strata with layers definitely known to represent the basal Kinderhook has been observed.

The Kinderhook Transgression

With the opening of Mississippian time an interior sea occupied a considerable area in the Mississippi Valley region. The greater proportion of limestone in the group in central and north-central Iowa suggests that clearer and deeper seas prevailed in those areas than to the southeast. The deposits formed at this time undoubtedly once extended a considerable distance northeast of their present belt of exposure.

Conditions During Osage Time

The exent of the changes at the close of Kinderhook time is not definitely known. The next succeeding Burlington limestones, exposures of which are now confined to the southeastern part of Iowa, appear to follow the Kinderhook group conformably. Inasmuch as they exhibit a marked thinning in passing from the city of Burlington to southern Louisa county, it is probable that they did not extend far to the northwest.

The Keokuk formation succeeds the Burlington without a stratigraphic break and has essentially the same geographic distribution in Iowa. It thins to the northwest and is shaly in its upper part, the argillaceous horizon gradually descending in the formation towards the northwest. This suggests a gradual recession of the sea to the south during Keokuk time.

Oscillations During Meramec Time

The contraction of the seas during Keokuk time was apparently continued through the Warsaw. The deposits of this age consist predominantly of shales. Both divisions of this formation are confined to the southeastern part of the state, the Upper Warsaw being even more restricted than the Lower.

At the close of the Warsaw time the interior sea retreated more rapidly to the south, apparently as a result of an uplift of the Wisconsin positive element to the north, and the Warsaw and earlier Mississippian formations were subjected to erosion.

The returning sea of Spergen time probably was but little more extensive than that of the Warsaw, since the deposits of Spergen age in Iowa are of the near-shore type and are likewise confined to the southeastern part of the state.

The close of the Spergen was marked by a southward retreat similar to that at the close of the Warsaw. The readvancing Lower St. Louis sea extended far to the north, overlapping all the earlier divisions of the Mississippian except the Kinderhook, upon which it rests in Humboldt county. Early in St. Louis time, however, another elevation of the northern area took place and the strand line retreated rapidly to a point somewhere between Alton, Illinois, and Ste. Genevieve, Missouri. The disconformity resulting from this retreat has been found as far south as Alton, but no trace of it is shown in the section at Ste. Genevieve. Following a slight interval of erosion the St. Louis sea returned as rapidly as it had receded and the deposition of Upper St. Louis limestone in Iowa resulted.

The unstable conditions of the St. Louis were terminated by still another uplift. The duration of the erosion interval which followed could not have been great, for the deposits of the returning Ste. Genevieve sea, which must have rivaled that of the early St. Louis in size, have not been found to rest upon formations older than the Lower St. Louis.

Warping at Close of Meramec Time

At the close of Ste. Genevieve time the sea withdrew from the upper Mississippi Valley again, and the entire region remained a land area until the close of the Mississippian period. A great warping took place during and following this emergence, which resulted in a tilting of the Mississippian and earlier formations to the southwest and is known to have been accompanied by the development of small northwest-southeast trending anticlines and synclines and by extensive brecciation of the hard, brittle St. Louis limestone. (See page 236.) Consequent upon this uplift erosion proceeded rapidly during the remainder of the Mississippian and the tilted beds were partly truncated, thus giving rise to a series of northwest-southeast belts of formational outcrops in Iowa, many of which were later buried by the Coal Measures.

This southwestward tilting of the beds in Iowa was related to a widespread late Mississippian deformation involving also eastern Nebraska, eastern Kansas and Missouri, which outlined a great southwestwardly pitching geosyncline later occupied by the early Pennsylvanian sea advancing along a narrow trough from the southwest and gradually spreading to the margins of the basin by overlap. A structure contour map of the geosyncline and a discussion of its influence on Pennsylvanian sedimentation have been published previously by the writer.[1]

The geosyncline was shallow in early Pennsylvanian time as is indicated by the fact that the maximum known thickness of the Cherokee stage, which doubtless represents the time of greatest sea extension in the province during the period, is only 712 feet. However, it must be remembered that the rim of the basin had been lowered considerably by pre-Pennsylvanian erosion. At the present time, the basin is considerably deeper as a result of subsidence during Pennsylvanian time.

