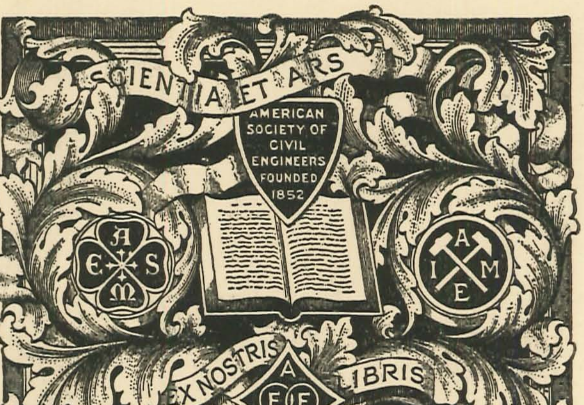
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IOWA
GEOLOGICAL SURVEY

VOLUME XXXI

Annual Reports, 1923 and 1924

with

Accompanying Papers

GEORGE F. KAY, Ph. D., State Geologist
JAMES H. LEES, Ph. D., Assistant State Geologist

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IOWA GEOLOGICAL SURVEY,
DES MOINES, DECEMBER 31, 1924.

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

GENTLEMEN: I beg leave to transmit to you herewith several papers with the recommendation that they be published as Volume XXXI of the Survey. This Volume will constitute the Thirty-second and Thirty-third Annual Reports of the Iowa Geological Survey. The titles of the papers submitted and the names of the authors of the papers are as follows:

Mineral Production in Iowa in 1923 and 1924, by James H. Lees.
The Geology of the More Refractory Clays and Shales of Iowa, by S. L. Galpin.
The Fertilizer Materials of Iowa, by John E. Smith.
Ash and Sulphur in Iowa Coals, by H. L. Olin and J. R. Troeltzsch.
Trilobites of Iowa and some Related Paleozoic Forms, by Otto Theodore Walter.

Respectfully submitted,
GEORGE F. KAY,
State Geologist.

MINERAL PRODUCTION IN IOWA IN 1923 AND 1924

BY

JAMES H. LEES

MINERAL PRODUCTION IN IOWA IN 1923

1921

Products	Unit	Quantity	Value
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

1923

Cement	Bbl. of 376 lb.	5,570,675	$10,351,971
Clay products			7,033,924
Coal	short tons	5,710,735	20,517,000
Gypsum	short tons	566,724	5,368,532
Mineral waters	gallons	258,831	8,907
Natural gas	M cubic feet	80	172
Sand and gravel	short tons	3,597,160	2,181,881
Stone and lime	short tons	611,866	775,134
			$46,237,521

The output of minerals and mineral products in Iowa during 1923 had a higher value than that of any preceding year in the history of the state with the exception of the abnormal year 1920, when the value of the state's mineral output shot up twenty millions of dollars in one year, after which it dropped back twenty-two millions the next year. The production in 1923 seems to represent a healthy growth and a natural reaction from the de-

[1] The statistics for 1923 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.

pression of the two preceding years. It is noteworthy that the increase in value and quantity of output was not limited to one item but was shared by all the major branches of the mineral industry. This increase amounted to $10,048,123 over the output of the preceding year. Perhaps the most striking increase was that of nearly three millions of dollars in the value of the cement shipments, although the increase in the output of gypsum products of $1,222,350 is also worthy of note.

The following table shows the value of the mineral production in Iowa during the ten years ending 1923.

Production of minerals from 1914 to 1923

Year	Coal	Clay wares	Gypsum	Cement	Other (a)	Total
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
1923	20,517,000	7,033,924	5,368,532	10,351,971	2,966,094	46,237,521

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

COAL.

The production of coal showed a gratifying increase in 1923 over that of the preceding year, insofar as total tonnage and total value were concerned, as the former showed an increase of over one and a third millions of tons and the latter one of over four million dollars. However, the average value per ton at the mines declined from $3.72 in 1922 to $3.59 in 1923, a drop of thirteen cents. It may be noted that the larger output was made by a smaller number of mines, as there were forty-three fewer operators in 1923 than in the preceding year. Also the number of miners was less by 1,409 in 1923. But to offset these decreases the average number of days worked was fifty more in 1923 than in 1922 and hence the output might well be considerably larger.

Monroe county, with only nine producers operating fourteen mines, was in the lead, in both tonnage recovered and value received. In contrast with mining conditions in Monroe was the case of Appanoose county, the second in rank, in which forty-two companies operated fifty-four mines. The next largest producers in order of their output were Marion, Lucas, Polk, Dallas, Boone and Jasper. The tonnage of the Lucas county mines was somewhat larger than that of the mines in Polk county but the value was slightly less, owing to the higher price per ton received by the Polk county operators.

The appended table will show by counties the coal production of 1923 with a comparison of the totals with those for 1922.

Coal Production in 1923 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 of days worked
		Short tons	Short tons	Short tons	Short tons	Value		Under-ground	Surface	Total	
Appanoose	42	863,671	48,737	19,259	931,667	$ 3,464,000	$3.72	2852	248	3,100	146
Boone	5	216,092	46,235	2,107	264,434	1,222,000	4.62	617	51	668	178
Dallas	5	527,520	14,430	3,911	545,861	1,915,000	3.51	918	90	1,008	213
Guthrie(1), Jefferson(1), Keokuk(1)	3	....	6,449	....	6,449	20,000	3.01, 3.00, 3.33	20	1	21	100, 183, 120
Jasper	3	81,852	15,223	6,316	103,391	363,000	3.51	192	27	219	142
Lucas(2), Warren(3)	5	725,001	6,700	23,788	755,499	2,612,000	3.45, 3.60	909	86	995	192, 174
Mahaska	8	Incl. in "Local trade"	37,411	Incl. in "Local trade"	37,411	130,000	3.47	84	7	91	169
Marion	16	675,054	42,686	22,577	740,317	2,478,000	3.35	1,187	111	1,298	203
Monroe	9	1,490,213	32,536	35,033	1,557,782	5,510,000	3.53	2,231	180	2,411	198
Page(2), Taylor(1)	3	9,954	18,685	....	28,639	136,000	4.57, 5.00	71	6	77	212, 230
Polk	15	380,606	274,802	12,423	667,831	2,428,000	3.63	1,249	122	1,371	191
Van Buren(2), Wayne(2)	4	21,927	7,710	....	29,637	105,000	2.63, 3.95	99	7	106	231, 181
Wapello	10	Incl. in "Local trade"	33,067	Incl. in "Local trade"	33,067	108,000	3.27	77	6	83	146
Small mines	14	8,750	....	....	8,750	26,000	3.00	....	....	....	....
	142	5,027,502	556,180	127,053	5,710,735	20,517,000	3.59	10,506	942	11,448	181
Production in 1922	185	3,653,352	579,907	101,902	4,335,161	16,119,000	3.72	11,846	1,011	12,857	131
Difference in 1923	—43	+1,374,150	— 23,727	+ 25,151	+1,375,574	+4,398,000	— .13	— 1,340	— 69	— 1,409	+ 50

The following is the list of operators during 1923 and 1924:

Adams County
Joe Aukeny, Villisca
Bixler Coal Co., Corning
Pleasant Valley Coal Co., Nodaway
Ruth Coal Co., Carbon

Appanoose County
Acken Coal Co., Mystic
Appanoose Coal & Fuel Co., Mystic
Armstrong Coal Co., Commerce Bldg., Kansas City, Mo.
Barrett Coal Co., Mystic
Beggs Coal Co., Mystic
Big Three Coal Co., Centerville
Bradshaw Coal Co., Dean
Brazil Coal Co., Brazil
Caldwell Coal Co., Exline
Carbon Fuel Co., Centerville
Center Coal Co., Centerville
Centerville Block Coal Co., Centerville
Citizens Coal Co., Centerville
Clark Coal Co., Daniel Clark, Centerville
Diamond Block Coal Co. (Lodwick Bros.), Mystic
Domestic Coal Co., Cincinnati
Duff Coal Co., Mystic
Eagle Coal Co., Centerville
Egypt Coal Co., Mystic
Farmers Coal Co., Mystic
Fisher Coal Co., R. No. 1, Plano
Fowler & Wilson Coal Co., Ottumwa
Gillispie & Lovendusky Coal Co., Mystic
Gott Coal Co., Centerville
Grandon & Anders Coal Co., Plano
Harkes Coal Co., Keith & Perry Bldg., Kansas City, Mo.
Hawkeye Coal Co., Mystic
Helman Bros. Coal Co., Plano
High Test Coal Co., Centerville
Hooten Bros. Coal Co., C. P. Houser, Seymour
Hunt Bros. Coal Co., Mystic
Interurban Coal Co., Mystic
Iowa Block Coal Co., Exline
J. A. Koontz, Centerville
Lee & Jones Coal Co., Mystic
Liberty Coal Co., Mystic
Livingood Coal Co., Centerville
Allen Long Coal Co., Mystic
W. W. Lowe, Brazil
McConville Coal Co., Centerville
Midway Coal Co., Centerville
Monitor Coal Co., Centerville
Murray & Askern Coal Co., R. No. 1, Mystic
Mystic Coal Co., Mystic
National Coal Mining Co., Lincoln, Nebr.
New Oriental Coal & Mining Co., Centerville
New Phoenix Coal Co., Brazil
North Hill Coal Co., Centerville
Peacock Coal Co., Brazil
Potier Coal Co., Mystic
Prairie Coal Co., Centerville
Rinehart Coal Co., Plano
Roach Coal Co., R. No. 1, Plano
Rosebrook Coal Co., Mystic
Ryals-Yagzy Coal Co., Dean
Shamrock Coal Co., Rathbun
Star Coal Co., Mystic
Sterling Coal Co., Centerville
Sunshine Coal Co., Centerville
Thistle Coal Co., Cincinnati
United States Coal Co., Centerville
Winifred Coal Co., Mystic
Woodland Coal Co., 16 West Washington St., Centerville

Boone County
Black Diamond Coal Co., c/o A. Johnson, Boone
Boone Coal Co., Boone
McCaskey Coal Co., Pilot Mound
Ogden Coal Co., Boone
Sayre Coal Co., 201—7th St., Des Moines
Scandia Coal Co., 606 Grand Ave., Des Moines
South Side Coal Co., Fraser

Dallas County
Dallas Coal Co., 326 Liberty Bldg., Des Moines
Norwood-White Coal Co., Des Moines
Radiant Coal Mining Co., Ottumwa
Scandia Coal Co., Des Moines
Shuler Coal Co., Des Moines

Greene County
Buckeye Coal Co., Rippey
Carpenter Coal Co., Moingona

Guthrie County
W. H. Scott, Guthrie Center, R. R. No. 5

Jasper County
Acme Coal Co., Prairie City
Colfax Consolidated Coal Co., Colfax
Newton Coal Co., Newton
Sunny Brook Coal Co., Colfax

Jefferson County
W. F. Faulkner Coal Co., Fairfield
C. S. Henness, Fairfield
O. S. Sedgwick Coal Co., Fairfield
Jos. Voight Coal Co., Batavia

Keokuk County
Big Four Coal Co., What Cheer
Carson Bros., What Cheer
Newcomb Bros. Coal Co., What Cheer

Lucas County
Central Iowa Fuel Co., Des Moines
Iowa-Nebraska Coal Co., Des Moines

Mahaska County
Jay Beadle Coal Co., Beacon

Bloes & Gyttes Coal Co., Beacon
Davis & Sons, Beacon
Rosser Davis Coal Co., Beacon
Douds & Seams Coal Co., Oskaloosa
Edwards Bros. Coal Co., Beacon
Equality Coal Co., Albia
Fedro Coal Co., R. F. D., Givin
Fisher Coal Co., Evans
Frehn & Cons Coal Co., Oskaloosa
Givin Coal Co., Givin
William Griffiths Coal Co., Oskaloosa
Griffiths & Lloyd Coal Co., Beacon
Herbig Coal Co., Oskaloosa
Hynick Coal Co., Given, R. R. No. 1
Larson Coal Co., Beacon
Lee & Kuntz Coal Co., What Cheer
Nelson & Knight Coal Co., Rose Hill
Nelson Bros., Oskaloosa
O'Brien & Evans Coal Co., Evans
Reese & Ellis Coal Co., R. F. D., Givin
Williams Coal Co., New Sharon
Dennis Wymore Coal Co., New Haven

Marion County
George Anderson Coal Co., Knoxville
Black Diamond Coal Co., Dallas
Perry Brown Coal Co., Knoxville
Geo. L. Burt Coal Co., Knoxville
Capitol City Coal Co., Cordova
Consolidated Ind. Coal Co., 139 West Van Buren St., Chicago, Ill.
Des Camp Bros. Coal Co., Flagler
Dunreath Coal & Mining Co., Des Moines
A. C. Geery, Harvey
Gold Goose Coal & Mining Co., Albia
Hayes Bros. Coal Co., Knoxville
Honey Creek Coal Co., Knoxville
Horse Shoe Coal Co., (Dupont & Villont) Bussey
Knox Coal Co., Knoxville
McCagg Coal & Mining Co., Central Life Bldg., Des Moines
Melcher Coal Co., Melcher
Midland Coal Co., R. F. D., Knoxville
Mulkey & Thomas, Knoxville
Pershing Coal Co., Des Moines
Red Rock Coal Co., Des Moines
Success Coal Co., Otley
Vernon Coal Co., Dallas

Monroe County
Albia Coal Co., Ottumwa
Central Coal Co., Oskaloosa
Consolidation Coal Co., Bucknell
Crescent Coal Co., Oskaloosa
Graham Coal Co., Avery
Head Coal Co., Albia
Hocking Coal Co., Hocking
Larson Air Line Coal Co., Albia
Maple Coal Co., Des Moines
Mashak & Willard Coal Co., Lovilia
Rex Fuel Co., Lovilia
Sheriff Coal Co., Oskaloosa
Smoky Hollow Coal Co., Albia

Page County
City Fuel Co. (Evans Coal Co.), Clarinda
Pearson Coal Co., Clarinda

Polk County
Acme Coal Mining Co., Des Moines
Adelphi Coal & Mining Co., 2300 East 24th St., Des Moines
Beck Coal & Mining Co., Des Moines
Bennett Bros. Coal Co., Des Moines
Bloomfield Coal & Mining Co., Des Moines
Des Moines Coal Co., 910 West Grand Ave., Des Moines
Des Moines Ice & Fuel Co., Des Moines
Diamond Block Coal Co., 307 Polk Bldg., Des Moines
Diamond Joe Coal Co., Runnells
Economy Coal Co., Des Moines
Liberty Coal Mining Co., 807 Locust St., Des Moines
Norwood-White Coal Co., Des Moines
Saylor Coal Co., 606 Grand Ave., Des Moines
Sprague Coal & Mining Co., Berwick
Urbandale Coal Co., Des Moines
Wright Coal Co., 606 Grand Ave., Des Moines
X. L. Coal Co., Des Moines

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

Van Buren County
Blue Jacket Coal Co., (A. L. Cahill) Farmington
J. Daniels & Sons, Douds
B. F. Donrad Coal Co., R. F. D., Mount Zion
Hugh Findlay Coal Co., Douds
Fletcher Coal Co., Stockport
Albert Gardner Coal Co., Bonaparte
H. M. Kirby Coal Co., Farmington
James Tweedy Coal Co., Douds
Moses Tweedy Coal Co., Fairfield

Wapello County
Charles Akers Coal Co., Ottumwa
W. J. Box Coal Co., Eldon
R. E. Cooper Coal Co., Ottumwa
H. H. Davis Coal Co., R. F. D., Ottumwa
W. O. Donaldson Coal Co., Ottumwa
Joe Genochio Coal Co., Ottumwa
Gibbs Bros. Coal Co., R. F. D., Ottumwa
Glendale Coal Co., 1317 Castle St., Ottumwa
Glenn Bros. Coal Co., R. F. D., Ottumwa
Griffiths Bros. Coal Co., Roger Griffiths, Beacon
Hazeltine Coal Co., Ottumwa
Wm. Henry, Eldon

Louis Kellar Coal Co., Eldon
Clarence Lambert Coal Co., Eldon
Geo. Latchem Coal Co., R. F. D., Ottumwa
Wm. McIntosh, Jr., Coal Co., Eldon
Mat Mier Coal Co., 914 E. 4th St., Ottumwa
Mier Coal Co., (Wm. Mier) R. R. No. 8, Ottumwa
Herb Orr Coal Co., Eldon
Howell Price Coal Co., Ottumwa
Ramsey Coal Co., Ottumwa
Richard Reese Coal Co., Ottumwa
Rutledge Coal Co., R. R. No. 3, Ottumwa
Seigel-Smith Coal Co., Ottumwa
George Simmer Coal Co., Ottumwa
Simpson Bros. & Howard, Ottumwa
Sinsky Bros., Blakesburg
Speer Bros. Coal Co., R. F. D., Ottumwa
Swartz Coal Co., Ottumwa
Union Coal Co., Ottumwa
Valley Coal Co., Ottumwa
Wapello Fuel Co., Eddyville
Homer Weist Coal Co., Eldon
J. M. Welch Coal Co., Ottumwa
Wickam Coal Co., Ottumwa

Warren County
Des Moines Ice & Fuel Co., Des Moines
Hartford Coal & Mining Co., Runnells

Wayne County
Rissler & Yocum, Melrose
Seymour Coal Co., Seymour

Webster County
Lehigh Coal Co., Lehigh

CLAY WARES.

The production of clay wares showed a fine increase in 1923, amounting to $1,294,475 over the output of 1922. This increase prevailed in every important branch of the industry, for although the tonnage of drain tile made in 1923 was slightly less than that of the year before the price realized was a little greater. The sewer pipe sold increased from 38,359 tons valued at $681,233 in 1922 to 54,828 tons valued at $865,676 in 1923. Hollow building tile for walls, including partition, load-bearing, back-up, blocks, furring, book tile, was made in 1923 to the amount of 297,253 tons with a value of $2,197,515. Other kinds of tile, including floor arch, silo tile, corn-crib tile, conduits, radial chimney blocks, fireproofing and roofing tile, were made to the value of $216,938. The quantity of vitrified brick sold for paving and other purposes was 31,523,000, with a value of $513,684. The pottery at Bellevue continued the manufacture of flower pots and other red earthenware, and there was a large increase in the output of miscellaneous wares over the state as compared with that of the previous year.

The table following will show the production by counties, so far as this may be revealed, and a comparison with the previous year.

Production of Clay Wares by Counties in 1923

Counties	Producers	Common brick		Face brick		Hollow building tile		Drain Tile		Other Products(1)	Total Value
		Thousands	*Value*	*Thousands*	*Value*	*Tons*	*Value*	*Tons*	*Value*	*Value*	
Appanoose(1), Audubon(2), Benton(4)	7	3,842	$ 42,496			1,107	$ 9,260	1,824	17,440	(a)(b)	$ 89,596
Boone(2), Cerro Gordo(3)	5	7,587	121,737	5,330	$ 96,938	158,714	1,208,351	49,754	410,124	(b)	1,849,154
Dallas	5	637	9,881	*	*	45,494	335,935	8,923	48,619		410,695
Clinton(1), Dubuque (1), Fayette(1), Floyd(1), Franklin(1)	5	4,733	59,314	1,975	43,138	12,747	89,229	22,373	190,237		381,918
Guthrie(1), Hamilton(1), Hardin(3), Henry(2)	7	116	1,886			2,290	16,937	20,349	209,361	35,495(a)(e)(d)	263,679
Jackson(1), Jasper(2), Jefferson(1), Johnson(2)	6	648	11,732			1,321	9,793	2,927	21,010	(d)	73,106
Jones(2), Marion(2), Marshall(1), Page(1)	6	1,227	18,342			14,762	87,639	3,715	31,468		137,449
Keokuk(3), Mahaska(2)	5	4,464	55,420	*	*	1,448	9,729	11,320	115,192	(a)(c)	359,057
Polk	7	7,881	110,327	13,162	256,034	22,249	174,266	8,498	84,637	569,346(a)(b)(c)(d)	1,194,610
Pottawattamie(1), Poweshiek(1), Sac(1), Scott(2)	5	640	9,852			9,713	71,208	4,490	40,393		121,453
Story(2), Tama(3), Union(1)	6	1,638	23,496	1,003	19,848	4,000	28,005	3,996	26,249	1,810(d)	99,408
Wapello(1), Warren(1), Washington(3)	5	8,103	106,048	†	†	25,780	189,131	6,298	44,047		339,226
Webster	8	4,478	59,739	1,812	40,237	26,209	184,970	29,211	270,059	701,090(a)(b)(c)(d)	1,256,095
Woodbury	3	26,813	299,060	*	*					(d)	458,475
Counties with less than three producers				6,064	133,996					290,940	
	79	72,558	921,853	29,346	590,191	325,834	2,414,453	173,678	1,508,836	1,598,591	7,033,924
Production in 1922	69	56,030	728,508	18,510	354,041	308,366	2,170,368	176,894	1,495,116	991,416	5,739,449
Difference in 1923	+ 10	+ 16,528	+ 193,345	+ 10,836	+ 236,150	+ 17,468	+ 244,085	— 3,216	+ 13,720	+607,175	+1,294,475

* Included with Counties with less than three producers.
† Included with Common brick for these counties.
(1) Includes: (a) Fancy brick, stove lining and miscellaneous brick and tile products, $105,643; (b) Vitrified brick, $513,684; (c) Sewer pipe, $865,676; (d) Pottery, raw clay sold, other clay products, $113,588.

The report of the Bureau of the Census on Clay Products Industries shows that in 1923 there were 2,287 establishments producing clay wares and that the persons engaged numbered 152,623. The total value of the products including pottery was $448,834,938. This represented an increase of 60.8 per cent over the output in 1921, which was valued at $279,749,086. Cost of materials used in 1923 was $136,917,435, including 10,605,860 tons of coal. The value of the output in the leading states of the Union is given in the table shown herewith.

State	Brick, tile, &c.	Pottery
Pennsylvania	$ 65,500,819	$ 7,852,092
Ohio	57,034,856	42,716,233
Illinois	31,537,522	4,562,677
New Jersey	22,184,989	23,831,737
New York	19,388,572	6,349,393
Missouri	18,509,934	94,985
California	17,488,167	3,691,325
Indiana	13,631,536	2,860,200
Kentucky	7,480,512	
Iowa	7,033,924	
U. S.	$312,813,459	$114,951,067

Other nonclay products valued at $21,070,412 bring the total value for the year to the value given above.

The output of different classes of ware in 1923 is shown in the following list.

Class	*Quantity*	*Value*	*Average value per unit*
Common brick, M	7,282,181	$ 94,472,666	$12.97
Vitrified brick	699,269	15,569,670	22.27
for paving, M	538,658	13,032,341	24.19
other uses, M	160,611	2,537,329	15.80
Face brick, M	1,931,175	38,891,834	20.14
Fancy brick, M	12,879	252,323	19.59
Enameled brick, M	19,502	1,670,852	85.68
Terra cotta, tons	138,462	16,486,039	119.07
Hollow building tile, tons	3,764,744	28,274,801	7.51
Roofing tile, squares	231,462	4,021,722	17.38
Other tile, square feet	62,462,615	19,781,435	
Drain tile, tons	615,640	5,099,955	8.28
Sewer pipe, tons	1,777,584	29,102,511	16.37
Stove lining, tons	54,684	1,218,970	22.31
Fire brick, thousands	1,134,233	46,676,637	
Other clay products		8,111,146	
Clay sold, tons	647,768	3,181,898	4.91
Pottery		114,951,067	

The United States Geological Survey also reported sales of raw clay amounting to 3,434,660 tons valued at $11,188,913.

The list given herewith shows the operators who reported production in 1923 and 1924 together with the kinds of clayware which they produced, according to the following schedule: 1, common brick; 2, face brick; 3, fancy brick; 4, building tile; 5, vitrified brick; 6, drain tile; 7, sewerpipe; 8, other products; 9, pottery; 10, raw clay sold. It may be seen from this list that there are a few discrepancies in the table given above. The Iowa Clay Products Company, with offices at Washington, has four plants, two in Keokuk county, one in Washington county and one in Wapello county, but in the table the output of all these is combined under Keokuk county. The Capital City Clay Company of Des Moines has two plants at Des Moines. The Gethmann Brick Company, of Gladbrook, Tama county, has one plant at that town and one at Reinbeck in Grundy county, but the output of both is credited to Tama county.

The Survey wishes to acknowledge the assistance of Mr. A. L. Urick, State Labor Commissioner, in making more complete the list of clay producers in Iowa. A number of names were added from his report on manufactories which were not in the Survey's list. These are indicated by stars opposite the names.

Allamakee County
- Postville Mfg. Co., Postville, office Minneapolis, Minn.

Appanoose County
- Centerville, Centerville Brick Co., 1

Audubon County
- Audubon, Audubon Brick & Tile Works, 1, 4, 6
- Kimballton, Crystal Springs Clay Works, 1, 3, 6

Benton County
- *Atkins, Rinderknecht Bros.
- Belle Plaine, Buckeye Clay Products Co., 4, 5
- Garrison, Garrison Brick & Tile Works, 1, 4, 6
- Norway, Norway Tile Factory (Mose Trojovsky), 6
- Vinton, Aikley Brick & Tile Works, 1, 6

Black Hawk County
- *Waterloo, Art Novelty Pottery (William Raab), 9
- *Waterloo, Waterloo Granite Brick Co., 1

Boone County
- Boone, Boone Brick & Tile & Paving Co., office Des Moines, 1, 2, 5
- Boone, Boone Clay Works Company, 1, 2
- Fraser, McHose Sand & Tile Co., 1, 4, 6

Buena Vista County
- Linn Grove, Linn Grove Brick & Tile Co., 1, 4, 6
- *Sioux Rapids, Sioux Rapids Drain Tile Works, 1, 4, 6

Cass County
- Atlantic, Atlantic Building Supply Co., 1, 4, 6

Cedar County
*Tipton, Tipton Brick & Tile Works, 1, 4, 6
Cerro Gordo County
Mason City, Mason City Brick & Tile Company, 1, 2, 4, 6
Mason City, National Clay Works, 1, 2, 4, 6
Mason City, North Iowa Brick & Tile Co., 4, 6
Clayton County
*Clayton, Clayton Brick and Tile Co., 1, 4
Clinton County
Dewitt, DeWitt Brick & Tile Works (Brown & Churchill), 1, 6
Dallas County
Adel, Adel Clay Products Co., 1, 2, 4, 6
DeSoto, DeSoto Brick & Tile Co., 1, 2, 6
Redfield, Redfield Brick & Tile Company, 1, 4, 6
Van Meter, Platt Company, Inc., 1, 4, 6
Woodward, Dallas County Clay Co., 4, 6
Dubuque County
*Dubuque, Frank Beutin, 1
*Dubuque, Clayton Brick & Tile Co., 1, 4, 6
Dubuque, John L. Heim & Son, 1
Fayette County
Clermont, Clermont Brick & Sand Co., 1, 2, 4
Floyd County
Rockford, Rockford Brick & Tile Company, 1, 2, 4, 6
Franklin County
*Sheffield, Sheffield Brick & Tile Co., 1, 4, 6
Sheffield, Sheffield Tile Company, 1, 2, 4, 6
*Sheffield, Smith Brick & Tile Co., 1, 4, 6
Grundy County
*Reinbeck, Gethmann Brick Co., office Gladbrook, 2
Guthrie County
Glendon, Glendon Brick & Tile Co. (Robert Goodwin, Jr.), office Menlo, 1, 4, 6
Hamilton County
Webster City, National Sewer Pipe Co., 6, 7, 8
Also has clay pit at Nevada, Story Co., 10
*Webster City, Therm-A-Jug Co., 9
Hardin County
Eldora, Eldora Pipe & Tile Co., 4, 6, 10
*Eldora, Eldora Sand Co., 10
*Eldora, Estate of Henry L. Huff, 10
Henry County
Mount Pleasant, Mount Pleasant Brick & Tile Mfg. Co., 1, 4, 6
Winfield, Winfield Brick & Tile Works (J. E. Pierce), 1, 4, 6
Howard County
*Cresco, (Cresco Brick & Tile Works) C. A. Marshall, 1, 4, 6
Jackson County
Bellevue, Bellevue Clay Products Company, 1, 4, 6, 9
Jasper County
Lynnville, Lynnville Brick & Tile Works (C. H. Newby), 4, 6
Newton, Newton Clay Products Co., 1, 4, 6
Jefferson County
*Batavia, Batavia Brick and Tile Co., 1, 4, 6
Packwood, S. F. Steigleder & Son, 6
Johnson County
Iowa City, Ferd. Goss Brick Yard, 1
Tiffin, Tiffin Tile Company, 1, 6
Jones County
Monticello, Monticello Clay Works (Frank D'Autremont), 6
Center Jct., Center Junction Brick & Tile Co., 6
Keokuk County
Hedrick, Hedrick Tile Works, 1, 4, 6
*Keota, Iowa Clay Products Co., office Washington, 1, 4, 6

Keswick, Keswick Brick & Tile Company, 6
*Richland, Iowa Clay Products Co., office Washington, 1, 4, 6
*What Cheer, Nelson Bros. & Lundberg, 1, 9
What Cheer, What Cheer Clay Products Co., 4, 6, 7, 8

Lee County
*Fort Madison, Julius Reichelt, 1

Mahaska County
Barnes City, Wilson & Morrow, 1, 4, 6
New Sharon, Peter Meyer, 1, 6, 8
*New Sharon, Cecil Bros., 1, 4, 6
Oskaloosa, Standard Clay Products Co., 1, 2

Marion County
Harvey, Standard Clay Products Co., office Oskaloosa, 4, 6
Knoxville, Knox Clay Products Co., Inc., 1, 4, 6

Marshall County
Marshalltown, Sieg Brick & Tile Company, 1, 4

Muscatine County
*Muscatine, Charles Stark, clay pipes

Page County
Shenandoah, Lake & Cottrill Brick & Tile Company, 1, 4

Palo Alto County
*Graettinger, Graettinger Tile Works, 6

Polk County
Des Moines, The Capital Clay Company, 1, 2
Des Moines, Des Moines Clay Company (2 plants), 1, 2, 4
Des Moines, Des Moines Brick & Tile Co., 4, 6, 10
Des Moines, Flint Brick Company, 1, 5
Des Moines, Goodwin Tile & Brick Co., 4, 6
Des Moines, Iowa Pipe & Tile Co., 6, 7, 8
*Des Moines, James Maine & Co., 1
Des Moines, Star Brick Yard, 1

Pottawattamie County
Council Bluffs, Wickham Brothers, 1

Poweshiek County
Deep River, Deep River Brick & Tile Co., 1, 4, 6
Grinnell, Grinnell Clay Products Co., 1, 4, 6

Sac County
Auburn, Auburn Brick & Tile Company, 4, 6

Scott County
Buffalo, Davenport Brick & Tile Co., office Davenport, 4
LeClaire, W. E. Martin & Sons, Inc., 1, 4, 6
*Pleasant Valley, Martin & Sons, 1, 4, 6

Story County
Nevada, Nevada Brick & Tile Works, 1, 4, 6
*Nevada, National Sewer Pipe Co. (T. J. Lyman), 10

Tama County
Dysart, Dysart Brick & Tile Company, 1, 6
Gladbrook, The Gethmann Brick Co., 2
Also has plant at Reinbeck, Grundy Co., 2
Gladbrook, Gladbrook Press Brick & Tile Co., 1, 2, 6
*Tama, Tama Brick & Tile Co., 1, 4, 6
Toledo, Toledo Brick & Tile Co., 1, 4, 6

Union County
Creston, Creston Brick & Tile Works, 1, 2, 4, 6

Wapello County
*Eldon, Iowa Clay Products Co., office Washington, 1, 4, 6
Ottumwa, Morey Clay Products Co., 1, 2, 4, 6
*Ottumwa, Ostdeik Brick Works, 1, 4, 6

Warren County
Carlisle, Carlisle Clay Products Co., Inc., 4, 6

Washington County
Crawfordsville, Crawfordsville Brick & Tile Co., 6

Kalona, Kalona Clay Co., Inc., 1, 4, 6
Washington, Washington Brick & Tile Works, 1, 4, 6
Wellman, Iowa Clay Products Company, office Washington, 1, 4, 6

Webster County

Clayworks, Johnson Clay Works Inc., 1, 2, 4
Fort Dodge, Bradshaw & Company, 1, 2, 4, 6
*Fort Dodge, Coats Mfg. Co., 4
Fort Dodge, Fort Dodge Brick & Tile Co., 1, 4
Fort Dodge, Plymouth Clay Products Co., 6, 7, 8
Fort Dodge, Vincent Clay Products Co., 4, 6
Lehigh, Lehigh Sewer Pipe & Tile Co., office Fort Dodge, 6, 7, 8
*Lehigh, George F. Drain, 10
Otho, Kalo Brick & Tile Company, office Ft. Dodge, 1, 2, 4, 5, 6

Woodbury County

*Correctionville, Woodbury County Tile Plant, 6
Sergeant Bluff, Ballou Brick Company, office Kansas City, Mo., 1, 2
*Sioux City, Lehigh Sewer Pipe & Tile Co., 6, 7
Sioux City, Tom Green Brick Company, 1
Sioux City, Sioux City Brick & Tile Co., 1, 2, 8
*Sioux City, Sioux City Crockery Co., 9

Wright County

Goldfield, Goldfield Brick & Tile Works, 1, 4, 6

CEMENT.

The upward trend in production and shipment of Portland cement which was noted in the report for 1922 continued and was accentuated during 1923. Production rose 34 per cent and shipments 24 per cent in quantity during the later year. These conditions seem to be the result of increased building and road construction activity and were shared in by the country at large, although some districts reported a decrease in construction work as reflected by sales of cement. The magnitude of construction work in the United States is shown by the figures showing value of contracts awarded in the district including Illinois, Indiana, Iowa, Wisconsin, Michigan, Missouri, Kansas, Nebraska and Oklahoma, which amounted to $1,006,422,000 in 1923.

The statistics showing the condition of the industry in Iowa may be summarized in the following table:

Production of Cement in Iowa, 1921 to 1923

	1921	1922	1923
Production, bbls.	4,590,920	4,272,432	5,732,470
Stock, Dec. 31, bbls.	993,090	790,447	952,242
Shipments, bbls.	4,151,439	4,475,074	5,570,675
Shipments, value	$7,439,983	$7,709,313	$10,351,971
Average factory price per bbl.	$1.79	$1.72	$1.86
Consumption, bbls.	3,118,469	3,242,436	3,624,857
Population, estimated	2,440,948	2,459,411	2.477,874
Consumption per capita, bbl.	1.28	1.32	1.46
Surplus production	1,032,970	1,228,638	1,945,818
Coal used during year, tons			589,117
Annual finished cement capacity of plants, bbls.	5,350,000	5,650,000	6,785,000

The following operators had plants in operation in Iowa in 1923:

Gilmore Portland Cement Co., Gilmore City
Hawkeye Portland Cement Co., Des Moines
Lehigh Portland Cement Co., Mason City
Northwestern States Portland Cement Co., Mason City
Pyramid Portland Cement Co., Valley Junction.

The Pyramid Portland Cement Company of Des Moines opened a new plant at Valley Junction, at the west margin of Des Moines, on August 15, 1923. This adds two kilns to the capacity of the state's plants. Each kiln is 240 feet long and 10 to 11 1/3 feet in diameter. At the close of the year the plants in operation in the state had a total of twenty-eight kilns. The Pyramid and Hawkeye plants use the wet process, the others use the dry process. All the plants use limestone and clay shale and burn the clinker with coal.

Cement production in the leading states of the Union is shown in the table below. It will be seen that Iowa occupies eighth place in both production and shipments.

State	Plants	Production	Shipments		Average factory price per bbl.	Consumption	
		bbls.	*bbls.*	*Value*		*bbls.*	*per capita*
Pennsylvania	22	38,157,482	38,610,852	$ 69,792,343	$1.81	11,281,290	1.23
California	9	11,001,910	10,882,802	26,022,156	2.39	10,373,163	2.69
Michigan	14	7,619,792	7,466,283	14,038,322	1.88	7,531,664	1.87
Missouri	5	7,305,997	7,143,883	13,237,141	1.85	3,492,453	1.01
Illinois	4	7,147,906	7,129,208	12,550,100	1.76	12,237,478	1.79
New York	9	6,990,174	6,853,062	12,834,471	1.87	15,881,436	1.46
Kansas	7	6,025,657	5,878,839	10,868,590	1.85	2,613,070	1.45
Iowa	5	5,732,470	5,570,675	10,351,971	1.86	3,624,857	1.46
Ohio	6	4,188,755	4,003,321	7,615,741	1.90	8,843,641	1.43
Texas	5	4,178,895	4,091,284	8,011,226	1.96	3,328,619	0.67
U.S.	126	137,460,238	135,912,118	257,684,424	1.90	134,703,313	1.21

The increase in the quantity shipped in 1923 in the various producing states ranged from 8 per cent in Washington to 46 per cent in Alabama and averaged 15 per cent for the country in general. California is again far in the lead in per capita consumption and Iowa ties with New York for tenth place although our state ranks tenth in total consumption while New York ranks first. Wisconsin occupies the unique position of standing third in per capita use and eighth in total consumption, with shipments of 5,064,000 barrels, although no cement is made in the state. Portland cement was made in twenty-seven states in 1923.

GYPSUM.

The gypsum industry reached the highest point in its history in 1923, both as to the amount of crude gypsum mined and as to the value of the finished product. The improvement which was evident in 1922 continued during 1923 in sales of crude gypsum as well as in those of finished plasters and manufactured products. The following table shows the figures of production during 1923, with those for 1922 in comparison.

Production of Gypsum in 1922 and 1923.

	1922		1923	
	Tons	*Value*	*Tons*	*Value*
Crude gypsum mined	536,905		685,041	
Sold crude				
to Portland cement mills	80,452	$223,187	134,566	$383,322
agricultural gypsum	45,062	136,451	329	1,961
Total sold crude	125,514	359,638	134,895	385,283
Sold calcined				
as stucco	11,691	98,608	17,681	120,130
as mixed wall plaster	260,167	2,272,290	315,435	2,505,183
as plaster of Paris, molding, &c.	3,263	33,341	1,937	21,366
as Keenes cement, dental plaster, &c.	3,927	75,635	6,085	97,677
as plaster board and wall board	23,720	862,061	44,183	1,583,681
As tile and block	24,169	444,509	46,508	665,212
Total sold calcined	326,937	3,786,544	431,829	4,983,249
Total sold	452,451	4,146,182	566,724	5,368,532

The following table will show the growth of the gypsum industry in Iowa during the last ten years.

Year	Mined	Sold crude		Sold calcined		Total sold	
	Tons	*Tons*	*Value*	*Tons*	*Value*	*Tons*	*Value*
1914	480,404	65,185	$60,486	335,065	$1,260,971	400,250	$1,321,457
1915	495,860	71,909	59,930	335,057	1,218,198	406,966	1,278,128
1916	522,293	60,846	59,297	373,416	1,437,498	434,262	1,496,795
1917	461,864	65,012	110,741	322,198	1,931,256	387,210	2,041,997
1918	327,927	57,719	160,148	218,178	1,786,266	275,897	1,946,414
1919	421,279	69,024	231,432	264,656	2,403,012	333,680	2,634,444
1920	571,895	110,839	414,431	321,400	4,008,534	432,239	4,422,965
1921	350,247	84,659	234,038	216,930	2,688,662	301,587	2,922,700
1922	536,905	125,514	359,638	326,937	3,786,544	452,451	4,146,182
1923	685,041	134,895	385,283	431,829	4.983,249	566,724	5,368,532

The gypsum industry the country over seemed to share in the prosperity enjoyed by the Iowa operators for the total quantity mined in 1923 exceeded that of the previous year by 26 per cent and the value of sales increased by $5,527,004, or 19 per cent. Iowa was well in the lead for second place, being excelled by New York alone, with Ohio in third position. These states have held these relative positions most of the time for a number of years. The following table summarizes the industry in the United States.

Gypsum production in the United States in 1923

State	Plants	Total mined	Sold crude		Sold calcined		Total value
		Tons	*Tons*	*Value*	*Tons*	*Value*	
California	3	111,832	*a*	*a*	24,936	$374,040	$670,495
Iowa	7	685,041	134,895	$385,283	431,829	4,983,249	5,368,532
Kansas	3	135,019	*a*	*a*	71,349	700,490	842,740
Michigan	6	586,978	135,616	355,067	341,746	2,897,926	3,252,993
Nevada	4	298,390	*a*	*a*	226,753	1,891,639	1,952,007
New York	8	1,361,116	230,080	717,999	823,241	9,626,746	10,344,745
Ohio	3	526,861	*a*	*a*	432,511	4,919,375	4,981,542
Oklahoma	4	290,121	47,041	125,182	202,323	2,123,713	2,248,895
Texas	4	344,104	....	....	254,512	2,177,983	2,237,024
Utah	3	44,531	*a*	*a*	33,520	269,148	286,957
Wyoming	4	....	....	....	27,945	176,791	176,791
Others (b)	16	335,802	c299,610	c993,905	230,713	2,169,619	2,525,434
U.S.	65	4,753,448	847,242	2,577,436	3,101,378	32,310,719	34,888,155

a Included under Others.
b Alaska, Colorado, Montana, Oregon, South Dakota, Virginia and New Mexico.
c These figures include also output of states entered under *a*.

The following Iowa plants were operated in 1923:

Centerville Gypsum Co., Centerville, Appanoose Co.

Beaver Products Co., Fort Dodge, Webster Co.
Universal Gypsum Co., operating the Iowana and Plymouth plants, Fort Dodge
Wasem Plaster Co., Fort Dodge
Cardiff Gypsum Co., Fort Dodge
United States Gypsum Co., Fort Dodge.

SAND AND GRAVEL.

The sand and gravel industry continued the upward trend which had been maintained in 1922 and the total tonnage and total value were materially larger in 1923, the tonnage increasing 955,178 tons and the value by $454,923, or 36 per cent and 26 per cent respectively. These increases were spread over nearly all branches of the business, the only decreases being in the tonnage of filter sand and the tonnage and value of unclassified sands sold. Perhaps the most notable increase in the industry was in the gravel used as railroad ballast. Probably the rise in the figures for this item is due in part to a special canvass of the railroads which was made by the United States Geological Survey in 1923 to obtain more complete returns as to the non-commercial material used by them. The increase is shown also in the figures for the nation as a whole.

The production and uses of sand and gravel during 1922 and 1923 are summarized in the table below.

Production of sand and gravel in Iowa by uses.

Class	1922		1923	
	Tons	Value	Tons	Value
Sand				
Molding	29,809	$ 32,613	35,654	$ 40,238
Building	842,254	466,326	1,004,261	512,413
Grinding and polishing	6,225	6,961	17,225	36,288
Engine	59,778	27,568	61,680	37,627
Paving	286,303	146,030	670,181	310,750
Filter	12,255	4,682	11,968	7,505
Other	76,700	36,835	31,364	20,455
Total	1,313,324	721,015	1,832,333	965,276
Gravel				
Building	328,297	314,541	343,078	331,045
Paving	757,329	629,549	837,558	634,020
Railroad	291,848	87,128	584,191	251,540
Total	1,377,474	1,031,218	1,764,827	1,216,605
Sand and gravel	2,690,798	1,752,233	3,597,160	2,181,881

The output by counties and its distribution among the different classes of these materials are shown in the table appended.

Production of Sand and Gravel in 1923

County	Producers	Building sand	Paving sand	Other sand (a)	Gravel	Total Tons	Total Value
Black Hawk(2), Boone(2)	4	$30,968	*	(3)	$101,057	200,953	$143,187
Bremer(1), Buena Vista(1), Butler(2), Cerro Gordo(1)	5	15,900	*	(3)	61,983	218,444	87,883
Cherokee(4), Clay(2)	6	43,207	*	(5)	216,556	506,304	273,812
Clayton(2), Clinton(4)	6	*	*	(1)(2)	28,744	91,816	75,069
Dallas(1), Des Moines(1), Dickinson(1), Dubuque(2)	5	9,669	*	(3)(5)	41,431	103,660	60,663
Emmet(1), Fayette(2), Floyd(1), Franklin(1)	5	13,177	....	(1)	*	31,716	25,811
Fremont(1), Hardin(2), Humboldt(1), Ida(2)	6	17,828	*	$5,941(3)(5)	*	85,421	61,177
Jackson	3	5,529	*	(3)	30,353	49,776	37,016
Johnson(2), Jones(1), Kossuth(1), Lee(2)	6	21,324	$16,605	....	8,461	76,597	46,390
Linn(5), Lyon(2) Mahaska(1)	8	47,118	34,491	....	23,545	184,571	105,154
Marion(1), Marshall(1), Monroe(1), O'Brien(1), Osceola(2)	6	12,437	*	(3)	7,637	51,105	25,639
Muscatine	5	40,810	*	66,403(2)(3)(4)(5)	124,371	354,433	260,586
Palo Alto(1), Plymouth(2), Sac(2)	5	*	*	(5)	128,935	377,959	149,073
Polk	13	80,211	84,197	9,931(1)(3)(4)(5)	266,739	669,129	441,078
Scott(2), Story(1), Wapello(3)	6	94,156	*	(1)(3)(4)(5)	23,795	203,825	144,275
Sioux	8	37,144	*	(4)	25,725	189,647	80,871
Webster(2), Woodbury(2), Wright(2)	6	17,337	57,016	(5)	81,104	200,963	155,516
Winneshiek	6	1,080	*	....	7,601	5,829	8,681
Counties with less than three producers		24,518	118,441	59,838	44,558		
	109	512,413	310,750	142,113	1,216,605	3,597,160	2,181,881
Production in 1922	102	466,326	146,030	108,659	1,031,218	2,690,798	1,752,233
Difference in 1923	+7	+46,087	+164,720	+33,454	+185,387	+906,362	+429,648

* Included in: Counties with less than three producers.
(a) Includes: (1) molding, $40,238; (2) grinding and polishing, $36,288; (3) engine, $37,627; (4) filter, $7,505; not specified, $20,455.

Preliminary figures for the industry over the entire country show that there was an increase of 48 per cent in quantity and 41 per cent in value over the figures for 1922. The increase shown in use of railroad ballast amounted to 146 per cent and there was a large increase also in the amount of sand and gravel sold for construction of buildings and pavements. The figures for 1923 include returns from 2,428 sand and gravel plants, which is 443 more than the number represented by the returns for 1922. The table below will show the quantity and value of the different grades sold in these two years.

Sand and gravel sold in the United States in 1922 and 1923.

Class	1922		1923	
	Short tons	Value	Short tons	Value
Sand:				
Glass	1,768,549	$ 2,866,366	2,034,958	$ 3,751,778
Molding	3,839,116	4,478,405	5,559,644	6,730,417
Building	29,375,466	17,574,579	39,234,762	23,751,244
Paving	10,669,772	6,481,601	15,632,419	9,187,468
Grinding and polishing	1,183,161	1,732,469	1,456,039	2,361,695
Fire or furnace	237,065	336,085	307,794	445,479
Engine	1,685,712	1,288,022	2,033,494	1,535,638
Filter	71,728	142,692	116,520	139,671
Other	864,354	569,701	989,641	570,175
Total	49,694,923	35,469,920	67,365,271	48,473,565
Gravel:				
Building	18,686,176	14,541,169	24,145,463	18,367,713
Paving	17,432,445	11,373,712	26,174,112	17,716,779
Railroad ballast	9,053,502	3,232,863	22,247,307	6,345,597
Total	45,172,123	29,147,744	72,566,882	42,430,089
Grand total	94,867,046	64,617,664	139,932,153	90,903,654

Sand and gravel are produced in Iowa by the following firms:

Black Hawk County
Cedar River Sand & Material Co., 908 L. & J. Bldg., Waterloo
Iowa Sand Co., H. C. Matthias, 1721 Franklin St., Waterloo
Waterloo Dredging Co., Waterloo

Boone County
McHose Sand & Tile Co., Frazer; office at Boone
Northwestern Gravel Co., office at Des Moines

Bremer County
H. S. Bunth, Waverly

Buena Vista County
Chicago & North Western Ry. Co., Sioux Rapids

Butler County
Aplington Cement Tile & Block Works, Chas. Willeke, Aplington
Waverly Gravel & Tile Co., Shellrock; office at Waverly

Carroll County
Chicago Great Western R. R. Co., Lanesboro

Cerro Gordo County
Ideal Sand & Gravel Co., Mason City
Chicago, Milwaukee & St. Paul Ry. Co., Plymouth; office at Chicago, Ill.

Cherokee County
M. J. Gillease Co., Cherokee
E. L. Halford & Son, Cherokee
Illinois Central Ry. Co., Cherokee
Northwestern Gravel Co., Quimby

Clay County
John Stolley, Spencer
Spencer Washed Sand & Gravel Co., Spencer

Clayton County
Clayton White Sand Co., Clayton
Langworthy Silica Co., Clayton; office at 902 Federal Bank Bldg., Dubuque

Clinton County
Clinton Sand & Gravel Co., 604 Wilson Bldg., Clinton
W. J. McAllister, DeWitt; office at 2103 E. 11th St., Davenport
Ed. Jenner, DeWitt; office at 629 E. Central Park Ave., Davenport
A. F. Barber, R. D. No. 2, Grand Mound
John Sampson, Grand Mound
Dallas County
Portland Cement Sand & Gravel Co., Booneville, office at 513 Youngerman Bldg., Des Moines
Des Moines County
Mississippi Sand & Gravel Co., Burlington
Dickinson County
Chicago, Milwaukee & St. Paul Ry. Co., Milford
Dubuque County
Frank Beutin, Garfield-Kniest Sts., Dubuque
Chicago, Milwaukee & St. Paul Ry. Co., Dubuque
Molo Sand & Gravel Co., Dubuque
Emmet County
Cement Products Co., Estherville
Fayette County
Clermont Brick & Sand Co., Clermont
L. S. Cooley, West Union
Floyd County
Iowa Foundry Sand Co., Floyd
Chicago, Rock Island & Pacific Ry. Co., Marble Rock
Franklin County
U. S. Keystone Silo Co., 628 McKnight Bldg., Minneapolis, Minn.
W. C. Nolte, Sheffield
Fremont County
Nebraska-Iowa Sand & Gravel Co., Crosby; office at Nebraska City, Nebr.
Hardin County
Chicago & North Western Ry. Co., Gifford
Northwestern Gravel Co., Gifford
Eldora Sand Co., Steamboat Rock; office at Eldora
Humboldt County
Humboldt Gravel & Tile Co., Humboldt
Ida County
Leonard Christenson, Ida Grove
Concrete Stone Works, Ida Grove
Jackson County
F. H. C. Habich, Bellevue; office at Galena, Ill.
Bellevue Sand & Gravel Co., Bellevue; office at Koss Construction Co., 5th & I. U. Ry. Tracks, Des Moines
Sabula Sand & Gravel Co., Sabula
Chicago, Milwaukee & St. Paul Ry. Co., Smiths
Johnson County
Hills Sand & Gravel Co., Hills
City Sand Co., N. Madison St., Iowa City
E. D. Porter, River Junction
Jones County
Chicago, Milwaukee & St. Paul Ry. Co., Monticello
N. B. Lathrop, Oxford Mills
Kossuth County
C. J. Lenander, Bancroft
Lee County
Jos. Jaeger, Fort Madison: office at Montrose
Keokuk Sand Co., Foot of Bank St., Keokuk
Linn County
Kings Crown Plaster Co., 98 First Ave. W., Cedar Rapids
Larimer & Shaffer, 931 North 1st St. W., Cedar Rapids
John Hoge, Springville
Hadwin Williams, Springville; office at Mount Vernon
Mrs. Rozella Corbett, Viola

Lyon County
Miller Sand & Gravel Co., Box 101, Doon
Chicago, Rock Island & Pacific Ry. Co., Granite
Mahaska County
Iowa Sand & Gravel Co., Tracey; office at Oskaloosa
Marion County
Harvey Sand & Gravel Co., Harvey
Marshall County
Empire Sand & Material Co., Marietta; office at Lock Box 467, Marshalltown
Hawkins Sand Co., 1110 N. 3rd Ave., Marshalltown
Monroe County
E. J. Erickson, Melrose
Muscatine County
Chicago, Rock Island & Pacific Ry. Co., Fruitland
Automatic Gravel Products Co., Box 34, Muscatine
The Hahn Muscatine Co., 301-302 Amer. Bank Bldg., Muscatine
Muscatine Sand & Gravel Co., Conrad Koehler, Prop., Muscatine
Northern Gravel Co., Muscatine
Pearl City Gravel Co., Ed. L. Hahn, Muscatine
O'Brien County
Paullina Construction Tile Factory, Paullina
Osceola County
Chicago, Rock Island & Pacific Ry. Co., Sibley
Sibley Cement Co., Sibley
Town of Sibley, Sibley
Palo Alto County
Chicago, Rock Island & Pacific Ry. Co., Graettinger
Graettinger Tile Works, Graettinger
Plymouth County
Big Sioux Gravel Co., Akron
Albert A. Wenzel, Pierson; office at Kingsley
J. J. Kemp, Oyens
Polk County
Chicago, Rock Island & Pacific Ry. Co., Avon and Commerce
Commerce Sand & Gravel Co., G. N. Doty, Pres., Commerce
Capital City Sand Co., Lovington; office at 308 W. Fifth St., Des Moines
Central Sand & Gravel Co., 504 Hubbell Bldg., Des Moines
Consumers Ice Co., 8th & N. Y. Ave., Des Moines
Coon River Sand Co., 308 9th St., Des Moines
The Des Moines Sand & Fuel Co., 510 Grand Ave., Des Moines
Eaton Sand Co., Des Moines
Service Sand Co., 901 S. E. 6th St., Des Moines
N. Leon Harris, R. R. No. 4, Lock Box 507, Des Moines
Independent Sand & Gravel Co., S. W. 7th & Tuttle Sts., Des Moines
Iowa Sand Co., J. C. Stevens, 20 Fulton Drive, Des Moines
Oak Park Sand Co., C. G. Cain, Sec., Des Moines
Reliance Gravel & Sand Co., Box 63, E. 28th St., C. B. & Q. tracks, Des Moines
Flint Crushed Gravel Co., Herrold; office at Des Moines
Commercial Sand Co., 513 Youngerman Bldg., Des Moines
Hawkeye Sand & Gravel Co., 906 Walnut St., Des Moines
Sac County
Chicago & North Western Ry. Co., Lake View
Northwestern Gravel Co., Lake View
Sac County, Office of Engr., Sac City
Scott County
W. G. Block Co., Box 528, Davenport
Builders Sand & Gravel Co., Nahant
Sioux County
D. A. Sorgdrager, R. D. No. 1, Alton
Alton Cement Works, Alton
S. R. Cooper, Hawarden
French & Briggs, Hawarden
C. A. Oehlerking, Hawarden

LeMars Gravel Co., Rock Valley and Hawarden
Schemmer Sand & Gravel Co., Rock Valley
Rock Valley Sand & Gravel Co., Rock Valley

Story County
Iowa State College, Ames
Story County Board of Supervisors, Ames; office at Nevada

Wapello County
Eddyville Sand & Gravel Co., Eddyville
Ottumwa Sand Co., Ottumwa
Wapello Sand & Building Material Co., 317-19 Church St., Ottumwa

Webster County
Johnston Bros., Clay Works
Chas. Larrabee, 1222 Sixth Ave., Ft. Dodge
Earl Wright, Ft. Dodge

Winneshiek County
Bernatz Bros., Decorah
Decorah Stone Products Co., R. Bucknell, Secy., Decorah
Geo. Wm. Higgins, Decorah
Wm. McNamara, Decorah
John T. Nolan, Decorah
J. H. Rosenthal, Decorah

Woodbury County
Woodbury County Gravel Plant, Correctionville
Remsen Sand & Gravel Co., Correctionville; office at Remsen

Wright County
Belmond Cement Mfg. Co., Belmond
Luick Gravel Co., Belmond
Chicago, Rock Island & Pacific Ry. Co., Belmond
Chicago Great Western R. R. Co., Belmond

STONE AND LIME.

In general the stone industry showed an improvement similar to that noted in other lines of the mineral industry. The total value of the stone and lime sold in 1923 exceeded that of the preceding year by $55,931 although the total tonnage was less by 15,567. This increase was not shared by all parts of the stone trade, for the output of dimension stone, including building, rubble and riprap, fell short of that of the preceding year by $71,600 and stone was used in agriculture to a less extent than during 1922, as was the case also with agricultural gypsum. The increases came in crushed stone in its various uses and here the gain was quite marked. The tonnages of the various classes of stone produced in 1922 and 1923 are shown in the following table:

Tonnages of stone and lime produced in Iowa

Uses	1922	1923
Building	5,560	2,910
Rubble and riprap	117,950	44,560
Concrete and road metal	417,550	449,760
Agriculture	59,720	50,810
Sugar factories	8,100	12,000
Railroad ballast and flux	11,830	43,510
Lime and sandstone	6,733	8,326
	627,443	611,876

It is evident from the table that the various industries which use crushed stone, particularly concrete and road constructions, are the ones on which the stone industry in Iowa depends very largely. In 1923 these used all but 55,796 tons of the total tonnage of 611,876. The limestone sold to sugar factories is used for refining sugar at the beet sugar factories at Mason City and Belmond.

The following table shows the value of the output of the different stone producing counties in the state so far as these may be given without revealing the business of individual producers. It also gives a summary of the business of 1922 by way of comparison with 1923. The value of the output increased in eleven counties in 1923 and decreased in ten counties. But the diminution in the ten counties amounted to only $73,278, while the increase in the eleven counties was $129,209. The great decreases were in Allamakee county, where extensive government work on Mississippi river used much stone in 1922 while none was used in 1923; in Des Moines county, where a large output in 1922 was followed by none in 1923; and in Dubuque county, which dropped nearly twenty thousand dollars in 1923.

Scott county is by far the largest producer, with an output for 1923 valued at $296,968, and Black Hawk county is second in rank. Lee comes third with $76,431 to its credit and Dubuque ranks fourth, with a production of $69,401, which is made possible to a considerable extent by the lime burning industry. Jackson county is fifth in rank, due also very largely to the lime made at Hurstville.

Production of stone and lime in 1923

County	No. of Producers	Building, rubble and riprap	Concrete and road metal	Agriculture	Other uses(a)	Total Tons	Total Value
Allamakee(1), Appanoose(1), Black Hawk(2), Cerro Gordo(2)	6	$ 2,781	$ 89,328	$ 5,255	(3)	86,325	$115,484
Clayton(2), Clinton(1), Dubuque(4)	7	12,250	49,955	*	(2)(4)	58,530	85,466
Hardin(1), Howard(1), Jackson(1), Johnson(1)	4	....	58,889	....	(2)(4)	57,382	117,554
Jones	3	15,433	8,242	1,466	....	20,773	25,141
Lee(3), Madison(1)	4	*	57,257	7,260	(1)	65,958	89,225
Linn(2), Marshall(2)	4	*	25,211	*	....	18,069	26,025
Mitchell(1), Pocahontas(1), Scott(3)	5	11,812	242,144	*	(1)(2)(3)	304,850	316,239
Counties with less than three producers		17,458		22,016	148,309		
	33	59,802	531,026	35,997	148,309	611,876	775,134
Production in 1922	34	131,402	451,943	49,226	86,632	627,443	719,203
Differences in 1923	—1	—71,600	+79,083	—13,229	+61,677	—15,567	+55,931

* Included under Counties with less than three producers.
(a) Includes: (1) Railroad ballast, $30,144; (2) flux, $19,110; (3) sold to sugar factories, $22,128; (4) lime and sandstone, $76,927.
"Other uses" in 1922 included: Railroad ballast and flux, $12,885; sold to sugar factories, $11,670; lime and sandstone, $62,047.

The output of limestone in the entire United States was 30 per cent greater in 1923 than in 1922. This increase was spread over all the important lines of the industry. The following table will show the comparative figures for the two years.

Limestone sold and used in the United States, by uses.

Use	1922 Quantity	1922 Value	1923 Quantity	1923 Value
	Tons		*Tons*	
Building	995,540	$12,418,873	1,105,990	$16,267,925
Rubble	286,340	470,264	327,180	484,771
Riprap	1,010,850	925,760	1,536,570	1,451,670
Crushed	32,786,300	33,224,879	41,386,550	42,540,754
Flux	18,690,270	14,208,457	25,562,140	20,333,939
Sugar factories	371,430	634,511	474,530	875,774
Glass factories	166,070	291,854	197,380	301,403
Paper mills	149,430	264,130	206,740	326,054
Agriculture	1,195,000	2,150,435	1,278,770	2,160,249
Other	3,317,430	3,808,764	4,625,510	4,877,468
Total sold	58,928,660	68,397,927	76,701,360	89,620,007
Portland cement	30,070,000		34,722,000	
Natural cement	148,000		212,000	
Lime	7,280,000		8,140,000	
Total used	96,426,660		119.775,360	

The amount of crushed stone used for road metal and concrete was 33,382,210 tons with an average value of $1.08 per ton, and the amount used for railroad ballast was 8,004,340 tons with an average value of $0.83 per ton. Iowa ranked twenty-fourth in value of limestone produced in 1923. The following list gives the Iowa operators of limestone quarries. Sandstone and lime producers are indicated in the list.

Allamakee County
U. S. Engineer's Office, Lansing; office at LaCrosse, Wis.
Wilkes Williams, R. D. No. 1, Postville
Appanoose County
Wm. B. Swan, Plano
Black Hawk County
Hawkeye Quarries Co., La Porte City; office at Cedar Rapids
A. Bartlett, 1165 E. Fourth St., Waterloo
Bremer County
Waverly Stone & Gravel Co., office at Fowler Bldg., Waterloo
Cerro Gordo County
Henry Kuppinger, Mason City
Ideal Sand & Gravel Co., Mason City
Quinby Stone Co., 24 13th St. N. E., Mason City
Clayton County
H. D. Kregel, Garnavillo, sandstone
Geo. Kohler, Guttenberg
Marquette Stone Products Co., McGregor
Clinton County
C. T. Hanrahan, Charlotte
Des Moines County
W. J. Welsh, Burlington; office at Potosi, Wis.
Dubuque County
Wm. Becker, 1333 Kaufman Ave., Dubuque
Fred W. Faldorf, 1155 Grand View Ave., Dubuque
Eagle Point Lime Works, Dubuque, also lime
Thos. R. Welsh, 202 W. Locust St., Dubuque
B. N. Arquitt, Farley
Hardin County
Hale Roberts Stone Co., Alden
Howard County
Cresco Stone & Concrete Co., Cresco
Jackson County
A. A. Hurst, Hurstville; office at Maquoketa; also lime
Johnson County
River Products Co., Coralville; office at 218 Johnson County Savings Bank Bldg., Iowa City
Jones County
The Reformatory, Anamosa
Geo. B. Shaler, Stone City
H. Dearborn's Sons, Stone City
Keokuk County
Russell B. Boyce, Sigourney
Lee County
McManus Quarries Co., Inc., Ballinger Sta.; office at Box 93, Keokuk
Keokuk Quarry & Construction Co., 1325 Main St., Keokuk
Burlington Quarry Co., Montrose; office at 17 S. Seventh St., Keokuk
Linn County
Ellis Park Stone Co., Cedar Rapids
J. E. Colton, Mount Vernon

Madison County
Peru Stone & Cement Co., Peru; office at 308 West 5th Street, Des Moines
Marshall County
County Engineer, Marshalltown
Mitchell County
Belzer & Brenden, Osage
Osage Stone Co. (H. L. Wilson), Osage
Pocahontas County
Gilmore Portland Cement Corp., Gilmore City
Scott County
Otto Thompson, Bettendorf Stone Co., Bettendorf; office at 820 Kirkwood Blvd., Davenport
J. A. Shaw, Big Rock
Dolese Bros. Co., Buffalo; office at 337 W. Madison St., Chicago, Ill.
Linwood Cement Co., 713 Kahl Bldg., Davenport
Van Buren County
Chequest Quarries, W. H. Swank, Mgr., Keosauqua

MINERAL WATERS.

The mineral water industry shared in the general improvement of business during 1923, for the amount sold was 76 per cent larger and the value of sales was 135 per cent larger than in 1922. The sales of medicinal and table waters aggregated 45,072 gallons, with a value of $8,907, an average price of about twenty cents per gallon. The actual prices ranged from five cents in bulk at wholesale to fifty-five cents for retail sales. The Colfax operators complained of restrictions due to high freight and express rates and special taxes. Fry's well at Colfax and the Colfax Mineral Spring also use a large amount of water for making carbonated drinks. The Grand Hotel at Colfax maintains a bathing establishment which served sixty-eight patrons during the year. The Hygeia well at Sioux City uses all its water for carbonated drinks as does also the Lime Rock Spring at Dubuque. The amount used for soft drinks at the various wells was 213,759 gallons, making a total reported use of mineral water in the state of 258,831 gallons. This does not represent nearly all the water used for soft drinks in Iowa, as there are a number of bottling establishments which do not report.