1 Jour. Geol., vol. XXV, pp. 150-156; 1917.

PLATES ILLUSTRATING MISSISSIPPIAN FOSSILS

On the following plates the illustrations are all natural size. Some of the type fossils suggested by Doctor Van Tuyl had to be omitted due to lack of space. This is especially true of the large Keokuk brachiopods to include which another plate would have been necessary. Most of the brachiopod illustrations were furnished by Doctor Stuart Weller from the original plates of his Monograph 1, Illinois Geological Survey. Some of the crinoids are copied from Wachsmuth and Springer's Crinoidea Camerata. All others are illustrations of specimens in the paleontological collections at the State University of Iowa.

—A. O. Thomas.

PLATE III

TYPE KINDERHOOK FOSSILS

Fig. 1. *Leptopora typa* Winchell.
Calycinal view of an incomplete colony.
In railway cut three miles northeast of Morning Sun.

Fig. 2. *Leptaena convexa* Weller.
Impression of the external surface of a brachial valve.
Bed No. 5, Burlington.
After Weller, Monog. 1, Ill. Geol. Surv.

Figs. 3, 4. *Schellwienella inflata* (White and Whitfield).
Brachial and lateral views of an internal cast.
Bed No. 7, Burlington. After Weller.

Fig. 5. *Chonetes logani* Norwood and Pratten.
Pedicile view.
Bed No. 6, Burlington. After Weller.

Fig. 6. *Chonopectus fischeri* Norwood and Pratten.
View of a very perfect pedicle valve showing the spines along the cardinal margin.
Bed No. 3, Burlington. After Weller.

Figs. 7, 8. *Productus arcuatus* Hall.
7. Pedicle view of a shell from Chouteau Springs, Missouri.
8. Lateral view of a pedicle valve from Bed No. 6, Burlington. After Weller.

Figs. 9, 10. *Paryphorhynchus transversum* Weller.
9. Pedicle view of a cast from Kinderhook, Illinois.
10. Anterior view of a cast from Chonopectus sandstone, Burlington. After Weller.

Figs. 11, 12. *Spiriferina solidirostris* White.
Pedicle and brachial views of the cotypes.
Bed No. 7, Burlington. After Weller.

Fig. 13. *Spirifer platynotus* Weller.
View of a brachial valve of one of the cotypes.
Bed No. 6, Burlington. After Weller.

Figs. 14, 15. *Spirifer biplicatus* Hall.
Pedicle and brachial views.
Chonopectus sandstone, Burlington. After Weller.

Figs. 16-18. *Spirifer subrotundus* Weller.
Pedicle, brachial and lateral views.
Chonopectus sandstone, Burlington. After Weller.

Figs. 19, 20. *Reticularia cooperensis* (Swallow).
Pedicle and brachial views of a specimen from Pettis county, Missouri. It is common at Burlington and elsewhere in Iowa. After Weller.

Fig. 21. *Edmondia jejunus* (Winchell).
View of right valve of an internal mold.
Wassonville.

Figs. 22, 23. *Nucula iowensis* White and Whitfield. = *N. houghtoni* Stevens.
Internal and external views of left and right valves, respectively.
Wassonville cherts, Wassonville.

Fig. 24. *Dentalium grandaevum* Winchell.
A typical specimen from the Wassonville cherts.

Fig. 25. *Straparollus obtusus* (Hall).
Apical view.
Oölitic beds, Humboldt.