NATURAL GAS.

A small amount of gas was used in 1923. This was derived as in previous years from shallow pockets in the glacial drift. The amount reported did not exceed 100,000 cubic feet with a value of about $172. Probably more gas is used than these figures would indicate, for since these gas pockets are usually found during well drilling operations their presence is not always reported to this department and no record is made of their use.

MINERAL PRODUCTION IN IOWA IN 1924*

Products	Unit	Quantity	Value
Cement	Bbl. of 376 lb.	4,881,613	$ 8,811,587
Clay products			5,692,147
Coal	Short ton	5,468,450	18,097,000
Gypsum	short ton	640,953	5,657,339
Mineral waters	*no census*		
Natural gas	M. cu. ft.	575	300
Sand and gravel	short ton	2,427,626	1,473,066
Stone and lime	short ton	610,408	739,632
			$40,470,971

* Figures compiled by the Iowa Geological Survey in cooperation with the United States Geological Survey and the Bureau of the Census. Acknowledgment is made of the use of tables and other data published by these organizations.

The mineral industry in 1924 did not bring to fulfilment the prophecy which the upward trend of 1923 seemed to show. In contrast with the output of mineral products during 1923, valued at $46,237,521, which had increased from $36,189,398 in 1922, the output in 1924 declined to $40,470,971, a drop of $5,766,550. This decline was shared by all lines of production except that of gypsum, which enjoyed an increase in nearly every branch of the industry. The decrease in other products would seem to be the result of diminished activity in the building trades as well as unfavorable agricultural conditions. Similar conditions seem likely to persist in 1925 and may perhaps be accentuated during that year. Production in the United States fell from $5,998,800,000 in 1923 to $5,318,000,000 in 1924, a drop of 11 per cent, a fact which indicates that Iowa was not alone in the experience of general depression. The following table will be of interest in showing the amount and increase of mineral production in the country as a whole.

Mineral production in the United States

Year	Value	Percentage of increase or decrease
1880–1913	$35,295,900,000	------------------
1914	2,111,172,000	—13
1915	2,394,644,000	+13
1916	3,508,439,000	+47
1917	4,992,496,000	+42
1918	5,540,708,000	+11
1919	4,595,770,000	—17
1920	6,981,340,000	+52
1921	4,138,500,000	—41
1922	4,647,290,000	+12
1923	5.998,800,000	+29
1924	5,318,000,000	—11
Total	85,523,059,000	

To this total metallic minerals contributed $29,636,510,000, non-metallic minerals $55,787,402,000 and unclassified minerals $99,147,000. Iowa occupied twenty-fourth place among the states of the Union in value of mineral produced in 1923.

CEMENT

Sales of Portland cement manufactured in Iowa declined from a total value of $10,351,971 in 1923 to that of $8,811,587 in 1924, a drop of $1,540,384 or nearly 15 per cent. However, the 1924 output still exceeded in value those of 1921 and 1922 and even that of 1920, which latter, valued at $8,742,854, had been the peak production up to 1923, so that perhaps the figures for 1924 should be compared with those for the years immediately preceding 1923, rather than with the latter year. The following table will show the state of the industry during 1922 to 1924.

Production of Cement in Iowa, 1922 to 1924

	1922	1923	1924
Production, bbls.	4,272,432	5,732,470	5,624,466
Stock, Dec. 31, bbls.	790,447	952,242	1,695,093
Shipments, bbls.	4,475,074	5,570,675	4,881,613
Shipments, value	$7,709,313	$10,351,971	$8,811,587
Average factory price per bbl.	$1.72	$1.86	$1.81
Consumption, bbls.	3,242,436	3,624,857	
Population, est.	2,459,411	2,477,874	
Consumption per capita, bbl.	1.32	1.46	
Surplus production	1,228,638	1,945,818	
Coal used during year, tons		589,117	
Annual finished cement capacity of plants, bbls.	5,650,000	6,875,000	6,685,000
Daily clinker capacity, bbls.			20,300

In the United States as a whole both production and shipments were larger in 1924 than in 1923 and the number of active factories increased from 126 in 1923 to 132 in 1924. The commercial district which includes eastern Missouri, Iowa, Minnesota and South Dakota produced in 1924, 14,851,000 barrels and shipped 13,982,000 barrels, valued at $19,224,000. Wisconsin and South Dakota each began production of cement in 1924. The following table giving statistics for 1924 may be compared with a similar table for 1923. Note that Iowa ranks eighth in production and ninth in shipments. Alabama came up from eleventh place in shipments in 1923 to a rank above Iowa in 1924.

Portland cement in the United States, 1924

State	Plants	Production	Shipments	
		bbls.	bbls.	value
Pennsylvania	22	40,468,000	39,847,000	$69,993,000
California	10	11,615,000	11,502,000	25,649,000
Michigan	15	9,162,000	8,993,000	16,367,000
Missouri	5	7,900,000	7,710,000	13,801,000
New York	9	7,547,000	7,450,000	13,708,000
Illinois	4	7,005,000	6,956,000	12,243,000
Kansas	7	5,894,000	5,817,000	10,122,000
Alabama	5	5,541,000	5,543,000	9,091,000
Iowa	5	5,624,466	4,881,613	8,811,587
Texas	5	4,566,000	4,488,000	8,482,000
Ohio	7	4,599,000	4,298,000	7,865,000
Washington	4	1,845,000	1,793,000	4,339,000
Other states	34	37,093,000	36,468,000	66,670,000
	132	137,460,238	145,747,000	267,319,000

CLAY PRODUCTS.

The value of the clay wares produced in Iowa during 1924 fell $1,263,962 below the figure of $6,956,109 which represented the value of the production of 1923. This decrease affected nearly every branch of the industry and was the combined result of a diminution in output and lower prices per unit. The following table will give a summary of the industry in 1923 and 1924.

Production of clay wares by classes in 1923 and 1924

Class	Plants		Quantity		Value		Av. unit value	
	1923	1924	1923	1924	1923	1924	1923	1924
			thous.	*thous.*				
Common brick	52	51	72,558	62,070	$ 921,853	$ 737,898	$12.71	$11.88
Vitrified brick		4	31,523	6,507	513,684	129,314		19.87
Face brick	22	19	29,346	23,785	590,191	451,136	20.11	18.96
			tons	*tons*				
Hollow bld. tile (a)	44	37	297,253	243,712	2,197,515	1,740,296	7.39	7.14
Hollow bld. tile (b)	8	16	26,073	53,412	195,006	446,246	7.48	8.35
Drain tile	54	54	173,678	147,499	1,508,836	1,266,586	8.69	8.58
Sewer pipe	5	5	54,828	52,998	805,676	793,840	15.79	14.98
Other products (c)						154,379		
	64	69				5,692,147		

(a) Includes partition, load-bearing, furring, book tile.
(b) Includes floor-arch, silo and corncrib tile; conduits; radial chimney blocks.
(c) Includes products not elsewhere specified, raw clay sold, pottery. Value of raw clay not included in state total.

A comparison of the figures given in this table with those for 1923 leads to the conclusion that there must have been a decided slowing down in building operations and in other civic improvements wherein clay products are used, as well as in land improvement represented by drainage and similar work. Insofar as construction of extensive drainage systems is concerned this let-down may be a distinct benefit.

The production of clay wares by counties is shown in as much detail as possible in the table given below.

Production of Clay Wares in Iowa in 1924

County	No. Producers	Common brick		Hollow building tile or block		Drain tile		Other products (a)	Total value
		thous.	*value*	*tons*	*value*	*tons*	*value*	*value*	
Allamakee (1), Appanoose (1), Audubon (2)	4	1,526	$ 17,103	2,642	$ 15,742	1,607	$ 9,663		$ 42,508
Benton (1), Boone (1), Buena Vista (1), Cass (1), Cedar (1)	5	2,829	35,550		(b)	1,492	13,168	$50,419 (2) (3) (4)	99,137
Cerro Gordo	3	3,130	46,022	144,181	1,100,189	40,805	328,028	*	1,487,179
Dallas	3	1,325	19,861	29,295	197,413	11,923	88,444	* (2) (3)	363,545
Dubuque (1), Fayette (1), Floyd (1), Franklin (1)	4	4,354	58,212	11,925	76,175	19,968	164,475	34,113 (3)	332,975
Grundy (1), Guthrie (1), Hamilton (1), Hardin (2), Henry (2)	7	289	3,776	1,531	14,221	16,590	191,195	56,911 (3) (6) (7)	266,103
Howard (1), Jackson (1), Jasper (2)	4		(b)		(b)	1,201	9,779	26,195 (1) (4) (7)	35,974
Johnson (2), Jones (2)	4	591	8,913			2,338	19,300		27,213
Keokuk (3), Mahaska (2)	5	2,838	31,285		(b)	8,222	72,076	188,137 (3) (4) (6) (7)	291,498
Marion (1), Marshall (1), Poweshiek (2)	4	342	3,051	3,270	20,684	2,597	18,433		42,168
Polk	6		(b)	24,057	164,025	6,289	65,390	594,760 (1) (2) (3) (6) (7)	824,175
Story (2), Tama (3)	5	1,193	16,846	2,023	8,553	1,339	8,618	15,945 (3) (7)	49,962
Union (1), Wapello (1), Warren (1)	3	6,081	65,683	32,404	209,531	7,177	48,226	*	341,299
Washington (4), Woodbury (2), Wright (1)	7	26,960	289,808	6,064	44,273	1,989	16,096	*	459,923
Webster	8	3,676	45,487	33,261	299,152	23,962	213,695	496,801 (3) (6) (7)	1,055,135
Counties or groups of counties having less than three producers								198,705	
Totals	72	62,070	$737,898	297,124	$2,186,542	147,499	$1,266,586	$1,501,122	$5,692,147

* Included with counties having less than three producers.

(a) Includes: (1) common brick from Howard, Johnson, Jasper and Polk counties; (2) vitrified brick, 6,507,000, valued at $129,314, from Boone, Dallas and Polk counties; (3) face brick, 23,785,000, value $451,136, including 1,580,000, valued at $32,873, from Webster county; (4) hollow building tile or block from Benton, Cass, Howard, Jasper, Jones, Keokuk and Mahaska counties; (6) sewer pipe, 52,998 tons, value $793,840, from Hamilton, Keokuk, Polk and Webster counties; (7) miscellaneous products, such as wall coping, flue lining, pottery, raw clay. The value of the latter is included in county totals but is excluded from state totals.

(b) Included in other products.

Production was reported from thirty-nine counties in the state. Cerro Gordo was the leading county, although this county has only three producers. Over a million dollars' worth of hollow building tile was made in this county, fully one-half the product of the entire state. It is interesting to note the change in the production of clay ware in Cerro Gordo county during the past ten years. The data for 1914 show that the output, valued at $1,555,944, was distributed—$39,976 for common brick, $990,993 for drain tile, and $525,035 for other products, including hollow tile and minor items. The total output of the county has not changed greatly but the emphasis has shifted decidedly. This shift is quite marked as regards the whole state. Until 1920 drain tile was much the most important item in the clay industry, but since that year it has declined steadily in value. On the other hand hollow building ware has been gaining in importance until its value exceeds that of drain tile although it has never been as high as was that of drain tile during its peak years.

The next county in importance is Webster, whose output is distributed chiefly among hollow ware, drain tile and, especially, sewer pipe, in which it is by far the leading county. Other important counties in order are Polk, Woodbury and Dallas.

Iowa ranks twenty-fourth in value of common brick, ninth in value of vitrified brick, seventeenth in value of face brick, third in value of hollow ware, second in value of drain tile, eighth in value of sewer pipe and tenth in value of unspecified products. All products exclusive of pottery made in the United States reached a total value of $299,583,393. This represented a decrease of 4.2 per cent as compared with 1923. Pottery products made in 1924 were valued at $118,014,985, an increase of 2.7 per cent over 1923.

COAL

The production of coal from Iowa mines in 1924 reached a total tonnage of 5,468,450. This showed some decline from the output of 5,710,735 tons in 1923 but still was ahead of the output during 1922, which was only 4,335,161 tons, the smallest output, by the way, since 1896. The tonnages recovered during the present decade have failed for the most part to equal those of the two preceding decades, since Iowa's output first reached the five million ton mark in 1899. A tabulation of the figures will help to show the stages through which the industry has passed during those years.

Production of coal in Iowa, 1900 to 1924

Year	tons	value	year	tons	value
1899	5,177,479	$6,397,338	1912	7,289,529	$13,152,088
1900	5,202,939	7,155,341	1913	7,525,936	13,496,710
1901	5,617,499	7,822,805	1914	7,451,022	13,364,070
1902	5,904,766	8,660,287	1915	7,614,143	13,577,608
1903	6,419,811	10,563,910	1916	7,260,800	13,530,383
1904	6,519,933	10,504,406	1917	8,965,830	21,096,408
1905	6,798,609	10,586,381	1918	8,192,195	24,703,237
1906	7,266,224	11,619,455	1919	5,624,692	17,352,620
1907	7,574,322	12,258,012	1920	7,813,916	30,793,847
1908	7,149,517	11,706,402	1921	4,531,392	17,256,800
1909	7,757,762	12,793,628	1922	4,335,161	16,119,000
1910	7,928,120	13,903,913	1923	5,710,735	20,517,000
1911	7,331,648	12,663,507	1924	5,468,450	18,097,000

The table shows not only the decline in recent years but also the fluctuation in production and the abrupt rise in unit value achieved during the war period and maintained to some extent ever since. A table giving the tonnage produced each year from 1840 to 1918 is given in the report of mineral production in volume XXVIII of these reports.

A table giving details of production in 1924 which follows shows that Monroe county maintained her usual lead, owing to the fact that the mines of the county though few in number, seventeen in 1924, are for the most part large and are prepared to produce large tonnages. Polk county, with twenty-three mines, came up to second place in both tonnage and value, a place which has been held for several years by Appanoose, which in 1924 took third rank, with seventy-one mines.

The thin Nodaway seam, which is utilized by nine mines in Adams, Page and Taylor counties, yielded in 1924, 40,097 tons, valued at $179,000. Iowa stood twelfth in tonnage in 1923 among

Production of coal by counties in 1924

Counties	No. Producers	Loaded at mines 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 of days worked
								Underground	Surface	Total	
		tons	*tons*	*tons*	*tons*	*value*					
Adams	5	....	7,799	....	7,799	$ 33,000	$4.19	36	5	41	171
Appanoose	61	711,641	88,128	14,031	813,800	2,860,000	3.52	2,891	240	3,131	134
Boone	9	227,799	63,727	3,568	295,094	1,189,000	4.03	679	49	728	176
Dallas	5	516,011	14,534	4,306	534,851	1,772,000	3.31	868	87	955	196
Greene	3	....	3,156	....	3,156	16,000	5.07	18	3	21	114
Davis(1) Jefferson(2)	3	....	3,433	....	3,433	11,000	3.84, 3.15	15	3	18	100, 154
Guthrie	5	....	5,148	....	5,148	25,000	4.86	28	3	31	137
Jasper	9	with "Local"	102,956	6,682	109,638	377,000	3.44	192	34	226	154
Keokuk	6		9,673	562	10,235	32,000	3.13	23	7	30	126
Lucas	4	618,073	2,538	20,161	640,772	1,886,000	2.94	653	73	726	189
Mahaska	30	with "Local"	56,937	513	57,450	175,000	3.05	177	35	212	105
Marion	21	767,102	744,150	24,389	835,641	2,525,000	3.02	1,145	114	1,259	195
Monroe	12	992,828	63,544	29,511	1,085,883	3,549,000	3.27	2,237	152	2,389	151
Page(2), Taylor (2)	4	with "Local"	32,298	with "Local"	32,298	146,000	4.41, 4.72	72	9	81	218, 200
Polk	19	400,538	478,612	13,932	893,082	3,028,000	3.39	1,614	174	1,788	176
Story(1), Warren (2) Webster(1)	4	with "Local"	28,096	3,800	31,896	97,000	4.12, 2.80, 4.03	99	15	114	240, 129, 200
Van Buren	6	with "Local"	8,645	with "Local"	8,645	27,000	3.12	23	5	28	142
Wapello	26	with "Local"	71,197	1,213	72,410	255,000	3.52	181	27	208	154
Wayne	4	with "Local"	27,219	with "Local"	27,219	94,000	3.44	108	9	117	128
	236	4,351,252	993,393	123,805	5,468,450	18,097,000	3.31	11,059	1,042	12,101	161

the coal producing states and eleventh in value. Estimates show that she held eleventh place in tonnage in 1924. The following figures give final data for 1923, including returns for wagon mines, and estimates for tonnage of 1924.

Coal produced in the United States in 1923 and 1924

State	1923		1924	
	tons	value	tons	value
Pennsylvania	171,879,913	$472,217,000	123,530,000	
West Virginia	107,899,941	285,481,000	110,000,000	
Illinois	79,310,075	198,388,000	67,880,000	
Kentucky	44,777,317	113,542,000	45,000,000	
Ohio	40,546,443	98,610,000	29,200,000	
Indiana	26,229,099	65,046,000	22,340,000	
Alabama	20,457,649	51,624,000	19,490,000	
Virginia	11,761,643	32,468,000	10,900,000	
Colorado	10,346,218	33,299,000	9,840,000	
Wyoming	7,575,031	20,916,000	6,850,000	
Tennessee	6,040,268	16,575,000	4,800,000	
Iowa	5,710,735	20,517,000	5,468,450	18,097,000
Total bituminous	564,156,917	1,513,327,000	483,280,000	
Penn. anthracite	93,339,009	506,786,768	90,214,000	
Total U. S.	657,495,926	2,020,114,000	573,494,000	

GYPSUM

Production in the gypsum industry exceeded the high record made in 1923, thus setting a new mark in crude gypsum mined, in the amount sold crude, in the amount and value of plaster sold, in amount and value of wall and plaster board sold and in total amount and value of sales. Perhaps the most remarkable feature of this record is the fact that it was made while every other branch of the mineral industry in Iowa was experiencing a reverse. The table given below shows the details of the industry during the past two years.

Production of gypsum in 1923 and 1924

	1923		1924	
	tons	value	tons	value
Crude gypsum mined	685,041		727,385	
Sold crude—to cement mills	134,566	$ 383,322	149,972	$ 371,331
agriculture and others	329	1,961	1,236	8,098
Total sold crude	134,895	385,283	151,208	379,429
Sold calcined—as stucco	17,681	120,130	68,280	459,044
as other wall plaster	315,435	2,505,183	314,751	2,462,304
as plaster of Paris, molding, casting plaster	1,937	21,366	5,503	55,626
as Keene's cement, dental plaster, plate glass works	6,085	97,677	3,660	31,770
as plaster board and wall board	44,183	1,583,681	55,486	1,719,322
as tile and block and for other purposes	46,508	665,212	42,065	549,844
Total sold calcined	431,829	4,983,249	489,745	5,277,910
Total sold	566,724	5,368,532	640,953	5,657,339

Most of the plaster grouped under the head of Keenes cement, etc., is sold to plate glass works for bedding glass in molding. Likewise much the greater part of the plaster sold in board form is made into wall board, which is the finished form, ready for tinting or other details to make a complete wall. Most of the plaster used in making tile and block goes into partition tile, the value of which in 1924 was $339,000. The rest was roof tile and special forms. Nearly a hundred thousand dollars worth of plaster was sold for miscellaneous uses in 1924. The same plants were in operation during 1924 as during previous years. The Acme Cement Plaster Company of Centerville and the Hawkeye Gypsum Products Company of Fort Dodge are listed as "not yet in operation".

The amount of crude gypsum produced in the United States in 1924 was 5,042,629 tons and the value of crude and calcined gypsum sold was $42,724,507.

STONE AND LIME

There was a slight decline in the production of limestone and lime in 1924, in both tonnage and value. The chief reduction was in the output of crushed stone for concrete and road work and in the manufacture of lime, while some branches of the industry showed an increase. The total value of the output was $739,632 as compared with $775,134 in 1923, a decline of $35,502. As in previous years much the greater part of the stone quarried in Iowa is crushed for various uses, as detailed in the tables below. Less than fifty thousand tons is used as dimension stone while the remainder is used in smaller form. The distribution of stone among its various uses is shown in the summary given herewith.

Tonnages of stone and lime produced in Iowa

Uses	1922	1923	1924
Building	5,560	2,910	3,290
Rubble and riprap	117,950	44,560	46,530
Concrete and road work	417,550	449,760	434,460
Agriculture	59,720	50,810	57,520
Sugar factories	8,100	12,000	14,050
Railroad ballast and flux	11,830	43,510	49,640
Lime, sandstone, other	6,733	8,326	4,918
	627,443	611,876	610,408

Scott county continued to be the leader in production, with Dubuque as second and Black Hawk as third in rank. Hardin and Johnson, with one producer each, are among the important counties of the state, and Lee holds a place next to that of Black Hawk. The latter county produces over eighty thousand dollars' worth of stone annually while Lee's output is worth about sixty thousand dollars.

The following table gives in as much detail as possible the production of stone in 1924.

Limestone and lime production in 1924

Counties	Producers	Building, rubble, riprap (a)		Concrete, road metal		Agriculture		Other uses (b)		Total	
		tons	*value*	*tons*	*value*	*tons*	*value*	*tons*	*value*	*tons*	*value*
Allamakee(1), Black Hawk(2), Clayton(2)	5	4,634	$ 8,612	64,100	$ 83,103	6,210	$ 4,202	....	....	74,944	$ 95,917
Cerro Gordo(2), Mitchell(2), Pocahontas (1)	5	with "Other uses"		37,670	44,112	with "Other uses"		14,550	$24,289	52,220	68,401
Clinton(1), Linn(1), Johnson(1), Jackson(1)	4	with "Other uses"		40,105	53,932	6,194	13,906	3,100	4,540	49,399	72,378
Dubuque	6	9,683	11,502	56,910	90,320	with "Concrete"		4,164	20,436	70,757	122,258
Jones	3	15,308	16,944	5,831	5,897	with "Concrete"		....	....	21,139	22,841
Henry(1), Lee(3)	4	with "Other uses"		33,093	52,763	3,821	3,617	9,960	12,739	46,874	69,119
Hardin(1), Madison(1), Marshall(1)	3	....	....	65,844	71,922	15,211	9,717	with "Concrete"		81,055	81,639
Scott	3	10,464	13,752	142,479	140,063	with "Other uses"		61,074	53,264	214,017	207,079
Totals	33	49,820	63,938	434,460	533,500	57,520	43,169	68,608	99,025	610,408	739,632

(a) Includes: Building, 3,290 tons, value $8,281; rubble and riprap, 46,530 tons, value $55,657.
(b) Includes: R. R. ballast, 38940 tons, value $33,415; flux, 10,700 tons, value $12,480; sugar factories, 14,050 tons, value $23,589; lime and miscellaneous, 4,918 tons, value $29,541.

Lime was burned at Dubuque and at Hurstville, near Maquoketa, as in former years. The value of the product is included in the figures for Dubuque and Jackson counties.

SAND AND GRAVEL

The production of sand and gravel suffered a rather serious decline in 1924 as compared with conditions in the previous year. This condition prevailed in every branch of the industry, in both sand and gravel production. It was in marked contrast with the rise in production which had occurred in 1923, a rise which brought the value from $1,752,233 in 1922 to $2,181,881 in 1923. The decline to $1,473,066 in 1924 doubtless is to be attributed to a falling off in building and road improvement. The table given herewith shows some phases of the industry not set forth in the table of production by counties.

Summary of sand and gravel production

Kind of material	1923 tons	1923 value	1924 tons	1924 value
Sand:				
Molding	35,654	$ 40,238	22,397	$ 24,209
Building	1,004,261	512,413	653,031	317,068
Paving	670,181	310,750	575,835	234,966
Cutting and grinding	17,225	36,288	with	filter sand
Engine	61,680	37,627	47,607	24,661
Filter	11,968	7,505	15,681	32,922
Other	31,364	20,435	10,879	3,954
Total sand	1,832,333	965,276	1,325,430	637,780
Gravel:				
Building	343,078	331,045	311,558	289,584
Paving	837,558	634,020	563,776	483,003
Railroad	584,191	251,540	226,862	62,699
Total gravel	1,764,827	1,216,605	1,102,196	835,286
Total production	3,597,160	2,181,881	2,427,626	1,473,066

Sand and gravel were produced in forty-three counties in 1924, and the leading counties in order of value were Polk, Muscatine, Cerro Gordo, Cherokee, Sac, Linn, Hardin, Boone, Black Hawk and Wapello. As several of these counties had less than three producers each their production can not be revealed in detail. These ten counties, however, produced in 1924 material valued at

$1,141,900, much the largest part of the state's output. It may be noted that several of these counties—namely Cerro Gordo, Cherokee, Polk, Sac, Hardin and Boone — are in the central part of the state, in the area covered by what is known as the Wisconsin glacial drift. This drift sheet contains great amounts of sand and gravel, both incorporated in the body of the drift and as masses of nearly clean sand or gravel. These latter are all ready for the shovel of the excavator, as in Cherokee, Cerro Gordo and Sac counties, and the former yields its store to the streams, from which it may be readily dredged, as is the case in Polk county. The other important counties are located on large streams—the Mississippi, the Cedar and the Des Moines—which have gathered their stores from the glacial drift across which they flow.

The following table shows the production in 1924 by counties and a summary of production in 1923.

Production of sand and gravel in 1924

County	Operators	Building sand		Paving sand		Other sand (a)		Gravel		Total	
		tons	*value*	*tons*	value	*tons*	*value*	*tons*	*value*	*tons*	*value*
Black Hawk(2), Bremer(1), Fayette(1)	4	28,979	$ 15,221	40,000	$ 20,000	(3) with	"Paving"	26,600	$ 25,400	95,579	60,621
Boone(2), Story(2)	4	15,419	8,017	with	"Building"	----------	----------	68,846	41,222	84,299	49,256
Butler(2), Franklin(1), Wright(2)	5	1,640	840	----------	----------	----------	----------	37,259	10,496	38,899	11,336
Cerro Gordo(2), Emmet(1), Kossuth(1)	4	47,072	25,243	15,000	8,000	(3) with	"Paving"	57,786	87,250	119,858	120,493
Cherokee(4), Clay(1)	5	43,381	15,238	28,415	9,126	----------	----------	102,232	62,268	174,028	86,632
Clayton (2) Winneshiek(3)	5	4,272	8,200	----------	----------	20,364	20,364(1)	424	163	25,060	28,727
Clinton(3), Lee(1), Scott(3)	7	85,610	35,646	with	"Building"	----------	----------	35,951	28,236	121,561	63,882
Dickinson(1), Osceola(2), O'Brien(2)	5	2,163	1,767	----------	----------	(3) with	"Building"	10,080	1,521	12,243	3,288
Dubuque(2), Jackson(2), Jones(1)	5	27,056	7,115	16,527	6,179	(3) with	"Paving"	57,170	32,715	100,753	46,009
Fremont(1), Humboldt(1), Webster(2)	4	50,440	21,437	17,913	9,115	(5) with	"Paving"	20,773	25,844	89,126	56,396
Hardin(3), Marshall(1)	4	with	"Paving"	20,594	7,067	(5) with	"Paving"	88,107	42,494	108,691	49,561
Ida(1), Sac(3),	4	22,168	10,730	with	"Building"	----------	----------	86,764	48,953	108,952	59,683
Johnson(2), Linn(5)	7	57,606	33,470	54,255	28,873	----------	----------	4,631	3,340	114,492	65,683
Lyon(2), Sioux(6)	8	25,283	14,050	12,692	5,069	----------	----------	15,039	6,221	53,014	25,340
Mahaska (1), Marion(1), Wapello(2)	4	38,724	16,533	66,516	29,021	(1)(5) with	"Paving"	18,037	21,364	123,277	66,918
Muscatine	5	53,006	32,418	90,382	18,406	32,889	47,553(2)(3)(4)(5)	162,476	141,026	338,753	239,403
Palo Alto(1), Plymouth(2), Woodbury(1)	4	29,056	11,726	----------	----------	(5) with	"Building"	105,565	20,913	134,821	32,639
Polk	11	138,846	66,533	226,187	99,182	14,896	5,620(3)	204,481	235,567	584,410	406,902
Totals	95	653,031	317,068	575,835	234,966	96,564	85,746(a)	1,102,196	835,286	2,427,626	1,473,066
Totals for 1923		1,004,261	$512,413	670,181	$310,750	157,891	$142,113	1,764,827	$1,216,605	3,597,160	$2,181,881

(a) Includes: (1) molding sand, 22,397 tons, value $24,209; (2), (4) grinding sand, filter sand, 15,681 tons, value $32,922; (3) engine sand, 47,607 tons, value $24,661; (5) other sands, 10,879 tons, value $3,954.

NATURAL GAS

The output of natural gas continued in 1924 in a small way, as in previous years. The amount consumed amounted to about 575,000 cubic feet, with a value at points of consumption of $300. The producing wells are located near Herndon in Guthrie county and near Letts in Louisa county.

Some wells were being drilled for oil but no commercial quantities had been found during the year.

MINERAL WATERS

Owing to lack of funds the collection of data regarding use of mineral waters has been discontinued.

THE GEOLOGY OF THE MORE REFRACTORY CLAYS AND SHALES OF IOWA

BY

S. L. GALPIN

CONTENTS

LIST OF ILLUSTRATIONS

REFRACTORY SHALES IN IOWA

All types of shale or clay softening under heat at or above 1370° C (Cone 12) and occurring in possible commercial quantities in Iowa come within the scope of this report.

Beyer and Williams[1] in their report on the Clays of Iowa have shown the distribution of clays and shales within the state. More recently, Beecher[2] has demonstrated that a few of these deposits contain clays of medium to fairly high refractoriness. The work upon which this report is based was undertaken to provide further information regarding the nature and occurrence of these more refractory deposits.

Previous reports had shown that the geologic range of the more refractory clays is limited to: (1) the Niagaran Series (Silurian); (2) the Des Moines Series of the Pennsylvanian (Upper Coal Measures); and (3) the Dokata and Benton of the Cretaceous. (See Plate I.)

White Clay in the Niagaran Series.

The Niagaran is essentially a limestone series, but includes some inconspicuous syngenetic clayey lentils which are more or less cemented by calcite, and a few epigenetic white clay deposits which occupy solution caverns. The lentils are less than a foot in thickness but of considerable horizontal extent. They occur seventy to perhaps one hundred forty feet above the base of the Niagaran, within what is known as the "Pentamerus" division of the series.

The clay of the cave or pocket deposits seems, because of its similarity and association, to have been derived from the lentils, through the action of ground water. Balls of white clay, of diameters up to two feet, were noted in the thin glacial drift near one of the pocket deposits. The clay from each type of

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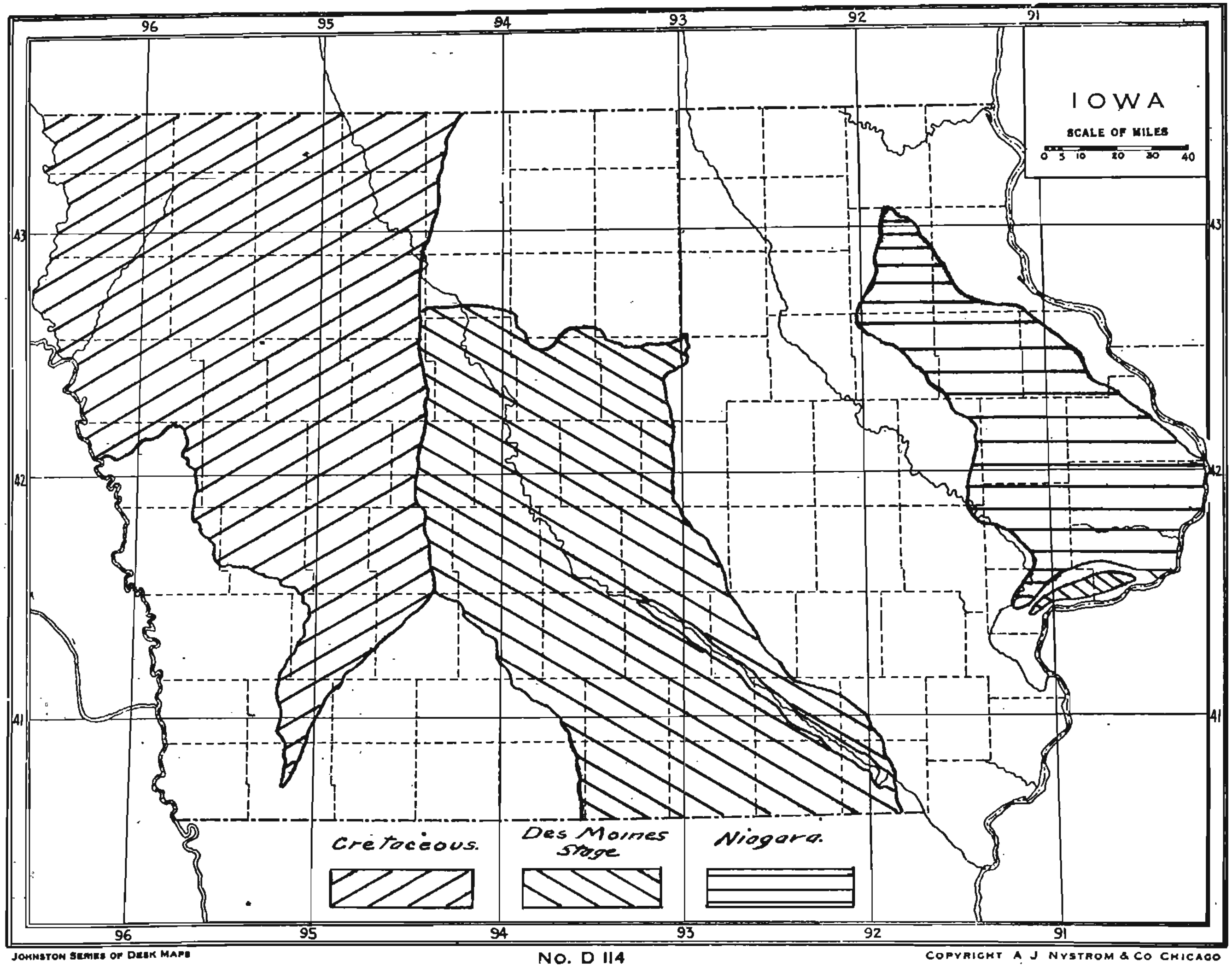
1 The Geology of Clays, Beyer, S. W., and Williams, I. A., Iowa Geological Survey, Annual Report, Volume XIV, 1903.

2 An investigation of Iowa Fire Clays, Beecher, Milton F., Engineering Experimental Station, Iowa State College, Bulletin 40, 1915.

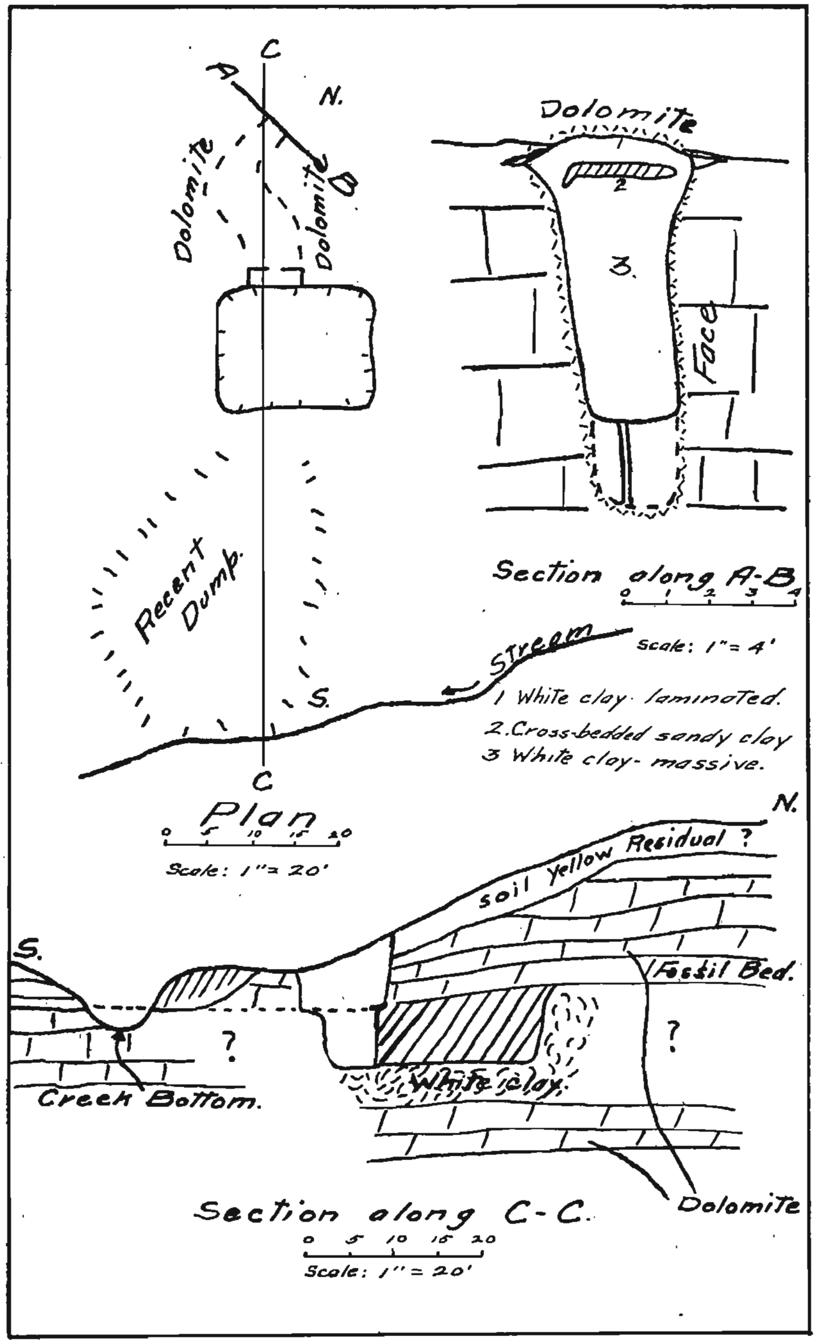


Showing distribution of outcrops of formations containing somewhat refractory clays.

deposit resembles that from the others except that in the lentils there is, in many places, sufficient calcite to cement the clay and to cause ready effervescence when it is tested with acid. Where it is not cemented by calcite, it is a white or nearly white soft clay, resembling the sedimentary kaolin of the South Atlantic Coastal Plain. Only the cave or pocket deposits hold any promise as possible commercial sources of white clay.

On the Eggers farm, in section 10, Deep Creek township, five miles northeast from the town of Goose Lake, Clinton county, there is a natural exposure of white clay thirty feet up the east side of a small ravine. The clay crops between two crumbling buttresses of rusty limestone and is covered for the most part by wash from higher ground and by glacial fill. Testing with an augur indicated a maximum depth of six feet, a width north and south of twenty feet and a probable length east and west of at least fifty feet. Because of the thickening of the drift the extension into the hill could not be determined. Samples obtained by boring show that the deposit is not wholly uniform. The clay lying near the limestone walls and floor was of more bluish color and contained white lumps of calcareous and silicious material. Samples of the two varieties of clay were examined microscopically and after blending were tested for working and burning properties. The results of tests are given with those of the clay next described.

The second deposit examined is on the Peter Jess farm (W. ½ sec. 35, T. 84, R. 6 E.) four and one-half miles east from Miles and about the same distance southwest from Sabula, Jackson county. This deposit was prospected some years ago and reports state that about two car loads of clay were shipped out. The old workings were reopened in 1922 through the efforts of Mr. Simon Gage and others of Sabula. This deposit shows more clearly the mode of origin of these clay pockets than that on the Eggers farm . The accompanying sketches, (Pl. II) indicate the shape and relationships of the clay body. It is quite apparent that the deposit fills an old cavern which resulted from the solution of the limestone along two series of vertical joint planes, one striking northwest and the other northeast. In a distance of twenty-five feet the trend changes three times. The roof of



Plan and vertical sections of white clay deposit near Miles.

the cave is a highly fossiliferous layer of dolomite. Just below this there was originally a thin layer of clay of the lentil type. The continuation of this lentil may be followed some distance along the banks of the nearby stream. Below the lentil the wall-rock is again dolomitic. The clay filling of the cave is packed tightly to the roof and shows stratification, especially in the upper part, where some brown sand appears in a four inch cross-bedded layer. Except for the uppermost foot, the deposit lies below the level of the nearby stream. The vertical thickness of the clay is about eight feet, the width three to six feet and the length, so far as the deposit has been worked, about twenty-five feet. From the nature of the origin of the deposit, it is likely to continue back into the hill a considerable distance, but nothing may be said as to the probable amount of clay obtainable. As the roof and wall rock is disintegrated to a brown sand for the depth of about an inch much care must be exercised to keep the clay clean as this sand adheres very persistently to the damp clay. A sample of this clay collected by Mr. J. B. Fidlar in 1916 was used in making laboratory tests.

Results of tests: Mechanical Analysis.

		Residue in percentage of sample used.		
	Slaked in	On No. 48 sieve	On No. 100 sieve	On No. 200 sieve
White Clay Eggers Farm	About 3 minutes	per cent 0.66	per cent 0.64	per cent 0.34
Bluish white Clay, Eggers	4 minutes	4.04	2.74	1.46
White Clay Jess Farm	2 minutes	0.4	0.54	1.70

In a microscopic examination of the material separated by sieving substantially the same materials were identified in each sample. On the 48 mesh sieve granular particles of calcite and fragments of quartz predominate. On the 100 mesh sieve unusual quartz crystals were retained. These crystals are doubly terminated, but the ends instead of being sharp are more or less completely rounded as if by etching. No prism facets were seen, there being instead an arrangement producing a series of reëntrants like the folds of an accordion's bellows. No evidence of twinning was noted. On the 200 mesh sieve some plates of kaolinite (?) were found in addition to the substances already noted. The best developed plates show a roughly hexagonal outline with angles of approximately 54°, 58° and 64°. A very little limonite and possibly pyrolusite also appear here.

It would seem from the sieve residues that washing of this clay through a 100 mesh sieve would eliminate most of its injurious impurities.

Tests of Working and Burning Qualities. Unwashed clay.

	Temper. Water	Per cent Drying Shrinkage	Per cent Fire Shrinkage	Per cent Absorption	Color
		Linear	*Linear*		
Clay from	30 per cent		Cone 4, 5 per cent	17.5	White
Eggers Farm	wt.		Cone 6, 7 per cent	10.6	Light Gray
	dry clay	5.7	Cone 8, 8 per cent	9.3	Light Gray
			Cone 10, 7 per cent	4.4	Light Gray
Clay from			Cone 4, 7 per cent	11.5	White
Jess Farm	33 per cent		Cone 6, 10.5 per cent	5.2	Gray, white specked
	wt.		Cone 8, 13.5 per cent	0.7	Gray, white specked
	dry clay	7.2	Cone 10, 9.8 per cent	1.0	Gray, white specked

Both samples slake readily, develop good plasticity and become steel hard at "cone 4".

Beecher[3] reports that a sample of white clay from northern Clinton county (presumably from the Eggers farm) fused at cone 30 and showed upon chemical analysis a composition like that of kaolin. Other tests upon the same material indicate that it fires with little warpage. So far as known these clays are the most refractory of any in Iowa.

Other deposits have been reported from Clinton and Jackson counties. A thickness of twelve feet of white clay is said to have been found in an excavation for a foundation at Miles. Report states that in sinking a well for the Chicago, Milwaukee and St. Paul Railway at Delmar white clay was encountered from a depth of 106 to 140 feet. Unfortunately, samples from these deposits were not to be had, so no estimate of the quality of the material may be given. No other deposits worth mention were found although a careful search was made over the region. This

[3] Beecher, Milton F., An Investigation of Iowa Fire Clays. Op. cit.

is not to be taken as proof that there is none, since but a small part of the surface affords rock exposures.

In properties these white clays resemble kaolin, but they are more plastic. Their bonding power is not so great as that of ball clay. The material has qualities which should make it of considerable value if deposits of sufficient quantity are uncovered. However, no strong hope of this is offered by the nature of those now known.

The Des Moines Series.

Rocks belonging to this series are found at the surface or directly below the drift in about twenty counties. The accompanying sketch map (Pl. I) shows the approximate boundaries of the areas so occupied. As the series has a gentle but general dip to the southwest, younger sedimentary rocks cover it to the west of the area indicated on the map, while on the east erosion has exposed formations of greater age. The thickness of the existing portion of the series increases from the eastern border to possibly four hundred feet on the west.

Shale and clay beds, with less extensive layers of sandstone, coal and limestone make up this lower division of the Pennsylvanian of Iowa. The assemblage of sediments bears evidence of deposition in shallow water. Preceding the Des Moines epoch, this region had been for a long time subjected to erosion. The general slope of the land at that time seems to have been toward the southwest. The principal streams naturally followed this slope, but the tributaries likely had northwest or southeast courses parallelling the strike of the then exposed rocks. The rocks now representing the Des Moines series were deposited as muds, sands and similar material as the pre-Pennsylvanian surface was slowly submerged. During the greater part of the epoch physiographic conditions existed which were similar to those along the Gulf coast of today. The position of the seashore was often shifting. These shiftings, together with actual warping of the land surface, resulted in a complete series of sediments, some representing subaerial; some, fresh water; and some, marine deposits. The land surface remaining above sea level was low. The climate was moist, temperate and lacking in marked seasonal extremes. As a result there were doubtless many streams, most if not all of them sluggish. Marshes and broad tidal flats bordered the sea, while swampy conditions prevailed far inland along the stream courses. Vegetation was abundant.

Because of the slow flow of the streams, no mineral sediment coarser than sand was carried by them. Their load was largely clay and silt. Considerable amounts of soluble material such as bicarbonates of calcium, magnesium and iron also were transported. Sand was deposited in stream channels, estuaries, and along parts at least of the seashore. Silts and muds were dropped upon flood plains, in lagoons, estuaries, swamps and marshes, upon tidal flats, and in the sea wherever the absence of currents allowed. Some, probably much of the soluble material of the river waters was carried considerable distances offshore although a portion was absorbed and entrapped by the fine material of the muds. As a result of the various conditions of deposition we find today several different kinds of shale and clay beds in the Des Moines series. Of these, three rather distinct types providing somewhat refractory clay may be distinguished.

The most abundant variety is a nonlaminated clay often found below coal beds and termed "fire clay". While in some states clays of this type are highly refractory, yet in Iowa there are few known occurrences of underclays possessing this characteristic. These clays are usually readily recognized because of certain peculiarities. Unlike most clay deposits the underclays are not laminated. When it is damp and undisturbed a deposit of this kind has a massive appearance, but on drying out shrinkage reduces it to irregular, many-sided small chunks. The beds are from a few inches to occasionally ten feet thick, three or four feet being a fair average. They thicken and thin in an apparently irregular manner. Single beds are seldom continuously traceable over an area greater than a few square miles, and within such an area they may show many differences in thickness and constitution. They rest upon shale, sandstone, coal or limestone, and any of these rocks may cover them. Coal, however, is far the most common overlying stratum. The natural color of the "fire clays" is some shade of gray, blue, green, pink, purple or in some instances it is nearly black. Close examination of a hand specimen usually reveals the presence of fossil leaf, stem or root fragments, the carbonaceous material being replaced more or less by pyrite or marcasite. Other harmful minerals usually evident to some extent are limonite, siderite, calcite and gypsum. Plasticity is usually high as is also the shrinkage and strength of both green and finished ware made from these clays. Most of the Iowa "fire clays" reach minimum porosity between cones 6 and 10 and soften at cones 12 to 24. A few thin seams provide material of greater refractoriness, and some have been found to fuse as readily as cone 4. Many of these clays are light burning, the purer representatives giving buff or gray colored ware. Except where the coarser grains of pyrite and siderite have been removed, black specks and blisters appear on burning.

The origin of underclays is not entirely clear. Their close association with coal led to the suggestion that they represent the soil which supported coal forming flora. More recently Stout[4] has proposed that the underclays represent the ash from the natural oxidation of vegetable matter, which but for that oxidation, would have formed coal. This seems reasonable if we include the admixture of varying but considerable amounts of clayey sediments with the residue from oxidized vegetation. Whatever their origin, these clay deposits show great similarity to coal beds in shape and extent and they are most commonly directly overlain by coal or by some rock containing much carbonaceous matter.

The second type of clay is smooth, plastic and laminated and usually gray or dove-colored although occasionally black or white. Thin layers of such clay are not infrequent, but beds over three feet in thickness are rare. In properties they are closely related to the underclays. In some cases, at least, the laminated shale may be made up of material from the same source as the "underclays" but transported and redeposited in water where growing vegetation could not serve to destroy the laminations usually formed during sedimentation.

The third type is a massive gritty shale, usually light gray in

[4] Stout, Wilbur, Theory of the Origin of Clays; Trans. Am. Ceramic Soc., XVII, 1915.

color. The thickness of deposits of this kind may vary from fifteen feet to only a foot within a horizontal distance of a few hundred feet. Pyrite is usually present in replacements of vegetable fragments, except where it has been removed through weathering and bleaching. Calcite, siderite and gypsum are not present in noticeable amounts. Occasionally such shales may be found to pass either laterally or vertically into sandstone. Transition into other shales, except in one or two cases where sandstone changed gradually upward into underclay, was not noted. There is a suggestion that some of these sandy shales are the result of chemical or biochemical reactions of solutions of aluminum sulfate (derived from weathering pyritic shale) with silica of sandstone. Logan[5] has proposed such an origin for the kaolin deposits of Indiana. Nothing approaching the purity of the Indiana deposits has been found, however, in Iowa. Shales of this class are of medium to low plasticity and low shrinkage. They attain minimum porosity at cone 6 to cone 16. A few deposits yield material softening at about cone 30. Others soften at cones 18 to 24. Because of their low shrinkage and slight tendency to warp, the better of these shales should be admirably suited to the manufacture of architectural terra cotta. Only those free from pyrite could be utilized, however, unless washing were resorted to.

THE MUSCATINE DISTRICT.

An outlier of Pennsylvanian strata extends from a short distance west of Muscatine eastward within two miles of Davenport. Shales here lie unconformably upon beds of Devonian limestone. Light burning shales have been dug at times near Fairport for use in local potteries. At present, clay is brought from the Illinois side of the river. Satisfactory exposures, either natural or artificial, are scarce. Small lentils of nearly white clay may be observed at Muscatine on the bluffs at the eastern edge of the city. Three feet of fissile white shale is exposed here at a level about fifty feet above Mississippi river. In sections 13 and 24, Montpelier township, there are exposures of a

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[5] Logan, W. N., Kaolin of Indiana: The Department of Conservation, State of Indiana, Publication 6, 1919.

light gray shale twenty to thirty feet above the base of the Pennsylvanian. While some of these beds have a thickness of as much as four feet locally, yet they seem to have no great lateral extent. Black shale usually is found above the white clay. The quality of some of these deposits seems good, there being little visible impurity, but unless the future brings to light more persistent beds there is little prospect for their extensive development.

THE SOUTHEASTERN DISTRICT.

This district comprises Lee, Van Buren, Des Moines, Henry, Jefferson, Wapello, Keokuk and Mahaska counties.

Shales of the Des Moines series in this region belong to the lower portion of the series. They rest upon the eroded surface of the St. Louis limestone (Mississippian). As there was considerable relief in this surface, the early Pennsylvanian deposits were laid down in the drowned valleys only and therefore at any horizon they form an irregular series. The thickening and thinning of individual deposits and the lack of continuous outcrops render useless any attempt toward correlation of beds in different parts of the region. Because of the general cover of glacial drift natural shale and clay exposures are confined to gullies and valleys of the smaller streams, and are by no means abundant in them. Road cuts, clay pits and coal mine shafts have brought to light other occurrences. The evidence gathered indicates an abundance of material here that will withstand temperatures above the softening point of cone 12. Several deposits have yielded clays fusing near cone 25. The "under clay" type is the most important in this region and may be found in beds from two to as much as ten feet in thickness.

A few outliers of Pennsylvanian rocks occur in Des Moines, Henry and Lee counties, and clays of good quality have been utilized from some of them, notably those at the Jester farm (Sec. 6, T. 69 N., R. 4 W.), about six miles southwest from Danville; at the Ed Noble farm (SE. 1/4 sec. 36, T. 70 N., R. 5 W.), about one mile northwest from Jester's; and at the Otis Watson farm near Danville. Little has been done at these pits during the past few years and the exposures are not good.

On the Noble farm the clay lies about thirty-five feet above the St. Louis limestone. A sample of the material taken in 1918 by Prof. J. E. Smith gave the following results upon testing:

Sample No. 78. Noble farm, southeastern Henry county.

	After drying	Cone 2	Cone 6	Cone 10
Total linear shrinkage, per cent	6.25	9.38	10.9	10.9
Absorption, per cent		9.5	5.2	2.4
Color		Gray	Gray	Gray
Hardness	Steel hard at Cone .02			

The exposure on the B. B. Jester farm is better, showing:

	Feet
Soil and sandy drift	0 — 3
Sandstone	12
Black shale	0 — ⅔
Coal	1
Black shale	1 — 1½
White clay	4 — 9

A sample (No. 4) of the white clay was taken by Mr. J. B. Fidlar in 1915, and was tested with the following results:

Sample No. 4, B. B. Jester farm, southwestern Des Moines county.

	After drying	Cone 2	Cone 6	Cone 8	Cone 10
Total shrinkage, per cent	5.5	6.0	7.5	8.0	9.0
Absorption		16.4	13.8	12.0	11.0
Color		light gray	gray	buff	light brown
Hardness		softer than steel	softer than steel	softer than steel	about steel hard

Tempering water, 20.1 per cent. Plasticity good.

Iron specks become noticeable at cone 2 and are bad at cone 10. Despite these the clay appears to be at least a second grade fireclay. This clay was formerly used in pottery manufacture in Burlington. A considerable quantity is available for open pit working, and geologic conditions seem favorable for mining, as a twelve to twenty foot sandstone layer could be used for roof. The six mile haul to railroad is a serious drawback, otherwise this deposit would doubtless be actively developed.

Washing this clay through a 200 mesh sieve removes only 0.3 per cent of the original clay. Microscopic examination of the separate shows mainly quartz, a little pyrite, granular calcite and a micalike mineral of low index of refraction (hydromica?).

White clay has been worked on the Otis Watson farm near Danville. At present the exposures are poor. The clay, which is about four feet thick, seems to be below a thick layer of soft sandstone. A sample collected by Mr. Fidlar has the following properties:

Sample No. 5. Otis Watson farm, Danville, Iowa.

	After drying	Cone 2	Cone 6	Cone 8	Cone 10
Total shrinkage, per cent	7.6	15.5	18	17.5	17.
Absorption, per cent		7.59	0.58	0.58	0.46
Color		light gray	dark gray	dark gray	dark gray
Hardness		harder than steel			

Tempering water, 31.5 per cent.

Only a few iron specks appear on the burned test pieces. This clay was formerly blended with Jester clays in the manufacture of pottery at Burlington. When washed through a 200 mesh screen 2.8 per cent of the original sample was held on the screen. This residue consisted of cherty material, root fragments, granular calcite, a little pyrite and a few scales of limonite.

Near Denova in Henry county light gray to nearly white clays outcrop at scattered points in sections 25, 26, 27, 34 and 35, township 71 north, range 7 west. It cannot be said that these outcrops belong to a single bed, but as they occur at about the same level and usually within twenty feet above the St. Louis limestone they evidently are of a single horizon. The beds are from two to four feet in thickness and are associated with darker shales. Turley Bros. of Burlington used several car loads of this clay for pottery, but no development has gone on since about 1912.

Tests of samples of this clay by Beecher[6] gave the following results:

Beecher's No. 26, sec. 26, Tippecanoe Twp., Henry county.

	After drying	Cone 3	Cone 5	Cone 8	Cone 10
Shrinkage, per cent	3.5	5	6	6.9	6.2
Absorption, per cent		8.4	5.4	3.5	3.7
Color		buff	buff	buff	buff
Final fusion, Cone 22					

6 Beecher, Milton F., An Investigation of Iowa Fireclays: Eng. Exp. Sta. Iowa State College, Bulletin 40, 1915.

Beecher's No. 36. Southwest of sec. 26, Tippecanoe Twp., Henry county.

	After drying	Cone 3	Cone 5	Cone 10
Shrinkage, per cent	7.5	11	12.5	
Absorption, per cent		7.4	4.6	
Color		buff	buff	dark buff
Final fusion, Cone 24+				

The variation in properties shown by these samples taken from two cuts in the same section is borne out by differences to be noted in the texture of the clay. At one place there will be no grit noticeable while at another, nearby, there may be a considerable amount of fine grit. Gypsum is present in a few places, but as it is in fair sized crystals, its removal by washing is not difficult. Pyrite seems to be absent although this may be due to weathering of clay at the surface.

It is worthy of note that these clays are all less than forty feet above the top of Mississippian limestones. In one instance, near Denova, the clay seems definitely to lie in valleys in the limestone surface, and it is possible that most of the occurrences are of this sort. If so the horizontal persistence of these beds is much less than is commonly thought.

Van Buren County.—While "underclays" are associated with the coal lenses of the county, they are as a rule so irregular both in character and thickness as to render their value for ceramic uses doubtful.

Of the deposits examined, all but one contained such quantities of pyrite that they were not sampled. The one exception was a thirty inch seam of dark gray gritless clay lying between two coal beds and twenty feet above the St. Louis limestone. This deposit is in the northwest quarter of section 36, township 68 north, range 8 west, and about one mile north from Farmington. Unlike the usual "fire clay" this bed is distinctly laminated. Microscopic examination of the material held upon a 200 mesh sieve disclosed the presence of numerous amber-colored particles having trigonal or oval outlines and in many cases point decorated surfaces. These were taken to be spores or spore cases. In addition minute grains and replacements of pyrite and many carbonized vegetable fragments were seen. Tests of a sample of the clay gave the following results:

Clay sample from near Farmington, Van Buren county.

	Drying	Cone 2	Cone 6	Cone 10
Total linear shrinkage, per cent	7.	13.5	13.6	14.1
Absorption, per cent		14.+	9.5	5.6
Color		Buff	Gray	Gray specked

Tempering water, 27.95 per cent weight dry clay.
Slaking, rather slow.
Oxidation, slow, but no evidences of swelling.

The clay has been used locally in the manufacture of common pottery. That so used was obtained at the same time the adjacent coals were mined.

Jefferson County.—Although the Des Moines shales are present over most of the county, the average thickness does not exceed fifty feet. Good natural outcrops are rare, and artificial exposures are but little more numerous. Two clay samples were taken in this county, the first from below an eight inch coal seam in what is known as Raney's clay pit, two and one half miles west from Fairfield. The sample was taken by Mr. J. B. Fidlar who reports twelve to fourteen feet of gray clay and shale below an eight inch coal seam. The results of tests on this sample follow:

Sample No. 6.

	Drying	Cone 2	Cone 6	Cone 10
Total linear shrinkage, per cent	6.1	11.1	12.1	12.6
Absorption, per cent		10.3	3.2	2.4
Color		light buff	gray	yellowish gray
Hardness		steel hard	harder than steel	harder than steel

Tempering water 24.4 per cent.

Beecher reports[7] tests on an eight foot stratum of gray gritty shale from near Fairfield. His sample (No. 34) burned a light buff at cone 11, shrank but 6 per cent at cone 10 and fused at cone 23. There are considerable quantities of this clay available without excessive stripping.

The second sample came from a natural exposure on the north bank of Cedar creek just east of the bridge on the Fairfield-Libertyville road. The nature of the clay and shale series is shown in the accompanying sketch. (See fig. 1.) The sample included

[7] Op. cit., p. 71.

all the section excepting the drift, sandstone and coal layers. Tests of this composite sample representing a total thickness of about thirty feet of clays and shale resulted as follows:

Shale and clay from section 3, township 71 north, range 11 west.

	Drying	Cone 2	Cone 6	Cone 10
Total linear shrinkage, per cent	5.8	10.	10.4	11.
Absorption, per cent		13.5	8.5	6.3
Color		Buff	Gray	Gray, specked and blistered

Tempering water 18.7 per cent.

Cedar creek section.

	Feet
Soil and drift	0–30
Dark shale, gray clay	3
Coal	1/12
Gray fire clay	2
Sandy clay	2½– 3
Drab fire clay	1
Coal (pyritic)	¼
Drab fire clay Dark gritty shale	10
Sandstone	½– 1½
Black shale	2½
Coal	⅜
Fire clay, some gypsum	3
Fire clay, some grit	4
Gray clay shale	2
Coaly shale	1
Unexposed to creek level	3
To top of St. Louis limestone	5–10

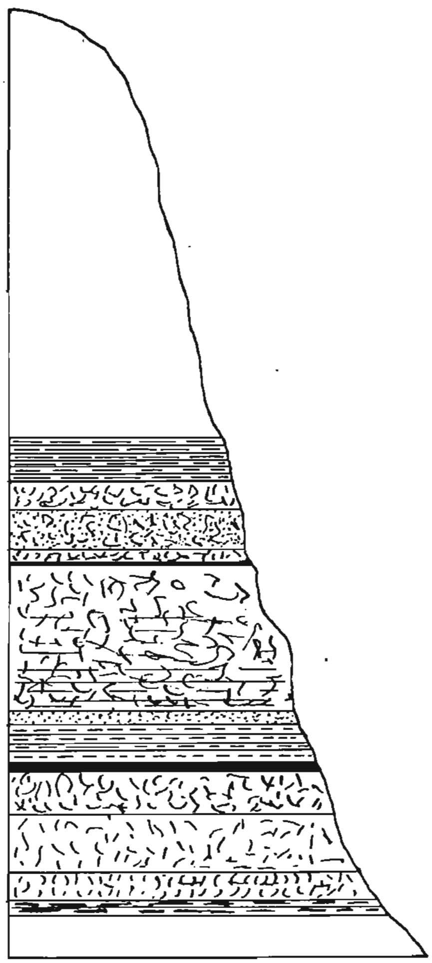

FIG. 1—Cedar Creek exposure near Fairfield-Liberty road.

Washing would considerably improve the quality of this clay as pyrite and gypsum are both in evidence. Considering the number and thickness of strata represented in the sample, the showing under test is remarkable. Conditions near this outcrop are favorable to strip pit operation. Fairfield is not over three miles distant and a branch line of the Chicago, Rock Island and Pacific Railway passes within two hundred yards to the east. The region seems worth investigation toward commercial development for the manufacture of vitrified clay wares.

Washington County.—Washington county contains a few scattered outliers of Des Moines series rocks, but as nothing of importance in the way of refractory clays had been previously reported, no work was done here.

Wapello County.—Samples of underclays were obtained from many localities in Wapello county. The results of tests on these samples indicate that there are few deposits, however, which might afford clays fusing above cone 12. A sample from thirteen feet of gray shale exposed in a gully in the southeast quarter of section 26, Washington township, and one mile east from Eldon, softened at cone 6. Another sample from near the center of the southeast quarter of section 22, one mile north of Eldon, gave the following results upon test:

Four feet of gray fire clay outcropping at stream level.

	Drying	Cone 2	Cone 6	Cone 10
Total linear shrinkage, per cent	7.6	12.1	11.1	15.
Absorption, per cent		11.9	11.2	?
Color		Buff	Gray	Brown

Tempering water 28 per cent.
The test pieces were beginning to fuse at cone 10.

Two samples were secured from near Laddsdale, one from below the No. 3 coal in the Anchor No. 2 mine, the other from a roadside exposure near the middle of the south half of section 31, Washington township. The second sample comes from a spot about three-fourths of a mile west from the source of the first and from a horizon some fifty feet higher. The clay below the coal is said to range from one to six feet in thickness. In different parts of the mine its character is different. Where the clay was sampled, the upper third is decidedly gritty, the lower third is smooth while the middle represents gradational material between the two extremes. Tests of this sample show low shrinkage, and fusion at cone 12.

The roadside exposure shows the following sequence:

		Feet
8.	Drift, variable	
7.	Shale, black; exposed	2
6.	Shale, gray; 1 inch limestone lentil	3
5.	Coal	¼
4.	Fire clay, gritty	1½
3.	Shale, gray limestone, lentils	2½
2.	Coal	3½
1.	Fire clay (exposed)	3

The sample was taken from 1, 4 and 6 and gave the following results upon test:

	Drying	Cone 2	Cone 6	Cone 10
Total linear shrinkage, per cent	6.7	10.9	9	13.3
Absorption, per cent		9.1	10	5.3
Color		Buff	Gray-buff	Gray

Tempering water 19.4 per cent.