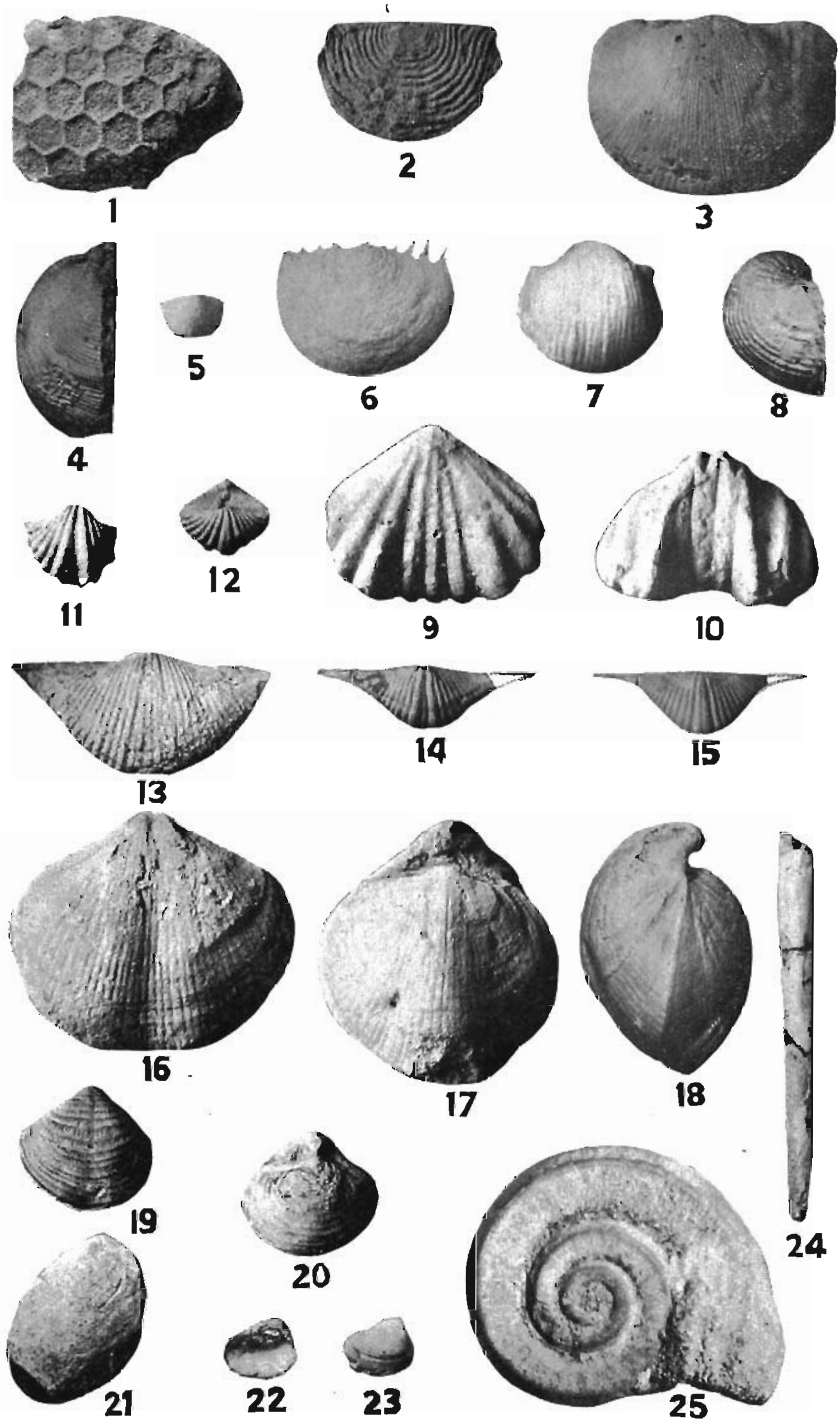
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PLATE IV

TYPE BURLINGTON FOSSILS

Figs. 1, 2. *Zaphrentis calceola* (White and Whitfield).
Two specimens showing size and curvature.
Bed No. 4, Burlington.

Figs. 3, 4. *Orbitremites norwoodi* (Owen and Shumard).
Basal and interradial views of a nearly perfect specimen showing the elevated ambulacra.
Upper Burlington limestone; Burlington.

Figs. 5, 6. *Cryptoblastus melo* (Owen and Shumard).
Interradial and apical views showing the sunken ambulacra. Burlington

Figs. 7, 8. *Macrocrinus verneuilianus* (Shumard).
Right posterior views of two typical calyces of one of the commonest Burlington crinoids.
Burlington.

Fig. 9. *Dizygocrinus rotundus* (Shumard).
Left posterior view of a typical calyx.
Burlington.

Fig. 10. *Uperocrinus pyriformis* (Shumard).
Anterior view of a typical calyx.
Burlington.