As the drift thickens abruptly up the hill only a limited amount of clay could be obtained here by open cut.

"Fire clays" are exposed at and near Ottumwa in many places. Samples from what appeared to be the purest clays were collected and tested, but all failed to stand up at cone 12. The accompanying sketch (fig. 2) shows the succession of strata in the pit of the Morey Clay Products Company as it was in 1918. The "pottery clay" near the top of the bank fuses at about cone 10. The gritty fire clay formerly used in making paving brick was not tested owing to the amount of limonite and pyrite contained.

Mahaska and Keokuk counties show little promise for the more refractory clays. Clays of the fire clay type are present below the coal worked near What Cheer. They are, however, decidedly sandy. Pyritic replacements of upright leaves and stems are frequent. These clays are "short" and tend to check and blister in burning. Because of the high content of pyrite the fusion point is below cone 12. Gritty underclays occur below the coal in some sections in Mahaska county, but in many cases sandstone replaces the clay. A gritty fire clay was formerly worked at Oskaloosa, speckled buff face brick resulting. This clay resembles closely that mentioned as occurring at and near What Cheer.

	Feet
Loess	8
Yellow clay	6
Black shale	¼
Pottery clay, pinkish, smooth	3
Gray to buff shale, some limestone lentils	8
Shale, black, pyritic	7
Coal	1¼
Sandstone and gritty fire clay	7

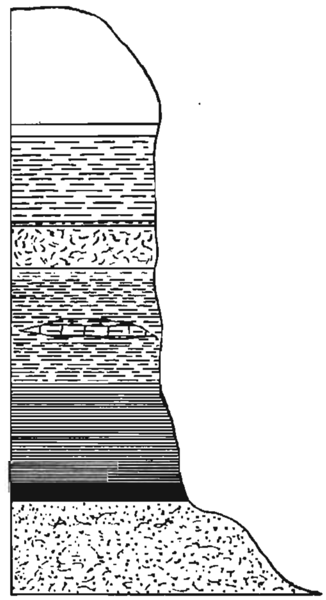

FIG. 2.—Ideal Section. Morey Clay Products Co., Ottumwa.

Outcrops of plastic underclay may be seen near Given, about seven miles south of Oskaloosa. The clay lies close to stream level. The overlying coal has been rather generally mined out and as a consequence very limited amounts of the clay are economically available.

Thin seams of plastic "fire clay" are rather common near New Sharon, in the northern part of Mahaska county. No deposit of sufficient thickness to be commercially promising was discovered.

THE SOUTHERN DISTRICT.

The southern district includes Davis, Appanoose, Wayne, Lucas, Monroe, Marion and Warren counties. The three southernmost counties, Davis, Appanoose and Wayne, have little to offer in the way of even somewhat refractory clays. "Underclays" are sufficiently abundant but samples from Mystic, Centerville and Cincinnati fused at or below cone 6. Pyrite and siderite in these clays render oxidation extremely difficult. This is unfortunate as large amounts are heaped upon the surface consequent to mining of coal from the thin Mystic seam.

The four remaining counties of the group are more promising although no deposits worthy of note were found in Lucas county. In Monroe county some of the clays and shales occurring below and above the worked coals are fairly refractory. Beecher[8] reports that light gray shale from above the coal in the Crescent Coal Company mine at White City fused at cone 18 and light gray shale from below the coal fused at cone 16. Both samples burn dark red.

At Lockman the following sequence of beds is reported by Mr. T. J. Evans:

		Feet	Inches
5.	Drift and sandrock	12	
4.	Shale, white and plastic	20	
3.	Coal		3
2.	Shale, black, coaly		4
1.	Shale, white, plastic	20	

Tests of a sample from No. 4 of this series, submitted by Mr. J. R. Clause of Lockman, resulted as follows:

	Cone 3	Cone 6	Cone 10
Absorption, per cent	5.5	5.3	8.6
Color	Brown	Brown	Lustrous brown
Hardness	Harder than steel		

Iron specks become noticeable at cone 3 and above.

Underclays occur with the coal at Ward and Hiteman in different thicknesses up to eight feet. The clay is smooth and slickensided, but contains much pyrite in fine disseminated grains and replacing vegetable matter. In most other mining districts of the county, coal is underlain by only thin clay or by sandstone. As the coal beds worked are usually thick, little or no clay is taken up.

In Marion county the only known refractory clays lie below the coal beds. Beecher gives the following information in his

8 Beecher, M. F., Op. cit., page 60.

report[9] regarding the firing properties of one of these deposits located near Morgan Valley:

	Drying	Cone 3	Cone 8	Cone 10
Total linear shrinkage, per cent	1.9	5.5	7.	6.
Absorption, per cent		6.5	2.3	9.*
Color		Brown	Brown	Brown *Black Cored

Fuses at cone 20-21.

Samples of other underclays collected in this county by Mr. J. B. Fidlar did not prove equal to cone 10 in refractoriness.

Natural outcrops of shale series including some fire clay types occur in the sharply cut valleys of eastern and northern Warren county. Of four samples from over the county none was as refractory as cone 12. The most refractory sample fused at cone 11. It was obtained from a three foot stratum of light colored gritty shale at the clay pit of the Carlisle Brick and Tile Company, one mile west of Carlisle. Because it is overlain by two feet of black carbonaceous shale this particular stratum is no longer used.

The northeastern quarter of Madison county contains many good exposures of Des Moines series shales, but according to the report of Beyer and Williams[10] no promising fire clays are to be seen. The same condition exists in western Warren county.

THE CENTRAL DISTRICT.

The central district includes Jasper, Polk, Dallas, Boone, Story and Marshall counties. The underclays of this district show variations similar to those of districts already treated. Apparently no dependence may be placed upon the refractoriness of this type. Some beds yield an easily fused clay while others from no great distance may stand up better than cone 20.

In Jasper county natural clay and shale exposures are rare and poor, and the material obtainable from such outcrops is hardly representative of the beds they indicate. Sandy fire clays and sandstone are the common associates with the coal seams.

Tests by Beecher[11] of gritty clays from above and below the

9 Op. cit., p. 71.
10 Op. cit., p. 447 et seq.
11 Op. cit., p. 55.

coal in mines of the Colfax Consolidated Coal Company gave softening points at cones 17 and 19 respectively. The refractoriness of these clays seems due in large measure to the quartz which they contain. They are not of good plasticity.

Polk and Dallas counties afford through their many clay pits and mines abundant opportunity for the discovery of refractory clays. Few, however were found, although many samples have been tested. Only the occurrences of clays that were found to fuse above cone 12 will be mentioned.

In the Maple Block No. 2 mine, about three and one-half miles northeast of Des Moines, a four to six foot stratum of dark clay is below the coal (3rd vein, depth from surface at shaft 165 feet). The clay is somewhat fissile and contains a little pyrite. The lower three feet of the clay appears to be of better quality than that next the coal. A sample of this clay taken from an entry where a fault had raised the clay nearly to the roof (a quarter of a mile east and a quarter of a mile north from the shaft) fused at cone 13.

Two coals are worked at the Bloomfield mine (SW. ¼ of sec. 12, Saylor township). The upper coal has no fire clay with it, but a little over four feet of clay underlies the lower. The following results were obtained upon testing a sample taken from the head of an entry directly below East 14th Street:

	Drying	Cone 2	Cone 6	Cone 10
Total linear shrinkage, per cent	4.7	7.8	9.4	11.
Absorption, per cent		11.7	6.5	3.3
Color		Gray	Gray	Buff with iron specks
Hardness		Harder than steel.		
Fusion cone 14				

In the pit of the Redfield Brick and Tile Company just west of Redfield, Dallas county, fire clay occurs as shown in the accompanying section. (See fig. 3.) A sample taken from stratum No. 2 of the section tested as follows:

Four foot layer of purplish clay, Redfield Brick & Tile Co.

	Drying	Cone 2	Cone 6	Cone 10
Total linear shrinkage, per cent	9.4	9.4	11	11
Absorption, per cent		12	9	6.4
Color		Purplish gray	Gray	Buff iron specks
Hardness (none given)				

Plasticity good.
Fusion point, cone 21 according to Beecher[12].

Fire clay, said to have been refractory, was formerly worked below a thin coal at a depth of 160 feet at Van Meter. With the closing of the mine this operation ceased. Clay of the fire clay type is exposed in old workings of the Platt Company at Van

Redfield Brick and Tile Co.

	Feet	Inches
Soil and drift	10	
Shale, gray, silty, carrying iron stained concretions Shale, brownish, rather massive	16	
Unconformity ?		
Shale, black		8
Fire clay, purple mottled	1	10
Shale, yellow at top, purple at bottom	6	
Shale, heavy-bedded, gray, with partings	10	
Calcareous layer, highly fossiliferous, soft or hard		3–6
Fire clay, gray to purplish	4– 5	
Greenish gray sandy shale. Exposed	2	

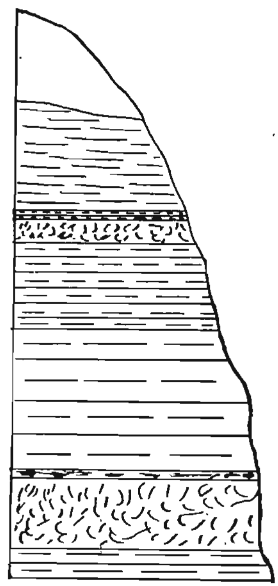

FIG. 3—Vertical section in clay pit at Redfield.

Meter, but according to local report it is neither particularly refractory nor of good working qualities.

Fire clay occurs toward the bottom of the Adel Clay Products Company's pit, one mile west from Adel. This clay has been used as a bond with fire brick grog in making brick for use in the kilns at the company's plant.

12 Op. cit., p. 60.

Boone Paving B. & T. Co.

	FEET
Drift	
Sandstone ledges	6
Gray shale	5
Clayey sandstone	7
Smooth laminated red and gray shale	7–8
Sandstone	2
Purple massive clay	7
Hard red & blue shale	3–4
Smooth black shale	1
Limestone	½
Coal	½
Gray shale	2
Cap rock	5/6
Fire clay	1
Shale	6
Sandy shale	2
Fine gray-blue shale	1
Blue shale	3
Sandy fissile shale	1
Dark gray fissile shale	½
Coal	¼
Fire clay, gritty	2½
Coal	2–2½
Dove fire clay	2
Concealed to low water level	7

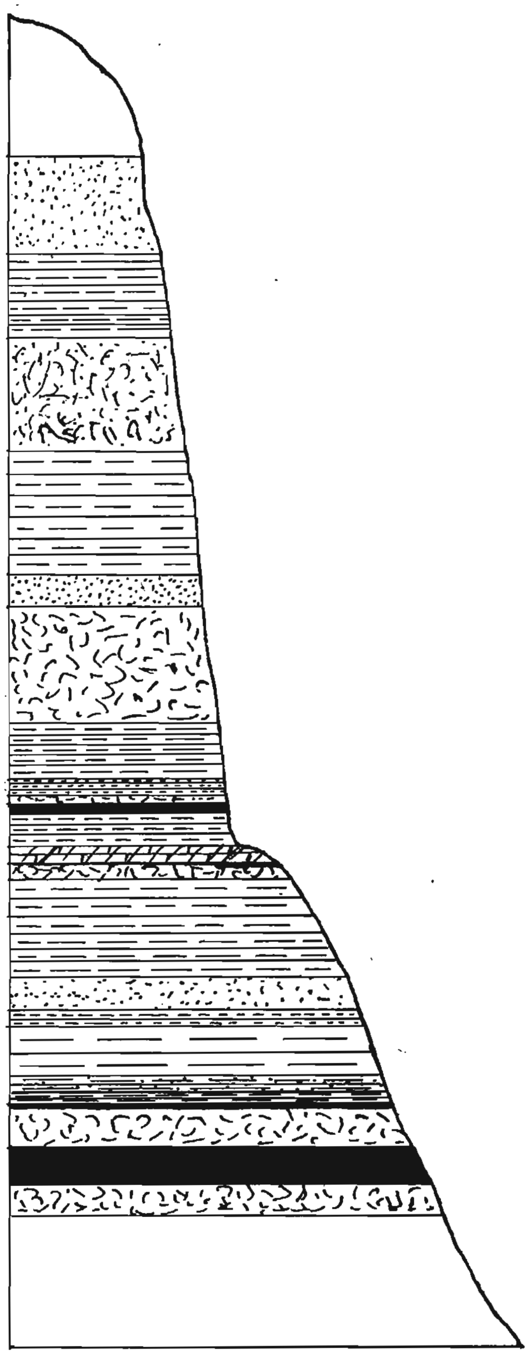

FIG. 4—Boone Paving Brick and Tile Co.

Rocks of the Des Moines stage appear in eastern Guthrie county but no important refractory clays have been seen or reported there.

In Boone county the most refractory clays now available are to be found at Logansport in the pit of the Boone Paving Brick and Tile Company, and in the underclay at the Boone Block Coal Mine, about half way between Logansport and West Boone.

At the clay pit a generalized section shows a great variety of sedimentary rocks. (See accompanying sketch, fig. 4.) The west end of the pit shows fewer strata than the eastern excavation. Two samples were taken from the west end (now abandoned), one being taken from a three foot layer of white, gritty but plastic clay lying above the "cap rock" which forms a floor of the old workings. The second sample is from a three foot blue-gray fire clay stratum about fifteen feet below the horizon of the first sample. Results of tests follow:

Gritty white clay, Logansport.

	Drying	Cone 2	Cone 6	Cone 10
Total linear shrinkage, per cent	6.25	6.25	6.25	9.4
Absorption, per cent		14.2	11.1	7.4
Color		Gray	Gray	Gray, a few iron specks
Hardness		Steel hard	Harder than steel	

Fuses at cone 20.

Gray fire clay, Logansport.

	Drying	Cone 2	Cone 6	Cone 10
Total linear shrinkage, per cent	3.13	6.25	7.8	9.4
Absorption, per cent		15.9	7.4	7.7
Color		White	Dirty white	Dirty white no specks whatever
Hardness		Steel hard	Harder than steel	

Fuses at cone 18.

The sample from the Boone Block Mine was obtained from the dump heap. The stratum under the coal is seldom over two feet thick, but much clay is taken up to give height in the entries.

Clay from below coal, Boone Block Mine.

	Drying	Cone 2	Cone 6	Cone 10
Total linear shrinkage, per cent	7.3	10.9	12.5	12.5
Absorption, per cent		7.6	2.1	4.0
Color		Dirty white	Gray, iron specks	Gray, iron specks
Hardness		Harder than steel		

Fuses at cone 16.

These tests would seem to indicate that the region between Boone and Des Moines river could provide large amounts of clay fusing between cones 16 and 20. However, little clay of this kind is available except through mining, or bench working.

Story and Marshall counties to the east and Greene county to the west of Boone have not proven worth further mention as regions of accessible refractory clays.

THE NORTHERN DISTRICT.

Included in the northern district are Webster, Hamilton and Hardin counties. These counties lie along the northern border of Pennsylvanian rocks in Iowa. Consequently the greater part of the series found here is of the lower one hundred feet of the Des Moines strata. Exposures of shale and clay are confined to the deeper valleys. The irregularity of the strata so characteristic of the Des Moines series elsewhere in the state is thoroughly illustrated through this region.

In Webster county the area most promising as a possible producer of more refractory clays lies along Des Moines river from Lehigh to Fort Dodge. Within this territory there are several clay strata of considerable refractoriness. These all seem to be of the massive sandy clay or shale variety. Smooth, highly plastic underclays are abundant, and appear in practically every clay pit of the region, but as a rule do not provide material fusing above cone 12. The sandy clays are thicker, more regular in thickness and less changeable in character than the more plastic fire clays. The greater uniformity of thickness may be attributed in part if not wholly to their greater resistance to "squeezing", a feature common to the typical underclays.

At the pit of the LeHigh Sewer Pipe and Tile Company strata shown in the accompanying section (fig. 5) are worked. Formerly shales at lower levels were used. Beecher[13] gives the results of tests upon a six foot bed of gray sandy clay lying below a four foot coal seam. This clay fuses at cone 21, and shrinks but 3.5 per cent at cone 10. The absorption remains high at cone 10, but there is considerable warpage. Great quantities of clay of this or similar kind are present in the hills about Lehigh. However, the heavy burden of glacial drift is a serious handicap to their development. On the east side of the river, some clay has been mined and the future will probably see more of such work.

Lehigh Sewer Pipe and Tile Co.

	Feet
Drift, variable but thick	0–40
Shale, red, smooth, finely laminated	1½
Shale, gray, sandy, some reddish areas	6
Shale, red, fissile	3
Shale, sandy	2
Sandstone	1
Shale, mottled gray and red	4– 5
Sandstone	1½– 2
Shale, red for the most part	5
Sandstone, clayey above	3– 4
Clay (Fire clay type)	0– 2
Shale, mottled gray and red; to pit floor	4– 6
Shale, gray. Reported	12–14

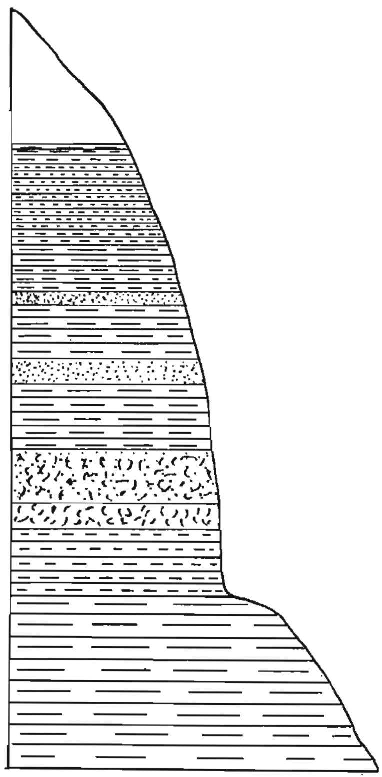

Fig. 5—Lehigh Sewer Pipe & Tile Co., Lehigh, Webster county.

At the pit of the Kalo Brick and Tile Company forty feet of shale and clay are utilized. The following section shows the succession of **strata**:

13 Op. Cit.

		Feet
6.	Shale, fissile but hard	3
5.	Sandstone, thick-bedded, hard	3
4.	Shale, black to gray, ocherous streaks	10
3.	Shale, black, clay ironstone concretions	20
2.	"Fire clay", gray, some pyrite	4
1.	Clay more sandy than No. 2	

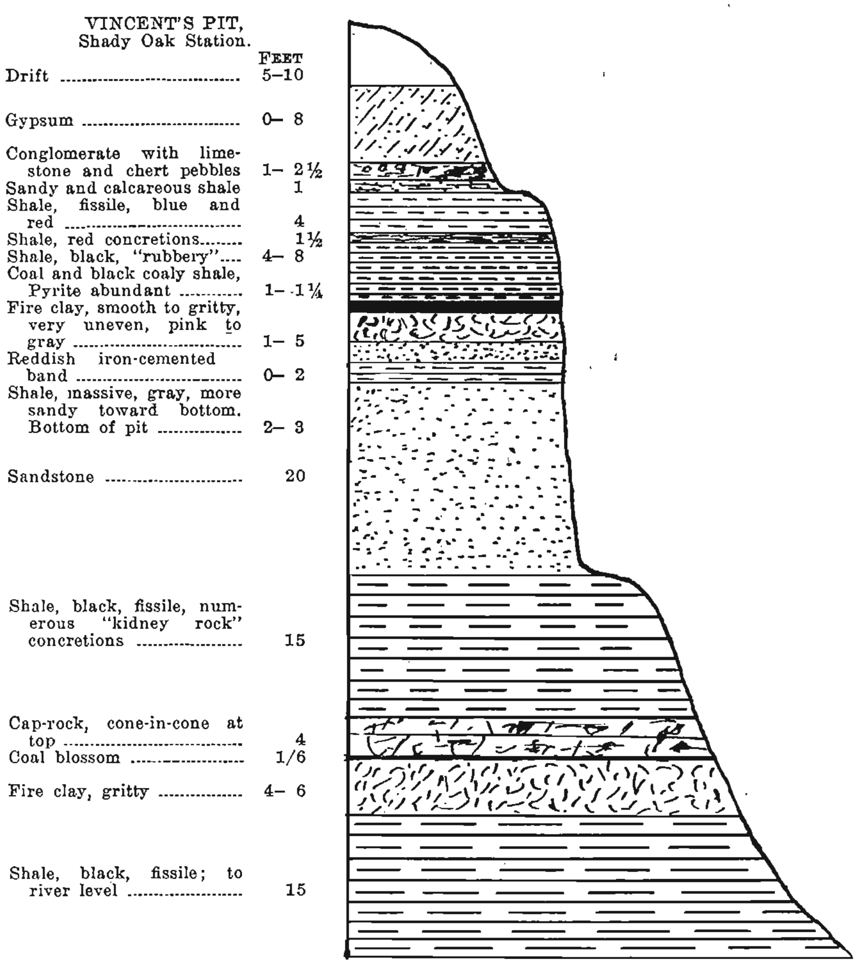

Fig. 6—Section at Shady Oak, Webster county.

Number 2 above was sampled by Professor J. E. Smith. Results of tests on this sample follow:

Fire clay, Kalo. (Schnurr Brothers).

	Drying	Cone 2	Cone 6	Cone 10
Total linear shrinkage, per cent	7.8	12.5	12.5	12.5
Absorption, per cent		6.8	3.4	4.2
Color		Buff	Brown, iron specks	Brown, iron specks
Hardness		Harder than steel		

Shales and clays are well exposed near Shady Oak in the Vincent Clay Pit and in natural outcrops. The accompanying sketch (fig. 6) represents the sedimentary beds of that vicinity. Tests on a sample of the lower fire clay (No. 2) resulted as follows:

Lower Fire clay, Shady Oak.

	Drying	Cone 2	Cone 6	Cone 10
Total linear shrinkage, per cent	7.8	7.8	9.4	9.4
Absorption, per cent		12.0	8.1	8.7
Color		Buff	Buff	Buff
Hardness		Harder than steel		

Another sample from the same horizon fused at cone 29-30, according to Mr. B. T. Sweely.

Only one clay sample from Hamilton county proved worth mention. This was obtained by Mr. Roddewig in the southwest quarter of section 16, township 87 north, range 26 west, in the west bank of Boone river, four feet above water level. The exposure shows:

	Feet	Inches
8. Drift	25–75	
7. Shale, coaly	3	
6. Limestone		10
5. Shale, coaly	2	
4. Fire clay	3	
3. Coal		10
2. Fire clay		15
1. Slump to water	2	

Both fire clays were sampled but that below the coal fused below cone 10. The upper clay fused at cone 12.

Refractory clays have been reported from near Eldora in Hardin county. Beecher[14] tested three such clays from the F. Berninghausen farm, on the west side of Iowa river, north of Eldora. All three samples fused above cone 20. Clay from a seven foot stratum burned buff at cone 11 without appreciable

14 Op. cit., p. 56 et seq.

warpage and fused at cone 23-24. Unfortunately these clays proved to be of very limited extent and were soon worked out. No deposit of workable size could be found in this region at the time of our visit (1918). It is quite probable that other lenses of clay equal to that tested by Beecher occur, but past experience would not encourage one to hope for extensive deposits.

Des Moines series shales are supposed to occur in southern Humboldt county, but nothing of interest related to the present work was found there.

The Cretaceous.

Rocks of Cretaceous age are thought to underlie most of the western third of Iowa, yet, because of a thick mantle of glacial drift or loess, there are but few outcrops. Those of interest are confined to three localities: the Sioux City district, the region about Auburn, Sac county, and the vicinity of Red Oak, Montgomery county.

So far as is known, the shales in all these districts belong to the Dakota and the Benton divisions. The Cretaceous shales of Iowa are, as a rule, more silicious and refractory than those of earlier age. They most closely resemble the shales of the Des Moines series. In many cases the resemblance is such that distinction is hardly possible upon appearances alone.

Montgomery county was not visited as the report on Iowa Clays[15] shows no refractory stratum as much as three feet in thickness.

In southeastern Sac, and the adjacent part of Calhoun county there are a few exposures of clay and shale. The only clay of refractory appearance was found on the south bank of Coon river three-eighths of a mile south from Grant City. The clay rises ten feet above stream level and is of the fire clay type. A sample of this clay was tested with results as follows:

Fire clay, Grant City, Sac county.

	Drying	Cone 2	Cone 6	Cone 10
Total linear shrinkage, per cent	9.4	10.9	12.5	12.5
Absorption, per cent		9.3	3.4	3.4
Color		Buff	Gray	Gray
Hardness		Harder than steel		

15 Beyer and Williams, Op. cit.

Little may be said of the extent of this deposit. The strata in the clay pit of the Auburn Brick & Tile Company a short distance to the east show nothing of this kind.

The best exposures of Cretaceous shales are found along the river at and near Sioux City. At Sergeant Bluff, seven miles south from Sioux City, excavation of clay for brick making has exposed a thick section of shale and sandstone. The following beds appeared in 1918 and probably are to be assigned to the Dakota division of the Cretaceous:

		FEET
7.	Loess	40
6.	Shale, soft, sandy, yellow	0 — 20
5.	Clay, white	5/12 to 2
4.	Sandstone	20
3.	Lignite	1½
2.	Shale, blue and gray	20
1.	Shale, gray to white, gritty, shown by test pits	50

Samples were taken (1) from material thrown out in digging test pit; (2), from a six foot layer near the base of No. 2 above; (3), from No. 5 above. Mechanical analysis of these samples shows that they contain little that will not pass a 200 mesh sieve except quartz grains. Results of working tests follow:

Clay from 50 foot gray-white shale below pit.

	Drying	Cone 2	Cone 6	Cone 10
Total linear shrinkage, per cent	7.8	9.4	12.5	.11
Absorption, per cent		7.8	3.5	.01
Color		White	Gray, iron specks	Gray, iron specks
Hardness		Harder than steel		

Clay slakes readily, works a little short.

Six foot stratum of gray massive shale.

	Drying	Cone 2	Cone 6	Cone 10
Total linear shrinkage, per cent	7.8	7.8	9.4	9.4
Absorption, per cent		11.3	8.4	8.5
Color		Buff	Buff	Buff
Hardness		Harder than steel		

Two foot stratum of white clay above sandstone.

	Drying	Cone 2	Cone 6	Cone 10
Total linear shrinkage, per cent	7.8	9.4	12.5	12.5
Absorption, per cent		8.5	.02	.01
Color		Buff	Gray	Gray
Hardness		Harder than steel		

It seems quite probable that the whole assemblage of clays here would fuse at better than cone 10. Beecher[16] tested two clays from Sergeant Bluff, one evidently from the six foot stratum reported above. His sample fused at cone 27, gave 6.2 per cent shrinkage at cone 10 and showed very slight warpage at cone 11. These clays should be excellent material for the manufacture of architectural terra cotta.

Pits of the Sioux City Brick and Tile Company at North Riv-

	Feet
Loess	10–20
Sandy yellow shales	12
Dove shale, smooth	12
Shale	10
Ocher sandstone	13
Sandstone	10
Sandy shale	2
Shaly sandstone	12
Shale	3
Lignite	½
Fire clay	6
Gray shale	¼
Lignite	½
Fire clay	3

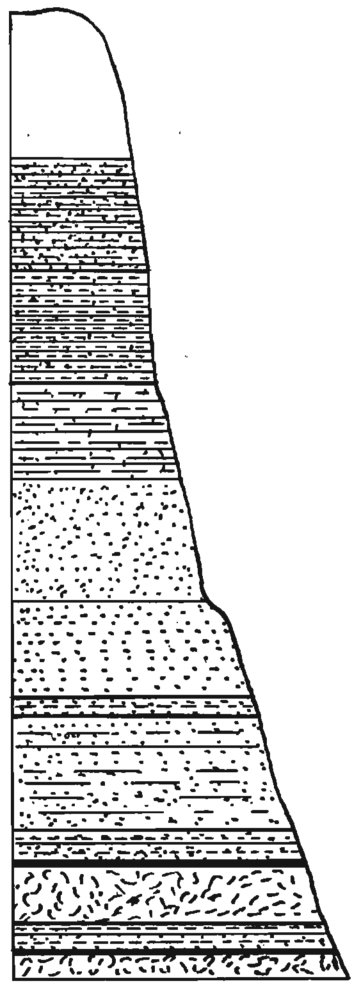

Fig. 7—Pit at North Riverside, Sioux City.

16 Op. cit., p. 60.

erside expose another thick shale series, but one quite different from that at Sergeant Bluff as may be seen from the accompanying section. (See fig. 7.) The North Riverside strata are presumed to represent a geologically younger series than those at the Bluff, that is the Graneros shale member of the Benton stage.

Fire clay of considerable purity has been reported from Crill's Mill, Plymouth County.[17] Very little could be found at this place at the time of our visit owing to mud left by a recent flood.

Conclusions.

Nothing so far discovered would indicate that Iowa possesses any strictly first grade refractory clays in commercial quantities. Its clays of the fire clay or underclay type seldom reach cone 25 in fusion. As a rule the more refractory of these clays are rather lacking in plasticity. Lack of uniformity in thickness and constitution is detrimental to their exploitation for particular uses.

Only a few deposits merit any special attention because of their commercial possibilities. These are such as the Jester and Denova clays in southeastern Iowa, the gritty underclays of Boone and Webster counties, and the white, gritty shales of Woodbury county. Apparently the white clays of Jackson and Clinton counties are the only ones which might be considered as possible refractory bond clays. Their known extent is too limited to warrant much investment in development.

Acknowledgments.

The writer wishes to acknowledge the assistance rendered by Mr. J. B. Fidlar and Prof. J. E. Smith in the field and by Mr. Lowell Hewitt and Mr. Ed Roddewig in conducting the clay tests.

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[17] Beyer and Williams, Op. cit.

THE FERTILIZER MATERIALS OF IOWA.

by

JOHN E. SMITH

CONTENTS

LIST OF ILLUSTRATIONS

FERTILIZERS

When one applies fertilizer to the land he is trying to supply one or more of three elements in a soluble form or to supply something that will change the elements already present but unavailable to the soluble form so that plants may use them or that they may act as reagents. These elements are nitrogen, phosphorus and potash. In recent years it has been found in some states (Oregon, e.g.) that sulfur when used as a fertilizer serves to improve the growth of alfalfa. Some of these and possibly other elements may aid vegetable growth in various other ways than by supplying plant food directly.

The materials considered in this work for the purpose of determining their value as fertilizers are peat, lake salts, gypsum, marl, pyrite, phosphates, limestone and dolomite. The fertilizer value in peat is found chiefly in its organic matter, nitrogen, phosphate and sulfur; that of gypsum, in its content of calcium sulphate and in its effects where it is used; that of marl, limestone and dolomite, in their calcium carbonate, magnesium carbonate and phosphate and in their chemical, physical and biological effects where they are used.

Potash

Several reports saying that certain Iowa lakes contained deposits of potash have been circulated. One of these emanated from the vicinity of Goose Lake in Greene county where samples were obtained for analysis at Iowa State College at Ames. The analytical tests which were made failed to show the presence of potash.

Since potash in lakes is found only in salt lakes and in arid and semiarid regions, it is useless to search for it in fresh water lakes in a state having the abundance of rainfall that is common here.

Gypsum

Many years ago most of the gypsum mined and quarried was used as a soil amendment but during the past decade only a small part, about three per cent of the output of the United States, has been so used. Recently it has been learned that one of the uses of gypsum when put on soil is to supply sulfur, which is now used on some crops, such as alfalfa, in some states. An exhaustive treatment of Iowa gypsum may be found in reference 63 recently issued by the Iowa Geological Survey. Iowa gypsum produces a high quality of "land plaster".

Pyrite

This name is used for two closely related sulfides of iron—pyrite and marcasite. Where it is pure and abundant, this mineral is used to some extent in the fertilizer industry. In Iowa it is most commonly found as a brassy-looking mineral in coal and is known as "sulfur" by many and also as "fool's gold".

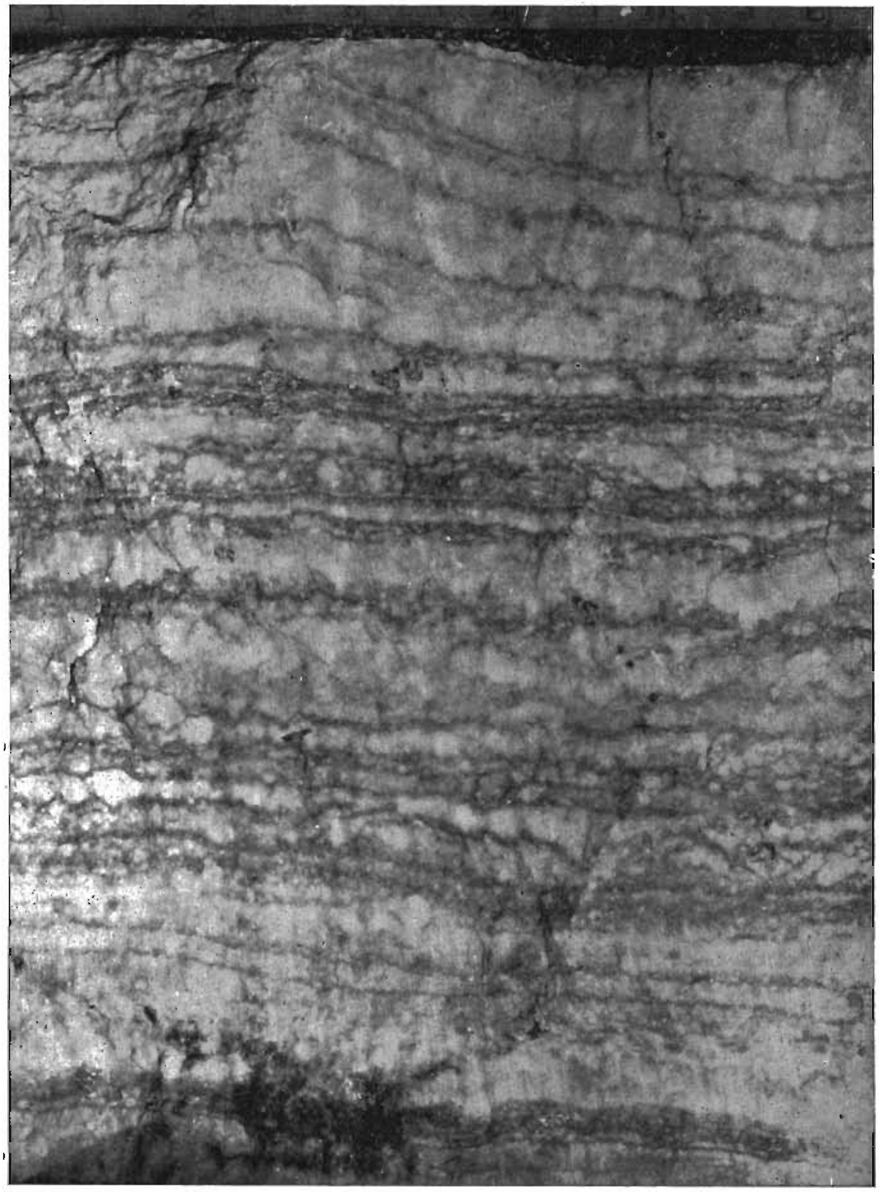
Investigations conducted during a long period of years in the department of mining engineering at Iowa State College show that it is impossible to separate the pyrite from the coal on a paying basis.

Peat

Methods of procedure.—Samples of peat were taken from representative locations in nearly every county in the area of the Wisconsin glacial drift. These were analyzed in the department of chemistry at Iowa State College. Tests having previously been made on Iowa peats for their fuel value, (ref. 15) it remained to test for possible value as fertilizer. The content of nitrogen and of phosphate was determined in each sample with the results as tabulated on page 102.

Though Iowa peat easily catches fire in the bog and burns slowly for weeks or even months it does not burn well enough to be used as a fuel where much heat is needed.

Uses of peat land.—Many of the areas covered with peat are lying as waste land, but some have been drained and are being used successfully as truck gardens which produce various kinds of vegetables for the market. Large areas in the northern counties of the state devoted to a single crop have been successful in growing excellent yields of potatoes and sugar beets of



FORT DODGE GYPSUM. VIEW SHOWING ITS BANDED STRUCTURE.

high quality. This suggests a possible use as an enrichment for other land.

USES OF PEAT.

As fertilizer.—In Europe peat is used chiefly for fuel but in America its principal importance is due to its value in the fertilizer industry. The manufacture of filler for chemical fertilizers requires the major part of the domestic product. Black, thoroughly decayed peat is considered better than the more fibrous brown types for this purpose. This use of peat is growing in favor.

Inoculated peat.—To increase its percentage of nitrogen, peat is now being inoculated with nitrifying bacteria. Inoculated peat is used for fertilizer in England, and in the United States commercial quantities have been manufactured and sold to a very small extent. Four per cent of nitrogen is reported in peat that was inoculated after repeated treatment with a dilute solution of ammonium sulphate.

Other uses.—Peat is also mixed with molasses and made into a stock food. About seven per cent of the peat produced in the United States is used in this way. Those varieties of peat which are fibrous are used as bedding for animals and for packing. The fine material sifted from moss litter by screening is known as "mull" and is used for deodorizing, disinfecting, filtering and also for packing. Some of the fibrous peats can be used in the manufacture of cloth and paper.

Analyses of peat.—The table below gives the locations from which samples of peat were procured for analysis and also the percentage composition of nitrogen, and of phosphate expressed as P_2O_5. Nearly all samples of peat contain small amounts, about one-half to one per cent, of sulfur. See the map (Pl. IV) opposite page 102.

Analyses of Iowa Peat.

County	Township	Lab. No.	Section	N. Per Cent	P_2O_5 Per Cent
Boone	Colfax	41	SE. ¼ of NW. ¼ of 34	2.37	0.78
Boone	Yell	44	NE. ¼ of SE. ¼ of 32	2.40	0.45
Calhoun	Sherman	46	SW. ¼ of 32	1.39	0.50
Emmet	Iowa Lake	68	NW. ¼ of NW. ¼ of 4	2.25	0.69
Greene	Bristol	45	SE. ¼ of SE. ¼ of 1	2.29	T
Hamilton	Lyon	21	SE. ¼ of NW. ¼ of 32	1.71	0.649 W
Hamilton	Lyon	22	SE. ¼ of NW. ¼ of 32	2.08	0.525 W
Hamilton	Rose Grove	63	SE. ¼ of 23	2.38	0.53
Hancock	Garfield	62	NW. ¼ of 30	2.43	0.48
Hardin	Concord	69	Line bet. 25 and 36	2.08	0.64
Story	Palestine	42	SW. ¼ of 22	1.34	0.78
Story	Franklin	43	SE. ¼ of NW. ¼ of 36	1.61	0.50
Webster	Dayton	47	NE. ¼ of SW. ¼ of 6	1.78	0.41
Winnebago	Center	65	NE. ¼ of 15	2.71	0.87
Winnebago	Center	66	NW. ¼ of SE. ¼ of 36	2.90	0.87
Winnebago	King	67	NW. ¼ of NE. ¼ of 26	1.50	0.81
Worth	Fertile	32		2.15	0.531 W
Worth	Fertile	33		2.16	0.486 W
Wright	Lake	61	NE. ¼ of NE. ¼ of 1	2.59	0.63
Wright	Blaine	64	NW. ¼ of NW. ¼ of 35	1.88	0.57

Analyses in the above table marked W were made by E. H. Wallace; those unmarked are by H. E. Flanders. These analysts are in the department of chemistry at Iowa State College.

DESCRIPTION BY COUNTIES.

The locations of peat bogs, their relative importance and their relation to the various morainic deposits (tentatively located) are shown on the accompanying map, Plate IV, which is based on incomplete field work. There has recently been a reassignment of names to some of these moraines. (Ref. 68.)

Boone County.—Boone county is in the middle of the southern extremity of the Gary moraine, which reaches its maximum development in the north-central part of the county. Here very little peat is found but in the western part of the county, where the moraine covers a wider tract, peat bogs have developed among the hills. In the southern half of the county, smaller but more numerous bogs are found scattered among the smaller recessional knobs and undulations.

Sample number 41 was collected from a ten acre bog of brown fibrous peat about three miles southwest of Napier. Though the bog does not exceed eighteen inches in depth, it is fairly typical of a number of small bogs in southeastern Boone, in northern

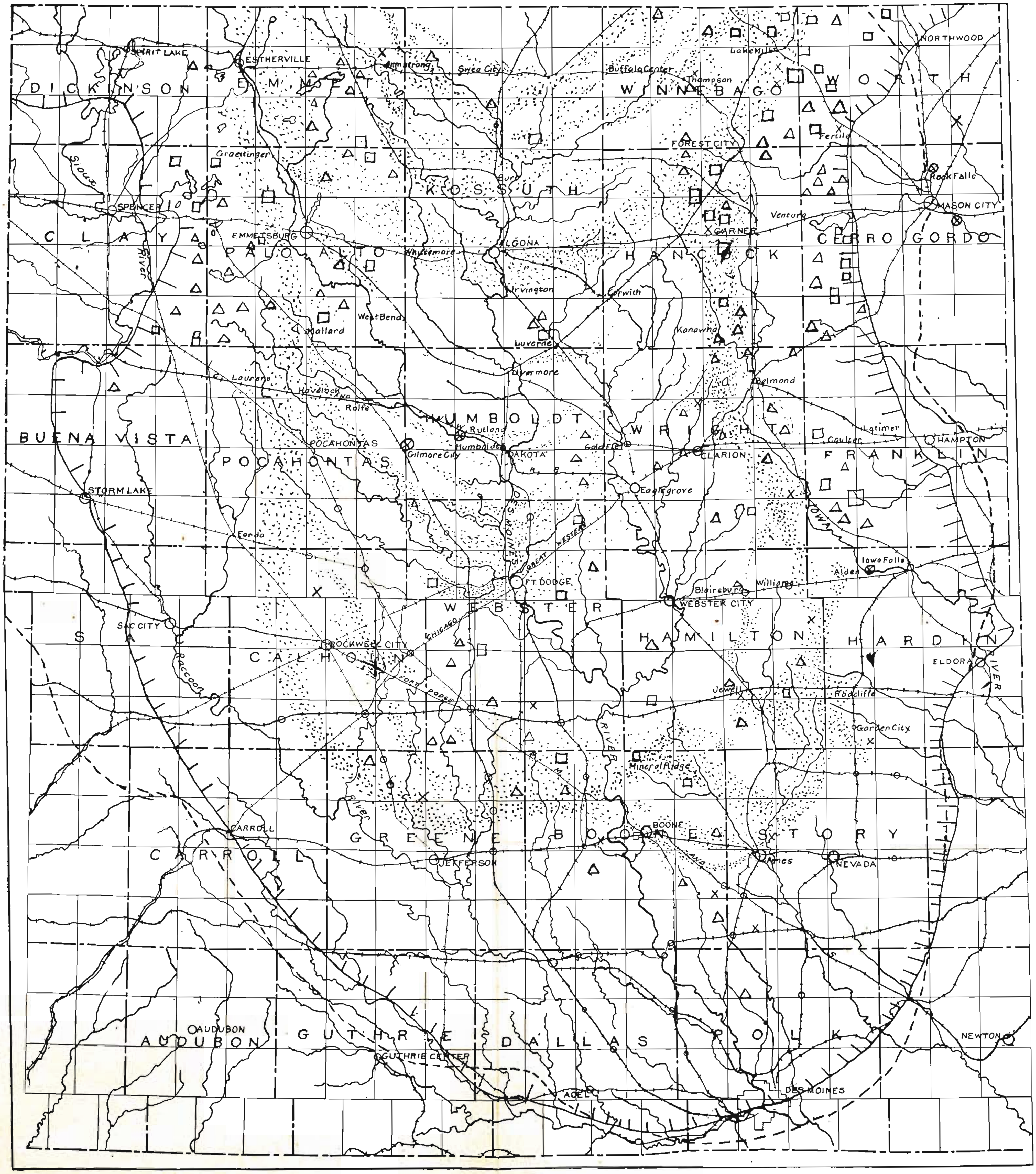


PLATE IV.—A PRELIMINARY MAP OF THE WISCONSIN GLACIATED AREA IN IOWA. LINE OF DASHES SHOWS BORDER AS DETERMINED BY THE IOWA SOIL SURVEY. THE RECESSIONAL MORAINES—THE GARY, HUMBOLDT AND ALGONA STAGES—ARE SHOWN IN DOTTED AREAS. OPEN SQUARES SHOW LOCATION OF IMPORTANT PEAT BOGS; TRIANGLES, LOCATION OF SMALLER BOGS OR GROUPS OF BOGS; X SHOWS LOCATIONS FROM WHICH SAMPLES WERE OBTAINED FOR ANALYSIS, EXCEPT NORTHEAST OF MASON CITY WHERE IT SHOWS TESTED OUTCROP OF LIMESTONE; X WITHIN CIRCLE SHOWS LOCALITIES PRODUCING AGRICULTURAL LIME. THERE HAS RECENTLY BEEN A REASSIGNMENT OF NAMES TO SOME OF THESE MORAINES (REF. 68).

Polk, and in adjacent parts of Dallas and Story counties. The triangles shown on the map represent a number of bogs in each locality.

Sample number 44 was selected from a drained bog, (fig. 8) near the Chicago and North Western railway about one mile east of the city limits of Ogden. The specimen consists of brown fibrous peat ranging from two to three feet in depth. Some of the plant ingredients of the rush type are remarkably well preserved. The bog lies between minor recessional deposits.

Calhoun County.—A bog located about half a mile west of the south end of North Twin Lake supplied the sample studied as

FIG. 8.—A drained peat-bog east of Ogden, Boone county. The peat is two to three feet thick.

number 46. The material is a very dark brown to black peat showing very little of the fibrous character. Some of it is well rotted. Several small bogs occur in this part of the county among the hills of the smaller moraines.

Cerro Gordo County.—The outer margin of the Wisconsin drift sheet extends nearly north and south and passes less than a mile east of the city of Clear Lake. From this margin westward there are several bogs in each township of the Wisconsin drift area, which includes all of the western tier of townships in the county.

Emmet County.—Very little peat is found in the western part of the county among the larger, higher morainic hills. The area from the river eastward lies wholly within the Algona recessional stages of the Wisconsin ice sheet and here a large number of bogs have formed. The sample analyzed, number 68, was taken from the large bog about three miles north of Armstrong in Iowa Lake township and about a quarter of a mile east of the school house. (See map, Plate IV, and table, page 102.) This bog covers approximately a thousand acres and has depths of three to nine feet with an average of about four feet. It lies between minor recessional ridges. This peat is fine in texture and is brown to nearly black.

Other important areas are found within two or three miles northwest and southeast of Gridley; about the same distances east and south of Halfa; about four miles southwest of Ringsted; a mile or more north and south of Swan Lake; and within two miles east of Mud Lake. Each triangle on the map represents several bogs. The chain of lakes drained by Jack creek seems to occupy a partly filled preglacial valley or other depression. The depressions containing the peat in this part of the county may trace their origin in part to the same cause but are due chiefly to unequal deposition of the glacial till.

Franklin County.—Most of the county west of a line drawn from Clear Lake to Ackley through Hampton is covered with Wisconsin glacial till and the bogs are all in this area. Several are located in Oakland township north and northeast of Burdette. These range in size from forty acres to two hundred acres and in depth from two to eleven feet. One of them extends along "Big Slough" from sections 35 and 36 in Morgan township through section 1 of Oakland and into section 6 of Lee township. Other bogs occur in Scott and Morgan townships as is shown on the map. The bogs of this county are very intimately associated with the best developed ridges of the moraines.

Greene County.—The Goose Lake area is the largest in the county. It lies just within the inner margin of the Gary moraine some eight miles northwest of Jefferson. Sample 45 was taken about 300 yards from the south end of the lake. Most of the peat is brown and fibrous, though some of it is nearly black and well decayed. It is about eighteen inches thick. Figure 9 gives a view of the lake before it was drained.

Hamilton County.—The largest area in the county, containing about 700 acres, is in the bed of the former Iowa Lake, four miles south and two miles east of Williams. It is nestled among the foothills and swells of the inner margin of the Gary moraine which is so prominent as a range of hills along the boundary between Hamilton and Hardin counties. Sample 63 was taken from the bog about 100 yards north of the highway which crosses

FIG. 9.—Goose lake, Greene county, showing some of the kinds of vegetation that enter into the composition of its peat.

its southern extremity. A depth of three feet was penetrated without reaching the bottom. The peat is dark brown, fibrous and lumpy.

A number of bogs aggregating nearly 1000 acres lie to the northwest and southwest of Jewell and within a radius of five miles of the city. The largest one of these is one and one-half miles west of Jewell and is known to extend to a depth of fifteen feet or more. Specimen 21 was dug near the northern margin of the bog but south of the North Western track and number 22 came from a spot farther out toward the center of the bog area. The higher phosphatic content of the former sample, as shown in the table, suggests that it may be from a guano by feathered inhabitants of the lake margin. The peat is brown, rather finely fibrous but not well rotted.

Each of the triangles shown near Jewell, Stratford and Stanhope on the map, Plate IV, indicates a group of several bogs. Some of the bogs in the county are found to be almost completely surrounded and underlain by a clay soil. Such an area in the ground moraine is located two and one-half miles southeast of Ellsworth and another may be found two miles northwest of Stanhope. Among the bogs on clay soil in the moraines may be mentioned that on the township line in section 4, Lyon township, five miles north of Jewell, and those in the central and northeastern part of section 23, Lincoln township.

Hancock County.—Between Britt and the margin of the Wisconsin glacial drift east of Clear Lake there are six or more well separated groups of recessional hills, ridges or ranges. The sample analyzed as number 62, a brown fine-grained, compacted peat, came from a bog about one mile west of Duncan and north of the paved highway, in a southward extension of the Eagle Lake depression. This lies between the first and second recessional ranges eastward from Britt, which are here about two miles from crest to crest. The large bog two miles south of Duncan is between the second and third of these ranges.

Hardin County.—Except in small areas chiefly in the western part, Hardin county is too well drained to afford conditions favorable for the accumulation of vegetable material and its preservation in the form of peat. The amount in the county is, therefore, not large. From a bog in sections 25 and 36 of Concord township, about three and one-half miles southeast of Garden City, sample number 69 was obtained. This is outside of the Gary moraine. The peat is black to dark brown, partly fibrous and partly decayed.

Polk County.—A number of small bogs are found in the upland area from Ankeny and Enterprise northward and northwestward past Polk City to the county line. In this area the retreat of the ice margin was sufficiently rapid and uniform to produce a somewhat irregular undulating surface whose small, low hills and broad swells are disposed in rather poorly defined recessional belts, which contain the bogs.

A large area of peat land, well drained, is located about two miles west of Herrold near the county line. It lies in a swampy area of the large, partly filled, interglacial valley of the old Moingona river and is extensively cultivated as a truck garden. Several smaller bogs are found along this old valley, some of them nearly as far south as the Fair Grounds where it joins the present valley of Des Moines river.

Story County.—Being situated well southward in the Wisconsin area, and chiefly outward from the Gary moraine, Story county has a relatively small area of peat land. The bogs of the county may be classified in three groups: those in the well defined moraines, which include most of the northern and eastern townships; those smaller bogs of the upland located as described for Polk county but continuing on to the north; and those of the valley bottom type.

Sample number 42 was collected one and one-half miles west of Huxley and represents the black, well decayed peat of the upland bogs. Sample number 43 is a valley bottom peat from a six foot bed about one-fourth of a mile up an unnamed tributary of Skunk river northeast of Ames. Each of the triangles placed on the map, Plate IV, signifies an aggregate of several small bogs.

Palo Alto County.—Peat is found in every township in Palo Alto county. Those containing bogs of large size or having several smaller ones that aggregate a large area are Independence, Nevada, Ellington, Booth, Lost Island, Emmetsburg and Walnut. More than 90 per cent of the peat land of the county lies within areas of distinctly morainic topography. Where moraines are in well defined ridges or ranges of hills, the bogs are located in depressions between them but where the moraines consist of a belt of hills and undrained depressions, the bogs are found to be irregularly distributed throughout the belt.

Webster County.—Here are afforded excellent examples of peat areas developed on the generally flat ground moraine. Nearly all of the bogs in the southwestern part of Webster county are of this type and are located wholly within an area of clay. The largest one, which covers about 1000 acres, is about four miles northeast of Harcourt and from here sample number

47 was obtained. It represents a black, fine, fairly well decayed peat which has a maximum thickness of three feet although much of it is not more than two feet thick. A characteristic feature of most of the bogs of the county is that they are shallow because of having been formed on a relatively flat surface. Each of the triangles shown on the map represents an aggregate of small areas.

Winnebago County.—Nearly all of the peat of Winnebago county lies in its eastern half, which is a region of distinctly

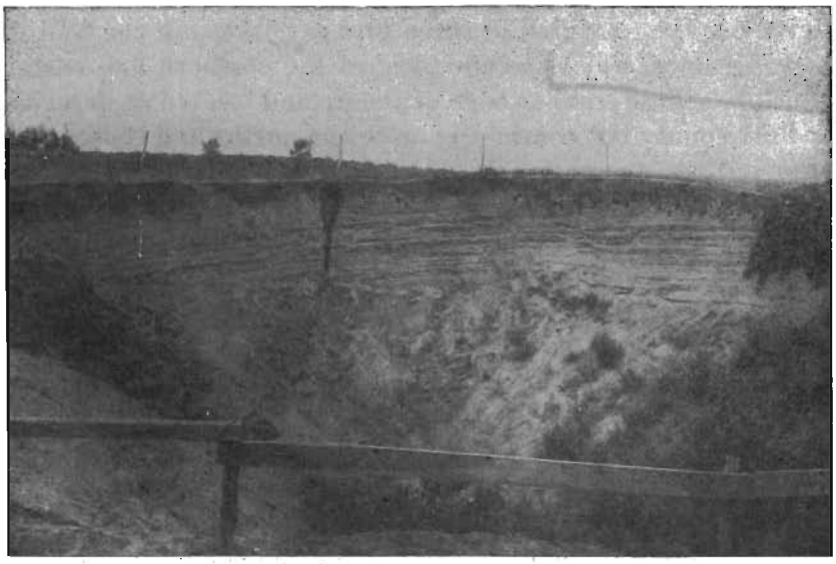


FIG. 10.—A gravel pit in a kame in the Algona moraine, Winnebago county.

morainic topography (see fig. 10), and most of the peat land is east of Lime creek. The Rice Lake, Turtle Lake and Bear Lake bogs are by far the largest and most important areas. One mile south of Lake Mills a brown fibrous sample, number 65, was dug; number 66, also brown and fibrous, was obtained four miles south of Lake Mills from the drained bed of Turtle Lake; and number 67, a good, dark brown to black peat, came from the bog half a mile east of Thompson. While these bogs attain maximum thicknesses of fifteen to thirty feet, each of the samples was made as a composite from the upper four feet of their respective sections.

Other important areas of peat are found north of the city of Lake Mills and also in the southeastern township of the county.

Worth County.—The Wisconsin till covers that part of Worth county lying west and north of a line passing approximately through Northwood, Hanlontown and Fertile. The bogs in the central and southern parts of this area are among the largest and best known in Iowa. Analyses 32 and 33 were made from brown but not well rotted material collected from two spots half a mile apart along the highway in the large bog northwest of

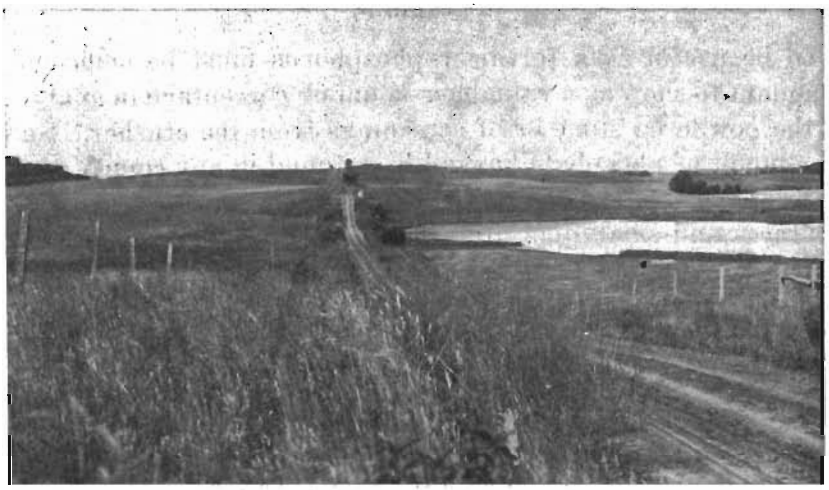


FIG. 11.—The Gary moraine near where the Humboldt moraines branch from it toward the southwest. Morse lake, four miles west of Belmond, Wright county.

the town of Fertile. This bog is situated just within the inner margin of the belt of hills forming the terminal moraine in this vicinity.

Wright County.—The peat land is found mostly in the eastern half of Wright county in and near the well defined morainic topography. The large bog one mile east of Wall lake is located in a depression between broad swells which mark stages in the recession of the margin of the glacial ice. Several bogs in the west-central and north-central parts of the county are in shallow basins in poorly defined recessional features and some of them are wholly within areas of clay soil.

Sample 64, a dark brown to black compacted peat, was obtained from the large bog three miles west of Dows. This bog is located entirely among the rolling hills of the Gary moraine. Sample number 61 came from the bog six miles due north of Clarion, and is a fine brown nonfibrous peat. This bog is in a westward extension of the Gary moraine where it branches to form an alignment with the outer swells and low, flat hillocks of the Humboldt stages of the Wisconsin recession. (See fig. 11.) Each of the triangles on the map represents several small areas of peat.

Phosphate

To be useful as a fertilizer phosphorus must be sufficiently abundant to show as a valuable amount or percentage in analyses of the powdered stone or of screenings from the crusher. Such an amount of phosphate has not been found in any county in the state.

Traces and small quantities, however, were detected in many

FIG. 12.—The limestone quarry at Decorah in which small quantities of phosphate were found.

places. Most commonly phosphate occurs along the cracks (joint planes and bedding planes) in the rocks in which it has been found. Evidently it has been carried to these cracks by percolating water from rock at a higher elevation. Near Decorah, Peru and Keokuk phosphate was found to be present in limited quantities along joint planes, bedding planes and also in a few thin beds of limestone as is shown in the respective sections for these localities. (See fig. 12.)

Phosphate was found in limestone and dolomite as follows:

Ordovician (Galena)	— at Decorah
Devonian (Wapsipinicon)	— at Independence
Devonian (Cedar Valley)	— at Glory, Black Hawk county
Devonian (Cedar Valley)	— at Waverly
Mississippian (Osage)	— at Keokuk
Pennsylvanian (Des Moines)	— at Laddsdale, Wapello county
Pennsylvanian (Missouri)	— at Earlham and Peru.

In many quarries which were tested no trace of phosphorus was found.

Limestone and Dolomite

Methods of sampling.—Composite samples of limestone and dolomite were obtained for analysis from the respective quarries and outcrops by taking fragments from each bed or layer of fresh rock at equal vertical distances, commonly a few inches, throughout the height of the face.

Field tests.—Many tests were made with reagents in quarries from which no samples were taken for laboratory study. The reagents which were used in all quarries and on all outcrops tested were kept constantly on hand during the progress of the work and consisted of hydrochloric acid (about 8 per cent), concentrated nitric acid, and crystals of ammonium molybdate.

Limestone and dolomite.—Limestone is composed of calcium carbonate, $CaCO_3$, when pure, and dolomite contains both calcium carbonate and magnesium carbonate. In these tests the distinction between the two was made with dilute hydrochloric acid, about 8 per cent. The limestone effervesces or "bubbles" freely when a few drops of the acid are applied to a surface of fresh rock but the dolomite does not effervesce when so tested. Both limestone and dolomite are soft and will not scratch the blade of a pocket knife but will be easily scratched by it. Sandstone, on the other hand, is composed of sand grains which scratch a knife blade easily.

Test for phosphate.—In the test for phosphates, a powdered crystal of ammonium molybdate was placed on a surface of the unweathered rock to be tested and a few drops of nitric acid were applied with a pipette to the powder. A yellow color appears in the powder if phosphate is present. If the color indicated more than a trace of phosphorus, a specimen was taken for use in making a percentage analysis in the laboratory.

Purity of rock.—Both limestone and dolomite when ground, crushed or pulverized are used in neutralizing the acid condition of the soil but the impurities do not aid in this work. Either is useful alone or a mixture of the two may be used after thorough grinding. The percentage of purity of a sample is found from its analysis given in the table by adding the percentage of calcium carbonate to that of the magnesium carbonate. In other words the purity of the rock considered as fertilizer is the total percentage of carbonates it contains. A rock having 70 to 80 per cent of carbonate can be successfully used but a smaller amount of rock will be necessary if it has a purity of 80 per cent or higher. The expense of freight and handling also decreases with the increase in purity of the rock.

Impurities.—While the amount of impurities present is commonly 5 to 10 per cent, it may run higher or lower in some tests. In most of the samples tested the impurity is largely silica, which is the chief substance in sand and in glass. The impurities also contain very small quantities of iron, aluminum and clay.

Chert.—Chert is composed of silica and is only an impure form of quartz. In nearly all of the larger groups of limestone beds in the state it occurs either as broad, flat, nodular lenses in the bedding planes between the layers of the rock or as lenses within the layers. Where chert is found between the layers of limestone, it may be thrown aside to prevent its passing through the crusher but where it is within the layers, this can not be done. It is very hard and breaks with shelly surfaces, forming sharp edges. It is worthless as fertilizer material and is an abomination in the process of crushing the limestone, which is not more than half as hard as the chert. (See fig. 18.)

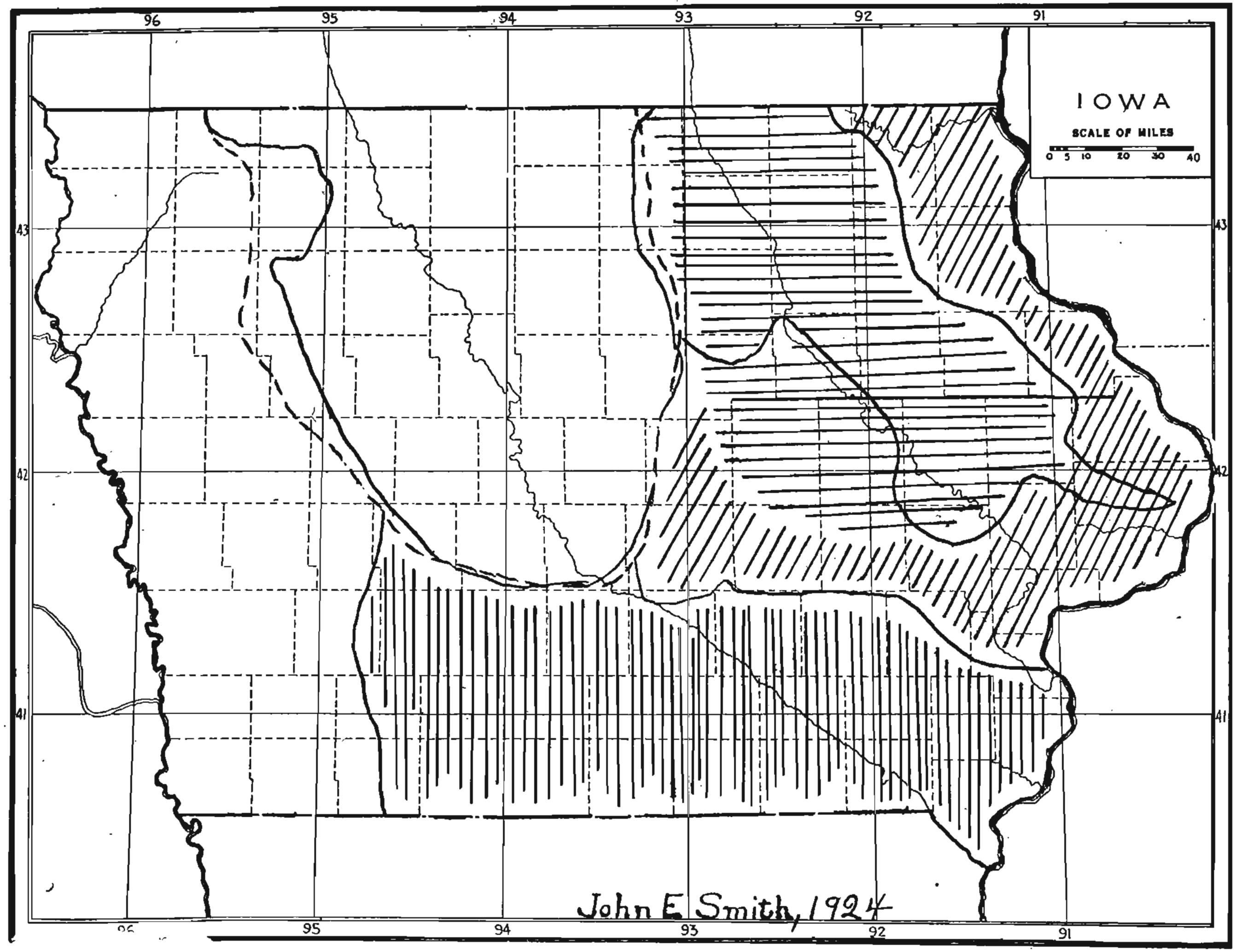
Chalk.—Chalk is a form or variety of limestone whose value as a fertilizer is, like that of other forms, determined by its location, abundance and purity. In some places it is soft and loose, in others it is harder and more firmly cemented. Chalk consists chiefly of the skeletal remains of very small forms of animal life. It is found in Iowa along the bluffs near Sioux City and northwestward where it occurs in layers ranging from a few inches to a few feet in thickness. Iowa chalk and its associated limestone are suitable for use wherever they are exposed in sufficient quantity to warrant the expense of installing a crushing plant.