Fig. 11. *Teleiocrinus umbrosus* (Hall).
Posterior view of a typical but rather small calyx.
Burlington.

Figs. 12-14. *Chonetes illinoisensis* Worthen.
Pedicle and brachial views of typical shells from Burlington limestone at Springfield, Mo. 14 is a view of the interior of a brachial valve from the Keokuk limestone of the same locality. After Weller.

Figs. 15, 16. *Productus burlingtonensis* Hall.
15. Pedicle view of a shell from Burlington. 16. Brachial view of a specimen from Quincy, Illinois. After Weller.

Fig. 17. *Rhipidomella burlingtonensis* (Hall).
Pedicle view of a typical shell.
Burlington. After Weller.

Figs. 18, 19. *Spirifer grimesi* Hall.
View of an incomplete pedicle valve showing the markings and the interior of another pedicle valve showing the muscle scar.
Springfield, Mo. After Weller.

Fig. 20. *Spiriferella plena* (Hall).
Interior of apical part of a pedicle valve showing the dental lamellæ.
Burlington. After Weller.

Fig. 21. *Athyris lamellosa* (Léveillé).
Pedicle view of a nearly perfect specimen.
From the Keokuk limestone; Warsaw, Illinois. It is also common in the Burlington limestone.

Fig. 22. *Lepetopsis capulus* (Hall).
Side view of a mold.
Bed No. 6, Burlington.

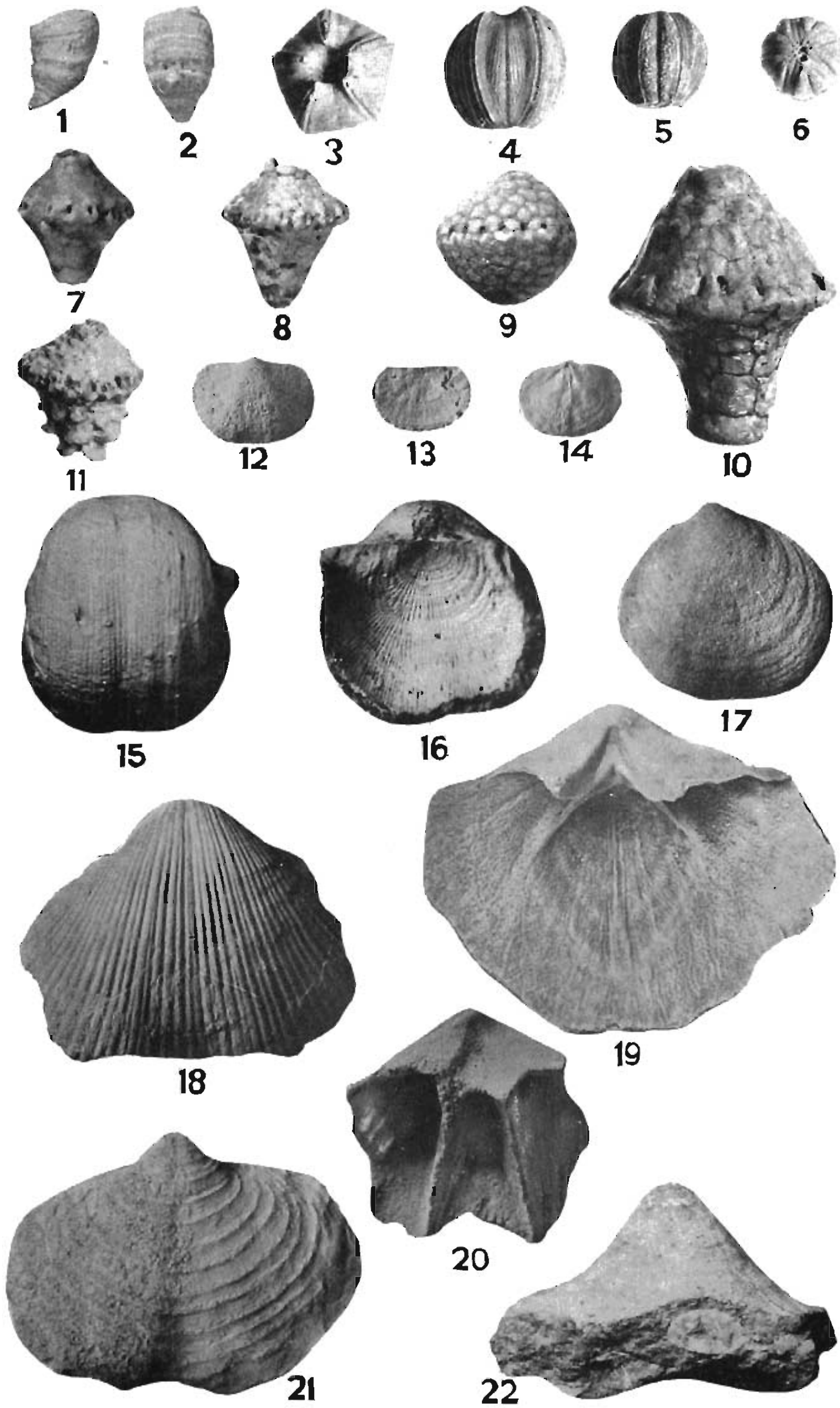
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PLATE V

TYPE KEOKUK AND WARSAW FOSSILS

Figs. 1, 2. *Palaeacis obtusus* Meek and Worthen.
Calycinal and lateral views of two colonies.
Keokuk.

Fig. 3. *Macrocrinus laguneulus* (Hall).
Postero-lateral view of a typical calyx from Keokuk.
After Wachsmuth and Springer.

Fig. 4. *Dorycrinus mississippiensis* Roemer.
Anal view of a very fine calyx.
Keokuk.

Fig. 5. *Archimedes owenanus* Hall.
Part of spiral axis.
Keokuk.

Fig. 6. *Orthotetes keokuk* (Hall).
Pedicle view of a large and nearly complete specimen.
Keokuk. After Weller.

Fig. 7. *Productus setigerus* Hall.
Pedicle illustration of a somewhat distorted shell.
Hamilton, Illinois. After Weller.

Fig. 8. *Tetracamera subtrigona* (Meek and Worthen).
Pedicle view of a large specimen.
Warsaw, Illinois. After Weller.

Figs. 9, 10. *Spirifer keokuk* Hall.
Brachial and lateral views of a nearly perfect specimen.
Keokuk. After Weller.

Figs. 11, 12. *Spirifer rostellatus* Hall.
Pedicle and brachial views of the holotype.
Specimen from Warsaw, Illinois. After Weller.

Fig. 13. *Myalina keokuk* Worthen.
Bed No. 6, Keokuk.