USES OF AGRICULTURAL LIME.

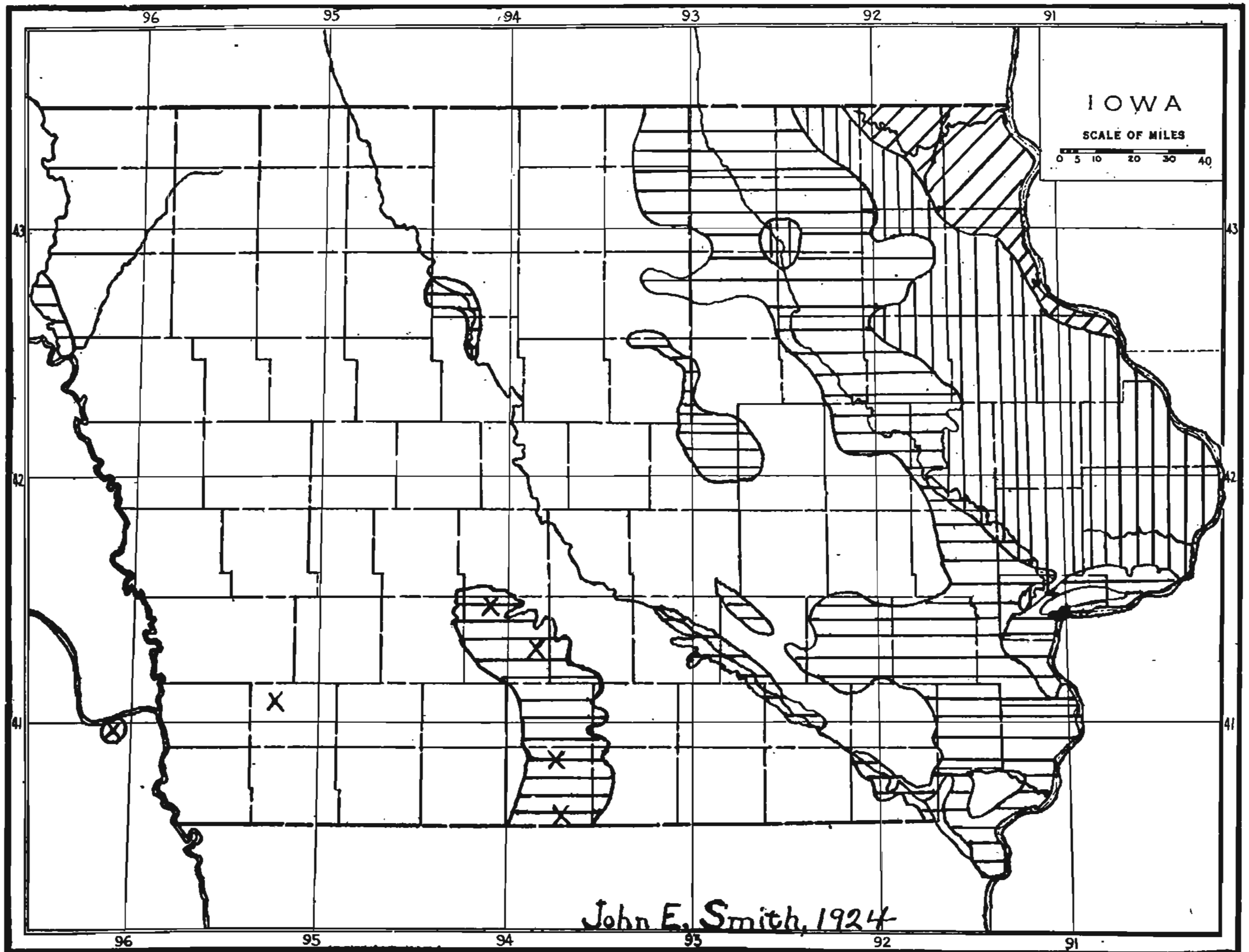
Lime is used in making cement, concrete, plaster, sheep dip, insecticides and sprays, also as a disinfectant in barns, chicken houses and elsewhere, in water purification and softening and in sewage purification. Limestone applied to soils corrects acidity, supplies available calcium for the use of plants, increases the effect of fertilizers and manures on soils, makes all plant food more available by aiding bacterial growth, assists in the control of certain plant diseases and insect pests, and as time goes on it improves the tilth of heavy soils and makes it possible to grow clover and alfalfa where none would grow without it.

About 10 to 15 per cent of the total output of lime in the United States is used as a soil amendment to neutralize "sour" or acid soil. For this purpose it is applied in two forms: first, as burned lime, also called quick lime before it is slaked and hydrated lime after slaking; and second, as raw, ground or pulverized limestone.

The hydrated or slaked lime is all very finely pulverized or powdered and its power to counteract the acid condition of the soil is largely exhausted during the first year after it is applied. The ground limestone on the other hand contains particles of many sizes, commonly less than three-eighths of an inch in diameter, and half of it or more should be ground to a fine powder. The finer particles are dissolved and used the first year



Map of Iowa showing approximate areas of relative need of lime on soils. The greatest need of lime is in the area shaded by horizontal lines; much lime is needed in the area shown by vertical lines; a smaller amount, in the area shown by diagonal lines, and some lime is needed in the unshaded areas. From many tests which have been made it is estimated that about 90 per cent of Iowa soils is in need of lime. A comparison of this map with Plate VI shows Iowa's limestone is where the lime is most needed.



Map to show by shading areas containing limestone and dolomite suitable for use as a fertilizer: horizontal lines show areas of limestone; vertical lines, areas of dolomite; diagonal lines, areas containing both limestone and dolomite. A thin layer of chalk is found in the area near Sioux City. X indicates limestone—if within circle, production of agricultural lime.

and some of the coarser remain in the soil to be dissolved and used later.

Lime from dolomite.—Some authorites consider that lime burned from dolomite is too caustic for repeated use on the same land. But no objection or very little is made to the use of raw, ground dolomite.

Need of agricultural lime in Iowa.—Hundreds of tests made by the Department of Soils, Iowa State College, show that nearly 90 per cent of the soils of the state need lime and that some parts of the state are much more in need of it than others. See Plates V and VI, pages 114 and 115. One part or another of nearly every county in the state needs lime on its soil.

The excellent and favorable location of Iowa limestone with respect to the areas in which crushed limestone is needed as a soil amendment is readily seen by comparing the shaded areas of Plate V with those of Plate VI. It will be observed that the area of Iowan glacial till, shown on Plate V by horizontal shading, is in greater need of the use of lime on its soils than most other parts of the state.

MARL.

This is most commonly a mixture of lime and clay very poorly cemented. The lime generally has its sources in shells, many fragments of which are irregularly distributed through the mass, which is commonly loose enough to be shoveled. To be useful as a fertilizer marl should contain 50 to 80 per cent of lime. Most Iowa marls are not sufficiently rich or abundant to be worth considering as fertilizer material where so much excellent limestone is available for crushing.

A shell marl that could be used locally for fertilizer is found in numerous places in Floyd and Cerro Gordo counties. These outcrops "can be traced with little interruption from the exposures west of the fair grounds in Cerro Gordo county to those several miles south of Rockford in Floyd county" (ref. 17, pp. 326-329). "The most important section exposed in the county (Cerro Gordo) may be viewed in section 35 in Portland township, facing a convex bend in Lime Creek and continuing a distance of about a mile." This place is known as the "Clay

Banks". Three analyses of samples from here show that the marl contains 57.07 per cent, 57.42 per cent and 86.61 per cent of total carbonates respectively, though a sample taken just west of the Fair Grounds near Mason City runs as low as 36.78 per cent total carbonates. A hard, solid layer within the marl gave the test of 86.61 per cent mentioned above.

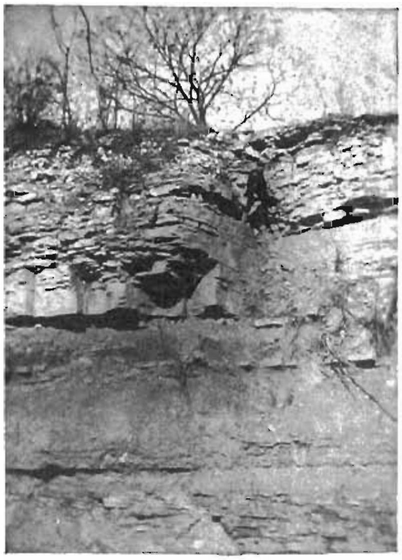


FIG. 13.—A view showing thin-bedded limestone above and thick-bedded limestone below.

The marl attains a thickness of twelve to twenty feet or possibly more and may be found also on the west side of Lime creek near Rockford just above the layers of clay that are used in brick and tile making. Numerous road cuts in both counties expose the marls near the hilltops west of Lime creek.

This layer of marl contains many of the most perfect fossils of shelled animals, one inch in diameter and smaller, that can be found in the state. Some benefit would result from the use of the marl without grinding but the shells in it are too coarse and should be crushed so that all of the lime in it may be available for it contains only a little more than half as much lime as is found in pure limestone. See also reference 67.

Analyses of Limestone in Northeastern Iowa

Township	Section	Height of rock face, feet	Length of quarry face, feet	Depth of stripping, feet	Quality of material	Railroad	Highway	Impurities, per cent	Calcium carbonate, $CaCO_3$, per cent	Magnesium carbonate, $MgCO_3$, per cent
				Allamakee County						
Center	NE. ¼ 6	6	50	2 – 4	Good	8½ mi	Yes	11.60	60.55	27.85
Jefferson	NE. ¼ 23	6	100	2	Good	1½ mi	Near	5.11	93.33	1.56
Makee	NE. ¼ 31	12	100	1½ – 2	Good	Yes	Yes	12.31	84.52	3.17
Ludlow	SE. ¼ 34	12	400	1½ – 2	Good	7 mi	Yes	7.57	91.71	.72
Makee	NE. ¼ 30	10	150	3 – 6	Good	1 mi	Yes	8.29	90.51	1.20
Post	SW. ¼ 16	12	400	1½ – 2	Good	3½ mi	Yes	10.10	87.43	2.47
				Bremer County						
LaFayette	SE. ¼ 35	20	400	10 – 15	Good	¾ mi	Yes	5.88	80.56	13.56
LaFayette	SE. ¼ 35				Good	¾ mi		10.28	80.33	9.39
				Buchanan County						
Perry	SE. ¼ 32	15	200	3½	Good	40 rd	Yes	4.45	91.80	3.75
Washington	SW. ¼ 35	15	300	1½ – 2½	Good	40 rd	Yes	6.64	91.95	1.41
				Butler County						
Pittsford	NE. ¼ 23	10	400	2	Good	Yes	No	3.89	70.79	25.32
Shell Rock	SE. ¼ 11	8	75	2	Good	25 rd	Yes		96.11	
				Chickasaw County						
Bradford	SE. ¼ 20	10	200	½	Good	½ mi	Yes	3.28	69.26	27.47
				Clayton County						
Boardman	NE. ¼ 23	16	150	2	Good	½ mi	Yes	5.55	88.42	6.03
Farmersburg	S. ½ 18	6	150	1 – 3	Good	Yes	Yes	3.22	66.36	30.42
Garnavillo	NW. ¼ 20	10	200	1 – 3	Good	7 mi	20rd	8.43	54.61	36.96
Cox Creek	NW. ¼ 9	15	200	3 – 5	Good	20 rd	Yes	3.16	63.75	33.09
Giard	SE. ¼ 21	12	100	2	Good	Yes	20rd	5.03	54.88	40.09
Boardman	SW. ¼ 23	10	200	1 – 5	Good	Across river	Yes	17.49	78.50	4.01
Wagner	NW. ¼ 25	10	100	1 – 3	Good	40 rd	Yes	7.14	68.36	24.50
				Fayette County						
Westfield	SE. ¼ 28	50	300	3 – 4	Good	Yes	Yes	4.92	89.99	5.09
Clermont	NE. ¼ 24	12	500	1 – 4	Good	3 mi	Yes	9.27	56.49	34.25
Clermont	NE. ¼ 34	15	100	1 – 3	Good	20 rd	Yes	14.60	67.72	19.68
Union	NE. ¼ 22	15	60	1 – 3	Good	Yes	40rd	4.28	85.81	9.91
Union	NW. ¼ 17	12	150	1½	Good	40 rd	Yes	2.85	88.02	9.13
				Floyd County						
Rudd	NW. ¼ 35	10	200	1 – 2	Good	3 mi	80rd	4.33	85.66	10.01
Floyd	SE. ¼ 16	20	200	2	Good	½ mi	Yes	13.00	68.82	18.18
Floyd	SE. ¼ 16	Screenings						9.26	70.22	20.52
Riverton	NW. ¼ 12	10	300	2	Good	2 mi	Yes	3.25	59.21	37.54
Rock Grove	NW. ¼ 17	15	600	2 – 6	Good	80 rd	80rd	5.05	85.26	9.69
Union	NW. ¼ 8	15	150	1 – 6	Good	80 rd	80rd	3.33	88.33	8.34

Township	Section	Height of rock face, feet	Length of quarry face, feet	Depth of stripping, feet	Quality of material	Railroad	Highway	Impurities, per cent	Calcium carbonate, $CaCO_3$, per cent	Magnesium carbonate, $MgCO_3$, per cent
					Howard County					
Vernon Springs	SW. ¼ 22	10	300	2	Good	40 rd	Yes	14.98	52.38	22.64
Forest City	NW.¼ 21	6	80	2	Good	1½ mi	Yes	11.43	85.31	3.26
Vernon Springs	SW. ¼ 22					40 rd	Yes	10.83	63.94	25.23
New Oregon	NW.¼ 3	12	100	2 – 3	Good	3 mi	Yes	9.00	65.72	25.28
Chester	SE. ¼ 24	10	150	2 – 3	Fair	1 mi	Yes	19.10	48.62	32.28
					Mitchell County					
Osage	SW. ¼ 26	8	200	2 – 3	Good	1 mi	Yes	1.56	96.47	1.97
Osage	SE. ¼ 27	25	600	6 –20	Good	1½ mi	Yes	2.82	90.84	6.34
Newberg	NE. ¼ 22	35	800	4 – 6	Good	1½ mi	40rd	4.58	67.84	27.58
					Winneshiek County					
Calmar	E. ½ 20	6	150	2 – 3		2½ mi	Yes	36.64	62.16	1.20
Fremont	SE. ¼ 28	15	125	1	Good	8 mi	Yes	4.54	92.90	2.56
Washington	SW. ¼ 28	20	200	2	Good	4 mi	Yes	11.28	63.63	25.09
Decorah	S.W. ¼ 21	12	100	2	Good	40 rd	20rd	11.48	84.80	3.72
Highland	NW.¼ 8	4	300	1	Good	4 mi	10rd	10.40	88.14	1.46
Bluffton	NW.¼ 11	100	1000	3	Good	12 mi	Yes	8.19	86.90	5.91
Sumner	SE. ¼ 18	10	100	2 – 3	Good	8 mi	Yes	10.39	85.36	4.25
Washington	Center 7	30	150	0	Fair	¼ mi	Yes	21.15	54.73	24.12
Madison	SW. ¼ 23	roadside cut			Good	3 mi	Yes	39.30	61.91	22.61
Pleasant	SW. ¼ 26	40	1000	0	Good	11 mi	Yes	8.68	58.45	32.87
Decorah	NE. ¼ 5	10	200	2½	Good	4 mi	Yes	7.10	90.99	1.91
Hesper	NW.¼ 14	7	60	2	Good	5 mi	Yes	7.25	89.62	3.13
Decorah	SE. ¼ 9	20	300	1	Good	1 mi	Yes	8.06	88.37	3.57
Highland	SE. ¼ 23	30	1000	6	Fair	11 mi	Yes	16.56	46.07	36.37
Bluffton	Center 17	12	120	1	Good	8 mi	Yes	14.80	66.46	18.74
Jackson	E. ½ 1	8	100	2 – 3	Good	2 mi	Yes	3.80	56.81	39.39
Frankville	N. ½ 23	12	200	2	Fair	7 mi		22.52	67.32	10.16
Frankville	N. ½ 10	20	150	3		10 mi		8.06	89.66	2.28

The total carbonates in any analysis in these tables are found by adding the calcium carbonates and the magnesium carbonates. This sum will give the percentage of purity of the rock as a fertilizer material.

All analyses given in the tables on pages 118, 126, 128, 138 and 142 were made by Horace J. Harper as were the analyses of screenings and stone dust from localities referred to in these tables.[1]

It will be noticed that the screenings and ground limestone are lower in percentage of total carbonate than the analyses from the face rock. This is due partly to the admixture of dirt during

[1] These data are used by permission of Dr. W. H. Stevenson and Dr. P. E. Brown, heads of the Department of Soils, Iowa State College, and of Professor Harper of the same department.

the process of crushing and handling but chiefly to the fact that the composite specimens and samples were all chipped from the solid rock while the material put through the crusher includes very thin layers of clay which are present in nearly all quarries along the cracks in the rocks—namely the joints and the bedding planes.

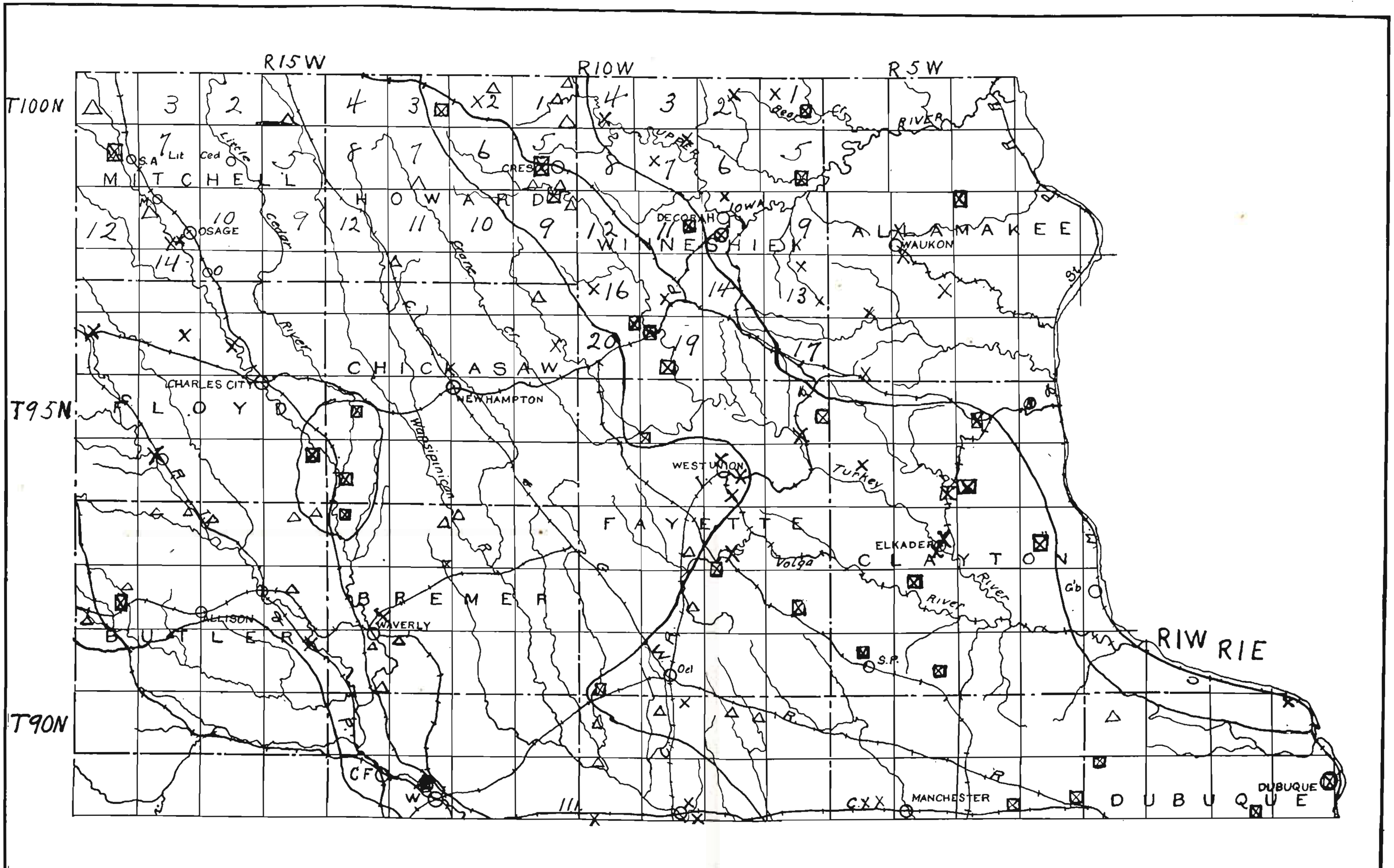
NORTHEASTERN COUNTIES.

The locations of many of the important outcrops and quarries in the great limestone region of eastern Iowa are shown on the maps of Plates VII, VIII and IX. These maps near pages 120, 130 and 140 respectively give details of the areas mapped on Plate VI including locations of the several details within their respective townships.

Allamakee County.—The analyses given in the table, page 118, show only one specimen of dolomite from Allamakee county, that from Center township, township 98 north, range 4 west, and this sample contains a total of 88.4 per cent of carbonates. It is therefore, a good grade for use as fertilizer. The analyses give 11.6 per cent of impurity in a sample from Post township in the southwestern corner of the county and 87.69 per cent of carbonates for the specimen from Makee township, number 98 north, range 5 west.

Jefferson is township 97 north, range 5 west and Ludlow is 97 north, range 6 west. In these and in Makee township, section 30, the total carbonates range between 91 and 95 per cent.

Bremer County.—The outcrops of limestone in Bremer county are practically all in the western end of the county and consist of limestone and magnesian limestone. In the southeast quarter of the southwest quarter of section 20 in township 91 north, range 13 west, in a ravine tributary to Quarter Section Run, is found limestone containing 96.57 per cent of calcium carbonate and 1.80 per cent of magnesium carbonate (ref. 44, p. 351). In section 8 of Polk township, three miles north of Plainfield, dolomite of the following composition is found: residue, 5.40 per cent; calcium carbonate, 55.23 per cent; magnesium carbonate, 39.03 per cent; total carbonates, 94.36 per cent (ref. 44, p. 358). Some analyses from Waverly (Devonian) (ref. 66, p. 531) show the following composition: insoluble, 2.25 and 7.74 per cent;



MAP OF NORTHEASTERN IOWA. X SHOWS LOCATION OF QUARRY OR OUTCROP OF LIMESTONE; X WITHIN A SQUARE, QUARRY OR OUTCROP OF DOLOMITE. A CIRCLE AROUND EITHER INDICATES PRODUCTION OF AGRICULTURAL LIME. OTHER QUARRIES AND OUTCROPS ARE INDICATED BY TRIANGLES. SOLID LINES INDICATE APPROXIMATE BOUNDARIES OF AREAS SHOWN IN PLATE VI.

iron and alumina, 1.32 and 1.67 per cent; calcium carbonate, 88.65 and 86.80 per cent; magnesium carbonate, 6.70 and 2.35 per cent. Tests for phosphate from the John Carey quarry in the south half of section 11, Washington township, give 1.74 per cent of P_2O_5. (Analysis by H. E. Flanders.)

Screenings from the ground material whose analysis is given in the table on page 26 tested as follows: impurities, 10.28 per cent; calcium carbonate, 80.33 per cent; magnesium carbonate, 9.39 per cent; total carbonate, 89.72 per cent.

Buchanan County.—North and east of a line drawn through Fairbank, Bryantburg and Winthrop and passing southeastward just west of Buffalo creek, the rock of Buchanan county is chiefly dolomite. A notable exception to this dolomite is found in the southwest quarter of the southeast quarter of section 2, Hazelton township, township 90 north, range 9 west, at the old lime kiln, where the rock is a good grade of limestone. The beds of limestone in the remaining western and southwestern parts of the county consist of rock containing about 90 per cent or more of calcium carbonate. (See ref. 23.)

The analysis given in table, page 118, for Washington township was made from a sample taken from the old city quarry at Independence. The results of field work seemed to show that this quarry had a uniform distribution of phosphate so tests for P were made and these yielded the following percentages of phosphate: 0.74, 0.78 and 0.74 respectively. (Analyses by H. E. Flanders.)

Butler County.—The bed rock in the eastern part of Butler county is nearly all a good grade of limestone. One sample which was analyzed was taken from a quarry about one and one-half miles west of Bristow in Pittsford township, which is township 92 north, range 18 west. This sample is strongly dolomitic. The outcrops around Dumont, however (see ref. 2), consist of a good grade of limestone. The analyzed sample from Shell Rock was procured in the northeast part of the city. For composition see table, page 118. The total carbonates in each of these samples exceed 96 per cent.

Chickasaw County.—More than half of the townships of Chickasaw county have no outcrops of bed rock. In the eastern part there are a few rather poor exposures of limestone along Crane creek and Turkey river. (See map, page 120.) In the western one-fourth of the county dolomite and highly magnesian limestone are found along Cedar river and one mile south of Nashua. These outcrops represent an abundance of rock which showed the following percentage composition: $CaCO_3$, 69.26; $MgCO_3$, 27.47; impurities, 3.28; total carbonates, 96.76.

The other specimen was collected from the outcrop along the railroad near the cemetery two miles south of Nashua. Here the test shows: 7.19 per cent of impurities, mostly silica; $CaCO_3$, 75.35 per cent; $MgCO_3$, 16.95 per cent; P_2O_5, 0.16 per cent; total carbonates, 91.80 per cent. (Analysis by E. H. Wallace.)

Clayton County.—Most of the outcrops south of Volga and the Turkey rivers, especially those high on the bluffs, are ledges of dolomite whose thickness aggregates 100 to 200 feet and which extend westward into Fayette and southward into Delaware and Buchanan counties. In the eastern and northern parts of the county the beds of limestone, shale and dolomite alternate much the same as is shown in the following section:

Section at Guttenberg
(Trenton-Galena)

		Feet
1.	Limestone, dolomitic, in heavy ledges, vesicular, coarse and buff-colored	100
2.	Limestone, magnesian, in beds two inches to a foot thick, fine-grained, compact and gray to coarse, rough and buff, some chert bands and nodules, partly changed to dolomite containing 16 per cent magnesium carbonate. Supplied limestone to the old kilns at the base of bluff	60
3.	Limestone, nonmagnesian, fine-grained, compact, gray, in thin uneven beds, lower part covered on slope	85
4.	Limestone, dolomitic, blue weathering to buff, beds eight inches to two feet thick. Exposed in the quarries	15
5.	Sandstone (St. Peter), covered, to water level in river	10

Farther northwest and north, limestone about ninety feet thick underlies this sandstone, and forms a considerable part of the steep bluffs along the deeper creek valleys and river valleys.

"All the evidence bearing on the subject points to the conclusion that the Galena dolomite is derived from non-dolomitic limestone by alteration which has taken place subsequent to the deposition of the strata." "Occasionally the change appears to take place first along the bedding planes and joints. A bed two inches thick was observed which had been partially altered to magnesian limestone on the upper and lower surfaces while the inner portion was unaffected. In other cases the alteration had commenced in that portion of the rock immediately surrounding the fossils, an orthoceros, for example, being encircled with a ring of magnesian limestone." "In the limestone portions of the rock the fossils are well preserved, but in the dolomitized parts they have been obliterated."

The samples analyzed were taken from two quarries near Elkader, from outcrops located respectively half a mile south of Farmersburg, two miles west of Garnavillo, one and one-half miles northeast of Osborne, one-fourth of a mile west of Beulah, and one-fourth of a mile north of St. Olaf.

Fayette County.—The outcrops in the western half of Fayette county consist chiefly of impure limestone but those in the eastern and northeastern parts are mostly dolomite or dolomitic limestone. The quarries about West Union and Fayette contain limestone testing 85 to 90 per cent of calcium carbonate and 5 to 10 per cent of magnesium carbonate. (See map, page 120.)

Other analyses for the county are given in reference 66, page 533, as follows. From the Maquoketa formation at Clermont: insoluble residue, 11.95 per cent; iron and aluminum, 2.80 per cent; calcium carbonate, 84.80 per cent; magnesium carbonate, 0.45 per cent. Dolomite from Williams' quarry six miles south of Postville in the Hopkinton formation: insoluble, 8.65, 8.50, 9.00, 10.64 and 9.52 per cent; iron and alumina, 0.66, 5.37, 3.00, 1.06 and 3.10 per cent; calcium carbonate, 58.13, 41.16, 52.12, 50.03 and 52.14 per cent; magnesium carbonate, 32.18, 45.18, 36.05, 38.50 and 35.72 per cent. At Auburn, in the Hopkinton formation, a limestone contains 98.52 per cent of calcium carbonate. The total carbonates at the Williams' quarry by analyses are 90.35 per cent, 86.34 per cent, 88.17 per cent, 88.53 per cent, and 87.86 per cent respectively.

Floyd County.—In Riverton township, 94 north, range 15 west, and all along Cedar river dolomite and highly magnesian limestone are common. In Rock Grove township, 96 north, range 18 west, near Nora Springs, and in Union township, 94 north, range 17 west, near Marble Rock, and also along Shell Rock river generally through the county the limestone is more nearly pure. At the concrete bridge northeast of Floyd station in township 96 north, range 16 west, alternating beds of limestone and dolomite one to three feet thick are found in the quarries. The composition of these beds is shown in the analyses by E. H. Wallace given below:

	Impurities, per cent	$CaCO_3$, per cent	$MgCO_3$, per cent	Total carb., per cent
No. 28. Dolomite	16.41	51.77	31.57	83.34
No. 29. Limestone	1.88	90.30	7.45	97.75

The deficiency in the composition of the dolomite is due to the presence of clay as an impurity. The screenings from the crushed rock from Floyd township whose analysis is given in the table on page 118 tested as follows: impurities, 9.26 per cent; calcium carbonate, 70.22 per cent, magnesium carbonate, 20.52 per cent; total carbonates, 90.74 per cent. For marl in Floyd county see page 116.

Howard County.—In the northern part of Howard county along Upper Iowa river and Beaver creek, the rock is mostly dolomite and this is true also of the outcrops in the southwestern part of the county around Elma. In the east-central part of the county some of the beds are more highly magnesian than others. The rock in the quarries near Cresco also is a magnesian limestone. Forest City township is 100 north, range 12 west, and Chester is in range 13 west. New Oregon is township 98 north and Vernon Springs is 99 in range 11 west. Township 98 north, range 13 west is known as Howard township.

Screenings from the city quarry in Vernon Springs township, SW. ¼ of sec. 22 (see table page 119), have the following composition: impurities, 10.83 per cent; calcium carbonate, 63.94 per cent; magnesium carbonate, 25.23 per cent; total carbonates, 89.15 per cent.

Mitchell County.—Recent analyses of limestones of Mitchell county will be found on page 119. Most of the outcrops in the northwestern part of the county consist of much dolomite and highly magnesian limestone. Professor Calvin says (ref. 28), speaking of the quarry at McIntire, "Any given bed may be unaltered limestone in one place and granular dolomite in another."