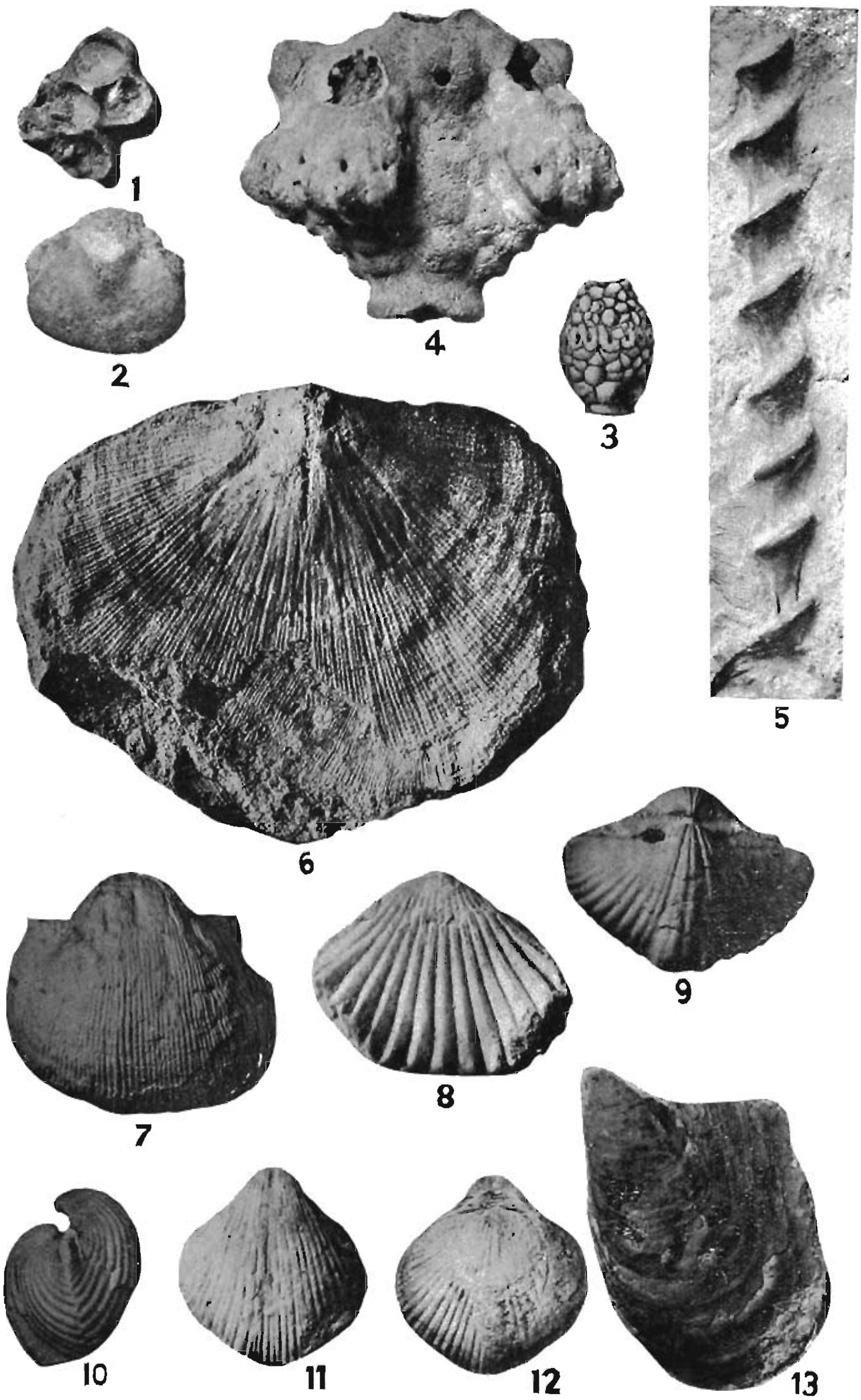
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PLATE VI

TYPE ST. LOUIS AND PELLA FOSSILS

Fig. 1. *Triplophyllum dalei* (Milne-Edwards and Haime).
Calycinal view of a fine specimen from St. Louis limestone.
Henry county, Iowa.

Figs. 2-4. *Triplophyllum pellaensis* (Worthen).
Lateral views and a calycinal views of three typical specimens. Note the spine bases.
Pella beds; Pella.

Fig. 5. *Lithostrotion canadense* Castelnau.
Part of a perfect colony from St. Louis limestone.
Mt. Pleasant.

Fig. 6. *Archimedes wortheni* Hall.
Portion of the screw-shaped axis of this peculiar fenestellid bryozoan. Upper Warsaw limestone. Keokuk.

Fig. 7. *Lingula varsoviensis* Worthen.
View of the holotype.
Warsaw beds; Warsaw, Illinois. After Weller.

Figs. 8, 9. *Orthotetes kaskaskiensis* (McChesney).
Brachial and pedicle views of somewhat broken specimens.
Pella beds; Fort Dodge.

Figs. 10-12. *Tetracamera arctirostrata* (Swallow).
Pedicle, brachial and lateral views of a specimen from Salem limestone.
Booneville, Missouri. After Weller.

Figs. 13-16. *Pugnoides ottumwa* (White).
Brachial, pedicle, anterior and lateral views of specimens from the Pella beds at Fort Dodge.

Figs. 17-19. *Girtyella indianensis* (Girty).
Brachial, pedicle and lateral views.
Pella beds; Pella. After Weller.

Fig. 20. *Spirifer pellaensis* Weller.
Brachial view.
Pella beds; Fort Dodge.

Figs. 21, 22. *Allorisma marionense* White.
Casts of two specimens viewed from the hinge and from the left side, respectively.
Pella beds; Ottumwa.

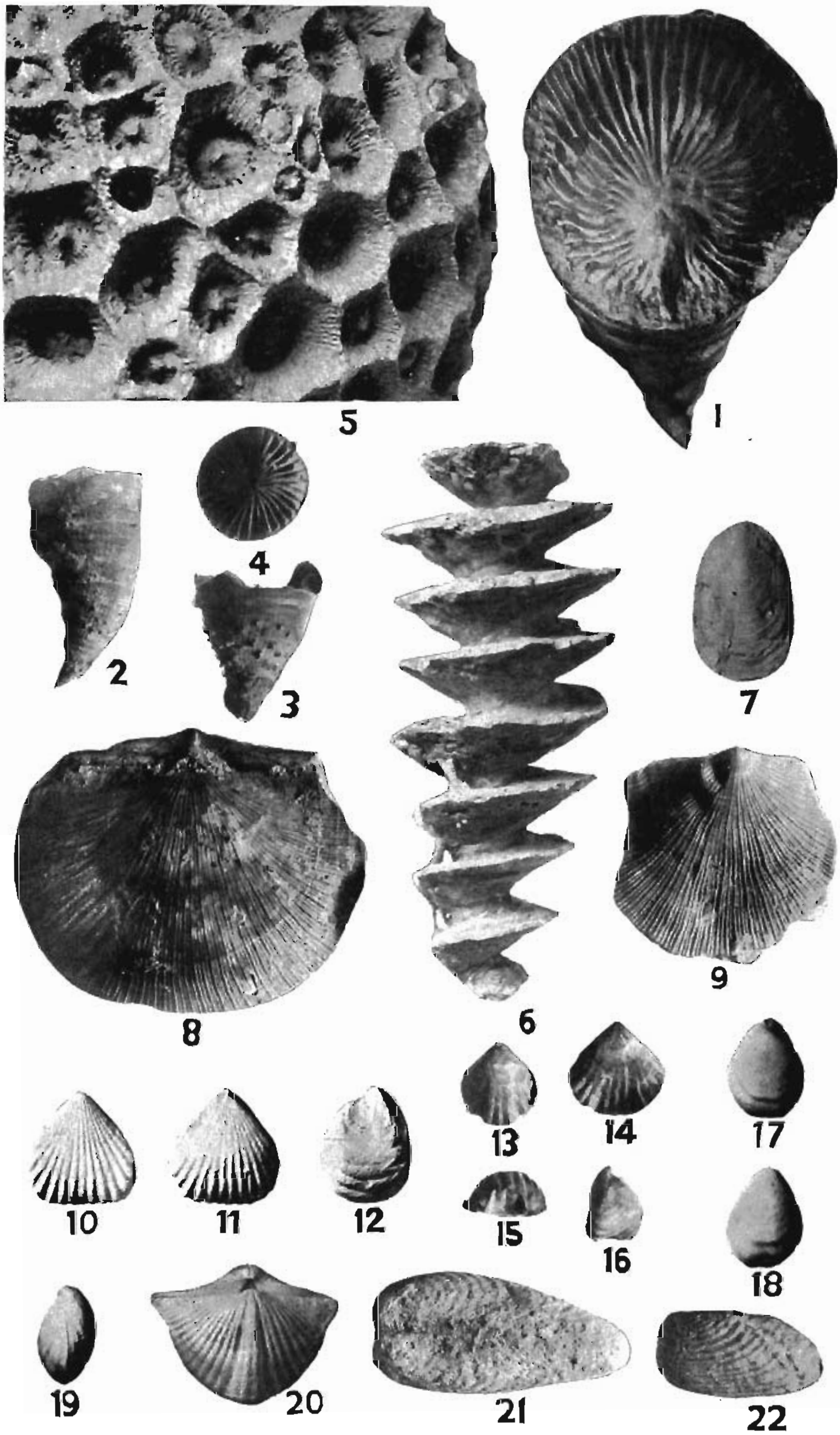
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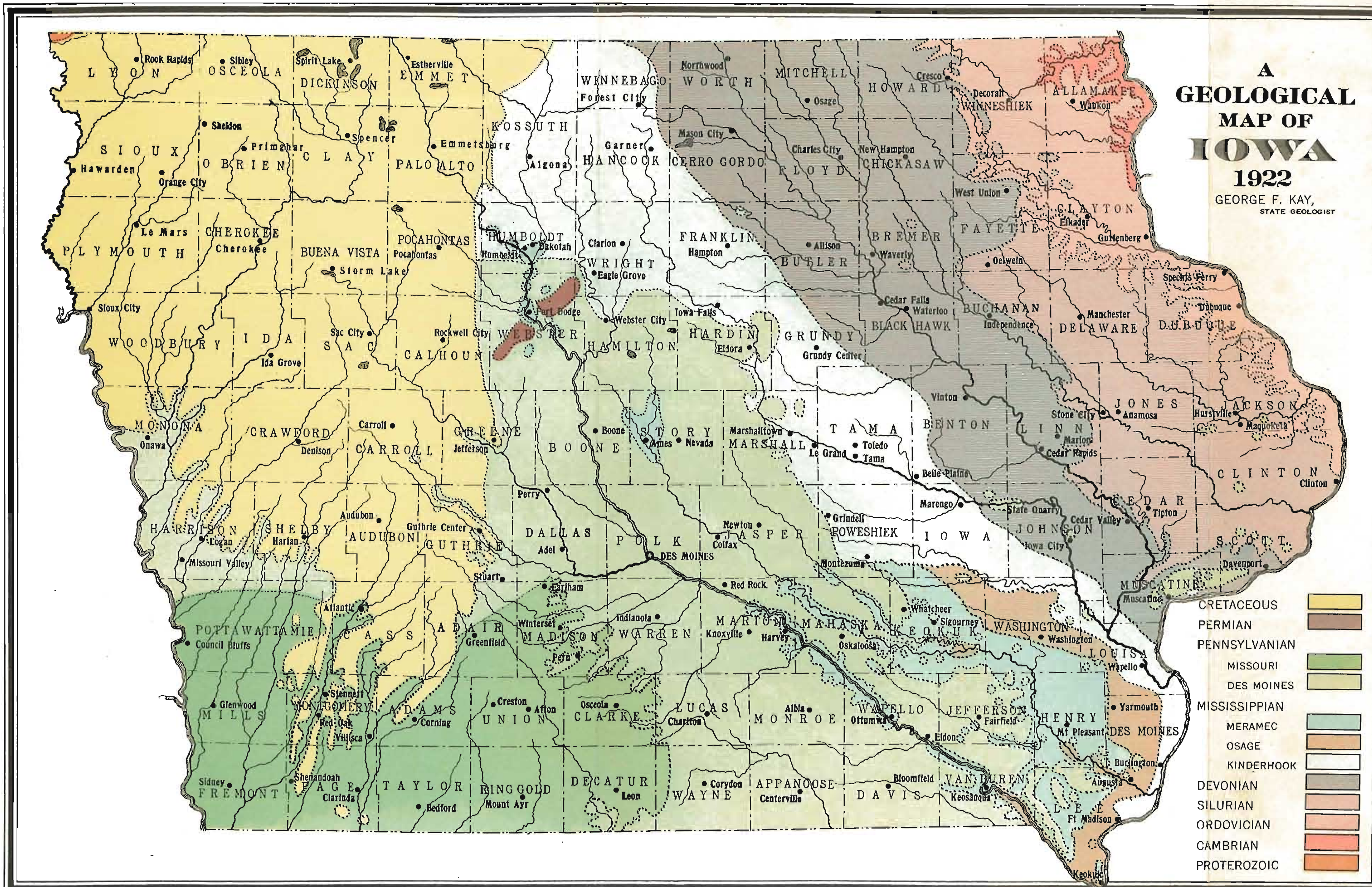
PLATE I

GEOLOGICAL MAP OF IOWA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GEOLOGICAL
MAP OF
IOWA
1922
GEORGE F. KAY,
STATE GEOLOGIST
CRETACEOUS
PERMIAN
PENNSYLVANIAN
MISSOURI
DES MOINES
MISSISSIPPIAN
MERAMEC
OSAGE
KINDERHOOK
DEVONIAN
SILURIAN
ORDOVICIAN
CAMBRIAN
PROTEROZOIC

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