Reference 66, page 535, gives three analyses of "Cedar Valley" limestone at Osage showing a purity of 98.01 per cent, 90.17 per cent and 98.01 per cent respectively.

New Burg township is 99 north, range 18 west. Osage is in the township of the same name, Cedar is an irregular township southwest of Osage and Otranto is in the northwest corner of the county.

Winneshiek County.—The analyses show that nearly all of the outcrops in Winneshiek county that have been tested consist of limestone rather than dolomite, though some of the areas contain a slightly magnesian variety.

Township 100 north, range 7 west is Highland; the same number in range 8 is Hesper and that in range 10 is Fremont. In township 99, range 7 west is Pleasant and 9 west is Bluffton. In township 98 north, Decorah is in range 8 and Madison is in range 9. In township 97 north, Frankville is in range 7 west, Calmar in 9, and Sumner in range 10 west. Washington township, 96 north, is in range 9 west, and Jackson is 96 north, range 10 west.

Three analyses taken from reference 66, page 537, of limestone from the Galena formation at Decorah, show respectively: insoluble residue, 14.53, 3.86 and 6.87 per cent; Fe and Al, 6.49, 2.54 and 1.00 per cent; $CaCO_3$, 72.89, 91.19 and 88.97 per cent; $MgCO_3$, 1.03, .84 and 2.86 per cent; total carbonates, 73.92, 92.03 and 91.86 per cent.

There are a number of outcrops of limestone in the county whose exact locations are unknown to the writer.

Section at Decorah

(One mile south of Court House, near stock yards)

		Feet
1.	Stripping or overburden	5 to 8
2.	Limestone, gray to buff, chert nodules larger above, small intraformational conglomerate near middle; gave weak reaction for phosphate	12
3.	Limestone, gray to buff, with bands of blue phosphatic limestone 4 to 12 inches wide	15
4.	Limestone, gray, a few narrow bluish phosphatic streaks	12
5.	Limestone, bluish, thin-bedded, weak reactions for phosphate along bedding planes and joints	2
6.	Limestone, shaly, contains much clay	1/3 to 1/2
7.	Limestone, blue-gray to buff, thick-bedded, some chert nodules; weak reactions for phosphate along the cracks	6

Analyses from above section
(by *E. H. Wallace*)

	Impurities, per cent	$CaCO_3$, per cent	$MgCO_3$, per cent	P_2O_5, per cent	Total Carbonates, per cent
Screenings from crusher	12.40	85.05	2.05	0.34	87.10
Composite from face rock	12.25	83.00	4.45	0.415	87.45
Select specimen from face rock	14.55	83.10	1.68	0.386	84.78
Phosphatic band in No. 3	10.02	83.50	4.61	1.83	88.11

In the southwest quarter of section 23, Madison township, the partly decayed limestone taken from a roadside cut was found to be composed of 61.19 per cent of calcium carbonate and 22.61 per cent of magnesium carbonate; total, 83.8 per cent (ref. 34).

Analyses of Limestone in North-central Iowa

Township	Section	Height of rock face, feet	Length of quarry face, feet	Depth of stripping, feet	Quality of material	Railroad	Highway	Impurities, per cent	Calcium carbonate, $CaCO_3$, per cent	Magnesium carbonate, $MgCO_3$, per cent
				Cerro Gordo County						
Lime Creek	S. ½ 34	25	2000	3	Good	Yes	Yes	1.33	97.70	1.17
Lime Creek	S. ½ 34	25	2000	3				3.39	95.23	1.38
Lime Creek	NW. ¼ 27	20	600	3	Good	Yes	Yes	1.98	89.24	8.68
				Franklin County						
Mott	NW. ¼ 28	15	100	2½	Good	Yes	60rd	6.24	69.22	24.54
Ingham	NE. ¼ 28	6	100	4 – 6	Good	Yes	20rd	8.23	85.04	6.73
				Hamilton County						
Independence	SW. ¼ 17	6	50	3	Good	4 mi	20rd	9.75	86.24	4.01
				Hardin County						
Hardin	NE. ¼ 19	20	400	1 –10 sandstone	Good	20rd	20rd	1.10	88.20	10.70
Alden	NE. ¼ 18	30	600	2 – 3	Good	Yes	Yes	.84	87.87	11.29
Alden	NE. ¼ 18	(Scrgs from Hale Roberts)				(muddy at times)		18.88	78.97	2.15
				Humboldt County						
Rutland	SE. ¼ 35	6	200	2 – 6	Good	1 mi	40rd	4.98	87.27	8.78
Corinth	NW. ¼ 3	12	60	1 – 6	Good	1½ mi	20rd	1.02	95.84	3.14
				Pocahontas County						
Garfield	SW. ¼ 25	20	900	2 – 4	Good	Yes	Yes	.75	88.81	10.44
Same location								3.13	93.80	3.07
				Webster County						
Cooper	SE. ¼ 17	6	70	6 –14		20rd	Yes	3.98	76.83	19.19

NORTH-CENTRAL COUNTIES.

Cerro Gordo County.—Several analyses of samples from this county have been made, see table on page 126, and these show a composition ranging from 95 to 98 per cent of total carbonates. Reference 66, page 532, gives two analyses of limestone from "Mason City" which contain 95.54 per cent and 98.47 per cent of carbonates respectively. A sample of the screenings at Northwestern Portland Cement Company's plant tested 96.61 per cent of carbonates. This high degree of purity is a characteristic of the limestones of the county.

An analysis by E. H. Wallace of a sample collected in the southeast quarter of section 19, Union township, about four miles east of Manly, on Shell Rock river, shows the composition of the rock to be P_2O_5, 0.22 per cent; $CaCO_3$, 74.30 per cent; $MgCO_3$, 23.30 per cent; total carbonates, 97.60 per cent. Concerning marl in Cerro Gordo county see page 116.

Franklin County.—The specimen of magnesian limestone which was analyzed (see table, page 126) came from the old quarry along the creek in the northwest quarter of section 28, Mott township, about two miles north of Hampton, and is 93.74 per cent pure. The northeast quarter of section 28, Ingham township, is about seven miles east of Hampton, near Hansell. The limestone here contains 91.77 per cent of total carbonates.

Hamilton County.—The sample of limestone from Hamilton county whose analysis is given on page 126 was taken from a thin bed in an outcrop on Boone river. Though the rock is good in quality it is not sufficiently abundant to make its exploitation a profitable enterprise.

Hardin County.—The northeast quarter of section 19, Hardin township, is at Iowa Falls, where the slightly magnesian limestone tested 98.9 per cent of carbonates. The samples from Alden township were taken at Alden (Hale Roberts quarry). The second test made on screenings from here runs lower in purity because of the mud and dust which sometimes are permitted to become mixed with the screenings. This reduction of about ten per cent in purity can be avoided by care in handling the material. See analyses, page 126.

Humboldt and Pocahontas Counties.—As shown in the tables, page 126, giving composition of limestones in Humboldt and Pocahontas counties, the maximum percentage of carbonates reaches 98.98 in one analysis and 99.25 in another. This area includes the producing localities around Gilmore City, the district near Rutland and the outcrops at Humboldt and southward along Des Moines river. The second analysis given in the table under Pocahontas county is for screenings at the cement plant, Gilmore City.

Analyses found in reference 66, page 533, give the following: "Humboldt", 97.98 per cent and 99.20 per cent of carbonates; and "near Gilmore City", 99.62 per cent total carbonates.

These percentages are among the very highest ascertained by test in the entire state.

Webster County.—The limestone of Webster county is of the same age (Mississippian) geologically considered, as that along Des Moines and Skunk rivers in southeastern Iowa and occurs in the bed and on the banks of Lizard creek and of Des Moines river near Fort Dodge and northward to the county line. The quality of this rock is excellent but its upper part is too near the level of the water table for it to successfully compete with the equally high grade limestone from Rutland and Gilmore City.

Analyses of Limestone in East-central Iowa

Township	Section	Height of rock face, feet	Length of quarry face, feet	Depth of stripping feet	Quality of material	Railroad	Highway	Impurities, per cent	Calcium carbonate, $CaCO_3$, per cent	Magnesium carbonate, $MgCO_3$, per cent
				Benton County						
Jackson	SE. ¼ 28	20	400	3 – 4	Good	Yes	No	3.62	87.67	8.71
Taylor	S. ½ 10	20	300	3 – 4	Good	1½ mi	Yes	9.97	89.32	.71
Harrison	NW. ¼ 9	25	400	2 – 3		3¼ mi	40rd			
				Black Hawk County						
Spring Creek	NW. ¼ 36	25	600	4	Good	Yes	Yes	11.65	72.81	15.54
Spring Creek	NW. ¼ 36	25	600	4	Good	Yes	Yes	11.27	80.32	8.41
Spring Creek	N.W. ¼ 36	screenings			Good	Yes	Yes	13.57	69.94	16.49
Cedar Falls	NE. ¼ 23	7	150	3 – 4	Good	Yes	Yes	4.13	80.63	15.24
E. Waterloo	NW. ¼ 14	30	600	3 – 6	Good	Yes	Yes	19.14	59.61	21.25
				Cedar County						
Gower	NE. ¼ 19	40	800	4 – 6	Good	Yes	Yes	3.22	57.35	39.43
Sugar Creek	SW. ¼ 15	20	300	4 – 5	Good	5 mi	Yes	2.10	55.24	42.66

Township	Section	Height of rock face, feet	Length of quarry face, feet	Depth of stripping, feet	Quality of material	Railroad	Highway	Impurities, per cent	Calcium carbonate, $CaCO_3$, per cent	Magnesium carbonate, $MgCO_3$, per cent
				Clinton County						
Waterford	SE. ¼ 27	12	100	2 – 4	Good	Yes	Yes	4.28	54.14	41.58
City of Clinton	NW. ¼ 12	25	300	6 –20	Good	80rd	Yes	1.94	59.44	39.62
				Delaware County						
Elk	SW. ¼ 16	15	300	2	Good	2½ mi	Yes	9.78	50.70	39.52
Delaware	35	10	200	2	Good	½ mi	20rd	1.85	54.21	43.94
Bremen	NW. ¼ 25	7	250	1	Good	160rd	20rd	1.06	57.73	41.21
Oneida	NE. ¼ 36	8	200	2	Good	Yes		1.54	56.91	41.55
Delhi	NE. ¼ 19	6	150	2	Good	80rd	20rd	7.99	54.39	37.62
Delaware	NE. ¼ 2	8	200	2 – 3	Good	160rd	Yes	4.25	63.48	32.27
				Dubuque County						
Vernon	NE. ¼ 10	25	500	2 – 6	cherty	Yes	Yes	3.61	52.82	43.57
Taylor	NW. ¼ 11	14	100	1 – 2	Good	20rd		4.10	53.78	42.12
''N. Dub-		screenings								
que''	SE. ¼ 7	25	600	2 – 3	Good	Yes	Yes	10.54	46.14	43.32
Taylor	SE. ¼ 6	30	400	3	cherty	Yes	Yes	7.53	52.60	39.87
				Jackson County						
South Fork	NW. ¼ 23	40	600	2 – 4	Good	1 mi	Yes	1.90	56.32	41.78
South Fork	W. ½ 12	30	500	2 – 4	Good	Yes	Yes	3.50	57.82	38.68
Bellevue	SE. ¼ 12	20	300	2 – 5	Good	40rd	Yes			
				Johnson County						
Jefferson	NW. ¼ 22	15	200	4 – 6	Good	80rd	Yes	3.94	94.18	1.88
East Lucas	SE. ¼ 3	30	300	2 – 6	Good	1 mi	Yes	4.52	94.47	1.01
Big Grove	23							5.47	93.11	1.42
				Jones County						
Fairview	NE. ¼ 6	50	600	3 – 8	Good	Yes	Yes	3.13	56.06	40.81
Fairview	SW. ¼ 5	40	600	3 – 8	Good	Yes	Yes	4.59	54.72	40.69
Fairview	SW. ¼ 5	Screenings			Good	Yes	Yes	5.88	52.86	41.26
Cass	SW. ¼ 33	60	800	4 – 6	Good	Yes	Yes	5.81	53.28	39.91
Cass	SW. ¼ 33	Screenings			Good	Yes	Yes	3.79	58.09	38.12
				Linn County						
Franklin	NE. ¼ 15	20	200	3 – 5	Good	40rd	Yes	2.06	58.03	39.91
Franklin	NE. ¼ 15	Screenings			Good	40rd	Yes	3.41	59.45	37.13
''Cedar Rapids''	NE. ¼ 27	25	200	4 – 6	shaly	Yes	20rd	24.64	65.39	9.97
Buffalo	NW. ¼ 20	20	200	3 – 5	Good	6 mi	Yes	Total	94.34	
				Marshall County						
LeGrand	SW. ¼ 3	30	300	2 – 5	Some chert	Yes	Yes	2.73	80.69	16.58
LeGrand	W. ½ 3	40	1000	10 –30	6 cherty layers	Yes	Yes	3.57	74.09	22.34
Marion	S. ½ 36	10	200	4 – 6	Good	Across 'river'	Yes			

Township	Section	Height of rock face, feet	Length of quarry face, feet	Depth of stripping feet	Quality of material	Railroad	Highway	Impurities, per cent	Calcium carbonate, $CaCO_3$, per cent	Magnesium carbonate, $MgCO_3$, per cent
				Scott County						
Davenport	NW.¼ 33	20	200	2 – 4	Shaly	Yes	Yes	12.88	85.42	1.70
Davenport	NW.¼ 33	20	200	2 – 4	Shaly	Yes	Yes	12.22	85.14	2.64
Buffalo	SW. ¼ 21	25	1000	3 – 5	Shaly	Yes	Yes	21.09	75.14	3.77
Buffalo	SW. ¼ 21	25	1000	3 – 5	Shaly	Yes	Yes	14.43	83.36	2.21
Buffalo	SW. ¼ 21	25	1000	3 – 5	Shaly	Yes	Yes	12.74	82.48	4.78
LeClaire	W. ½ 26	10	200	4 – 5		Yes	Yes	5.30	61.41	33.25
Buffalo	NW.¼ 24	30	600	3 – 4	Shaly	Yes	Yes	15.79	77.10	7.11
Buffalo	NW.¼ 24	30	600					15.57	76.12	8.31
				Tama County						
Indian Village	SE. ¼ 7	10	150	2 – 5	Good	1 mi	Yes		84.50	

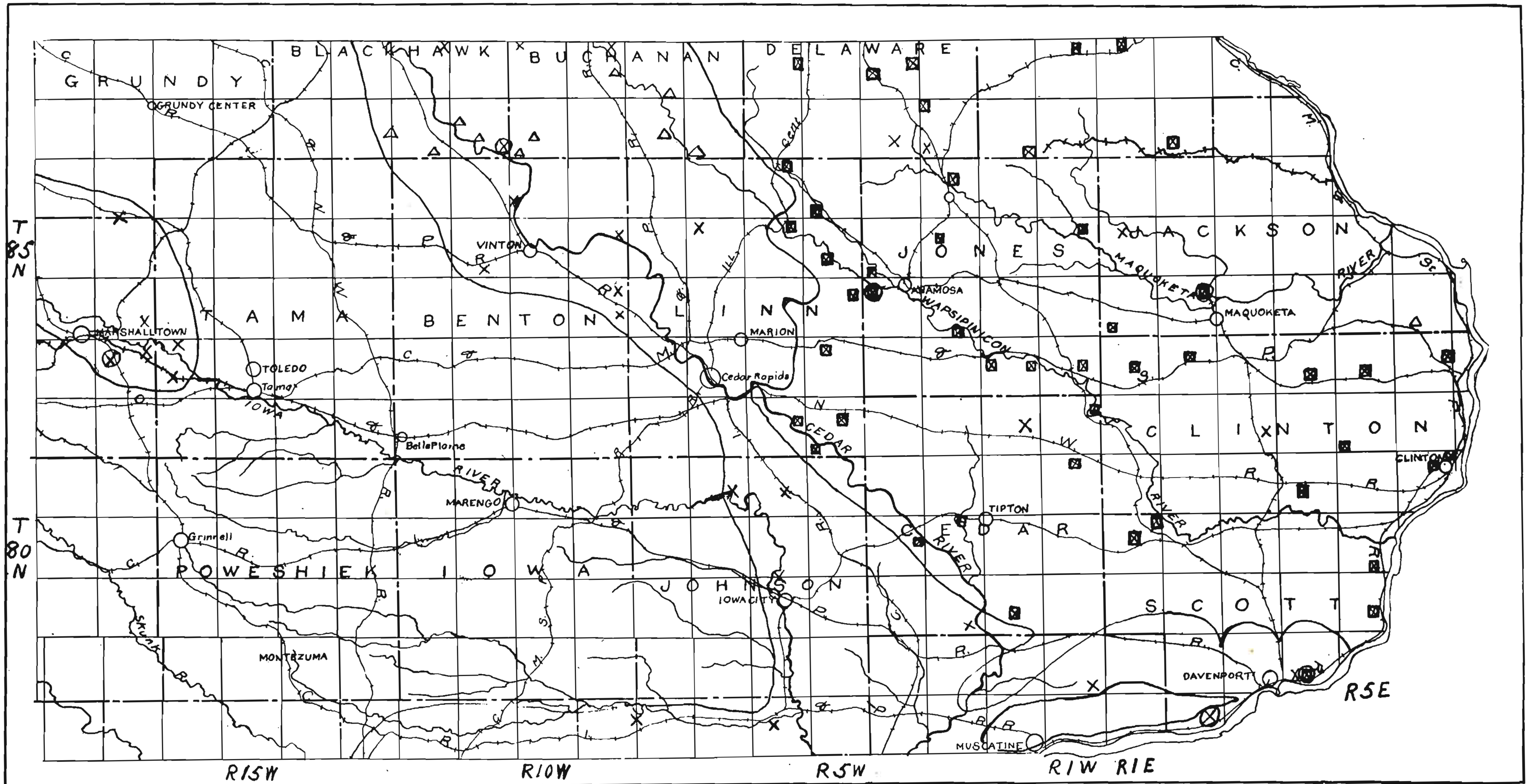
EAST-CENTRAL COUNTIES.

Benton County.—On the eastern margin of the city of Vinton there are several outcrops of good limestone some of which have been quarried to a small extent. The limestone in the old quarries near Shellsburg was carefully tested and, like that in the quarries at Vinton, was found to be well adapted to use as fertilizer though phosphate is absent in each of these localities. Limestone of good quality is found near Garrison also. North of Vinton on the Aungst farm and still further north on the same (west) side of Cedar river, quarries of high grade limestone were found to contain slight traces of phosphate. Several outcrops of high grade limestone are found east of Cedar river.

The principal outcrops of limestone in Benton county are shown on the map opposite page 130 and indicated in the table on page 128. Norton (ref. 47A, p. 374) also gives a number of analyses for Linn and Benton counties showing that the total carbonates range from 92 per cent to 96 per cent.

Black Hawk County.—Practically all of the limestone outcrops in Black Hawk county consist of magnesian limestone ranging in purity from about 80 per cent in the eastern and southern parts to 90 per cent of calcium carbonate in the region around Cedar Falls.

Reference 66, page 531, gives an analysis of a sample of lime-



EAST CENTRAL COUNTIES. X INDICATES LIMESTONE; X IN SQUARE, DOLOMITE; TRIANGLE, MINOR OUTCROPS AND QUARRIES. EITHER WITHIN A CIRCLE INDICATES PRODUCTION OF AGRICULTURAL LIME. A BLACK LINE SHOWS APPROXIMATE BORDERS OF THE AREAS OF PLATE VI.

stone (Cedar Valley) from Waterloo with percentages as follows: insoluble, 1.92; iron and alumina, 4.20; calcium carbonate, 63.59; and magnesium carbonate, 30.92; total carbonates, 94.51.

The succession of beds in the southeastern township of the county is well represented at the quarries of Hawkeye Quarry Company at Glory between LaPorte City and Brandon on the Interurban railway.

Section at Glory, Iowa
(Cedar Valley)

		Feet
1.	Limestone, weathered, brown to yellow, thick to thin-bedded	10
2.	Shale, clay parting, very thin	
3.	Limestone, buff to gray, lithographic in upper part; gives weak reaction for phosphate	5
4.	Shale, clay parting, maximum thickness about one inch	
5.	Limestone, blue, thin chert nodules and lenses, thin shaly partings present; tests for phosphate in cracks	10
6.	Limestone, buff, granular, very slightly phosphatic	1
7.	Limestone, blue, thick-bedded, two bands of buff color 4 feet apart; some slightly phosphatic nodules	10

Cedar County.—Cedar county, like Linn, has two areas of lime rock, the dolomite east and north of the line shown on the map along Cedar river and the limestone west of it. The position of the dividing line is only approximately correct as shown on the map and continues in a southeasterly direction across the northeastern corner of Johnson county. Analyses of the limestone show percentages of $CaCO_3$ as follows: 93.61, 96.91, 96.73, and one 78.75 with 20.16 per cent of $MgCO_3$ (ref. 66, page 531). Norton (ref. 47A, p. 374) gives an analysis of a stone at Lime City which shows a content of 99.11 per cent of total carbonates.

Gower township, referred to in the table on page 128, is number 80 north, range 4 west, and Sugar Creek is number 79 north, range 2 west.

Clinton County.—Clinton county is almost wholly in the dolomite area. An analysis of a sample taken from a quarry in the northeast part of the city of Clinton gives 59.44 per cent of $CaCO_3$ and 39.62 per cent of $MgCO_3$, total carbonates, 99.06 per cent (ref. 34); and one collected in the southeast quarter of section 27, Waterford township, 83 N., R. 2 E., contains 54.14 per cent of $CaCO_3$ and 41.58 per cent of $MgCO_3$, total carbonates, 95.72 per cent. Reference 57, page 395, in a section for a quarry near De

Witt, shows beds of dolomite and limestone in the same section. Figure 14 shows a view in one of the dolomite quarries at Lyons.

Delaware County.—The "Niagara limestone" of this county is chiefly dolomite and underlies nearly all parts of the county. Areas of limestone are found in the southeast quarter of section 8, Union township, 87 north, range 4 west, and along Prairie creek in sections 27, 28 and 29 of Coffins Grove township, west of Manchester. Along the bluffs near where Maquoketa river leaves the county and perhaps in other places there are also sev-

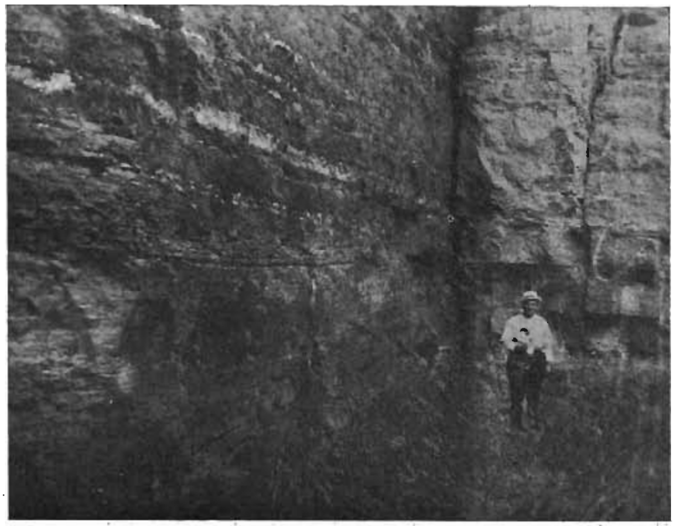


FIG. 14.—A quarry in dolomite at Lyons, Clinton county. Thin layers of chert nodules in the upper left quarter of the picture.

eral outcrops consisting chiefly of limestone. (See map, opposite page 130, and analyses, page 129.)

Chert occurs more or less extensively in nearly all of the outcrops in the county. In the quarry in the northwest quarter of the northwest quarter of section 6, Milo township, a few miles south of Manchester, chert and dolomite are found in nearly equal quantities. A large amount of chert is found also along a north-south ridge three to four miles east of Manchester and in several other places in the county.

Dubuque County.—Along the bluffs of Mississippi river at Spechts Ferry and at Zollicoffer Lake a good quality of limestone is found. Several analyses show the rock in the former location to contain 75 to 90 per cent of calcium carbonate and from a fraction of one per cent to nearly seven per cent of magnesium carbonate. Analyses of six samples from Zollicoffer Lake (ref. 66, p. 533) show the following percentages of calcium carbonate respectively: 80.14, 77.93, 78.24, 84.16, 86.33 and 90.20.

At Eagle Point in North Dubuque and probably at several other places in the county beds of limestone are found alternating with beds of dolomite in the same quarry or outcrop. A strip

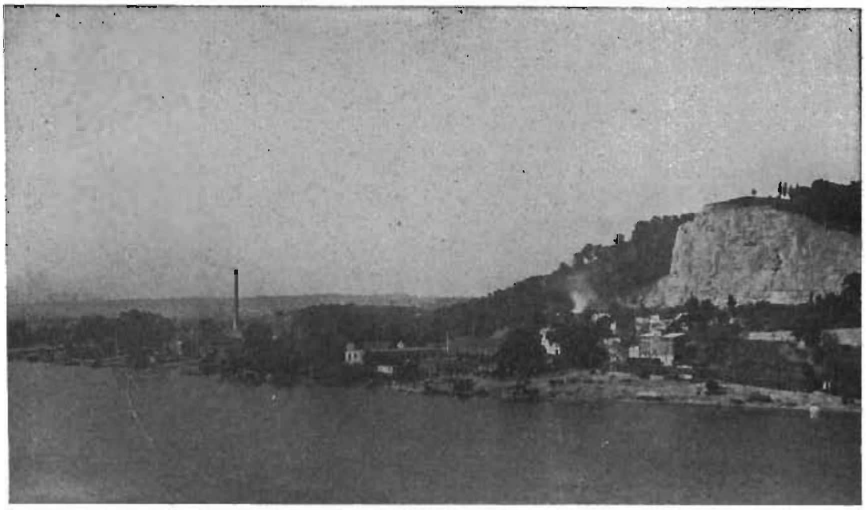


FIG. 15.—A view of the Eagle Point quarry taken from the bridge at Dubuque. Layers of limestone and of dolomite are found in this bluff.

about one township wide along Mississippi river contains some beds of limestone and some of dolomite promiscuously distributed. Underlying all of the upland to the west of this strip is the typical dolomite of northeastern Iowa. North Dubuque township referred to in the table of analyses is number 89 north, range 4 east, and the location referred to is the big quarry at the Mississippi river bridge at Eagle Point shown in figure 15. Taylor township is number 88 north, range 1 east, and Vernon township is in range 2 east, 88 north. The analysis given is that of screenings. An analysis (ref. 34) of face rock here (not given in the table, page 129) is $CaCO_3$, 55.35 per cent; $MgCO_3$, 40.97 per cent; total carbonates, 96.32 per cent.

Careful tests failed to show the presence of any considerable amount of phosphate in the limestones of the county.

Jackson County.—The outcrops and quarries of Jackson county are practically all in the dolomite area. In a few places in the county, as in an undeveloped area on North Maquoketa river in the east half of section 9, Brandon township, which is 85 north,

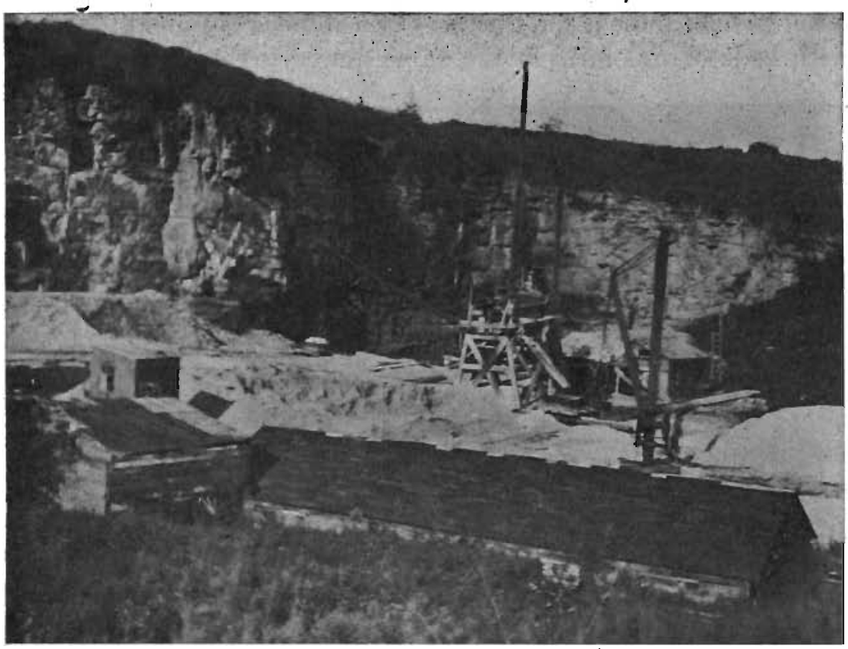


FIG. 16.—State quarry and crusher near Anamosa, Jones county. The rock is dolomite.

range 1 east, an area of limestone is found. The analyses given in the table on page 129 are from South Fork township, which is 84 north, range 2 east; and from Bellevue, which is township 86 north, range 4 east.

Johnson County.—Tests made some years ago at Iowa City show that the limestone at that town contains 87.79 per cent of calcium carbonate and 4.66 per cent of magnesium carbonate. The data given in the tables on page 129 refer to samples which were obtained from Jefferson township, which is 81 north, range 7 west; Big Grove township, which is 81 north, range 6 west; and East Lucas township, which is 79 north, range 6 west. These places can be easily located on Plate VIII, opposite page 130. The total carbonates for the above locations are: Jefferson, 96.06 per cent; East Lucas, 95.48 per cent; and Big Grove, 94.53 per cent.

Reference 66, page 534, gives an analysis of limestone at "Iowa City" whose total carbonates aggregate 94.45 per cent.

Jones County.—The analyses of rock from Jones county which appear in the table on page 129 refer to specimens from Fairview township, which is 84 north, range 4 west, and from Cass township, which is 85 north in the same range. The rock in this county is practically all in the dolomite area and this locality has produced many excellent specimens of fossil forms from the quarries and outcrops along Maquoketa river.

The third analysis given in the table of analyses for Jones county, page 129, shows the composition of screenings from the locality (Stone City) described in the second line of the same table. The analysis in the fifth line of the same table shows the test made on screenings from the locality described in the fourth line. A view of the State quarry at Anamosa is given in figure 16.

Linn County.—The lime bearing rock of Linn county may be divided into two groups separated by an irregular line extending in a southerly direction approximately along the middle of range six west, passing near Coggon and Central City, crossing Cedar river just below Cedar Rapids and running nearly parallel to the river and one to two miles west of it. East of this line the hard rock is chiefly dolomite; west of it limestone is found as marked on the map, page 130. Screenings from the northeast quarter of section 15, Franklin township, tested as follows: impurities, 3.41 per cent; total carbonates, 96.58 per cent. See analyses page 129.

Grundy, Marshall and Tama Counties.—LeGrand township, Marshall county, is 83 north in range 17 west and Marion is number 84 north in the same range. Clay township, 86 north, range 17 west, in Grundy county, contains the only limestone outcrops of the county. They are located near Conrad and Beaman along the creeks and contain limestone suitable for use as a soil amendment. These beds are but a northward extension of the rocks which outcrop in western Tama and eastern Marshall counties.

There are several outcrops of a good grade of limestone in

Tama county north of Montour in Indian Village township, number 83, range 16 west, and these beds extend into Carlton township which is just north of Indian Village. The character of this rock is well represented by the analyses made from samples obtained at a quarry just across the line in Marshall county in LeGrand township, 83 north, range 17 west, and in Marion township, 84 north in the same range.

FIG. 17.—An old quarry along the north bluff of Iowa river in Marshall county. The rock is limestone.

Analyses of the rock at Quarry which are given in reference 66, page 535, show it to contain calcium carbonate as follows: oölite, 98.30 per cent; blue limestone, 97.95 per cent. The more definitely stratified limestone contains 90.04 per cent and also 8.08 per cent of magnesium carbonate. No appreciable amount of phosphate was found in the samples. Figures 17 and 18 give views of some of the quarries in Marshall county.

Muscatine County.—Muscatine is famous for its development of the pearl button industry and there are more than twenty button factories in the city. The "button dust" or waste material from these factories is shown by analysis to be 97.46 per cent pure carbonate, and therefore of unusually high quality.

Scott County.—The map on page 130 shows the dividing line between the limestone and dolomite areas of the county to extend nearly east and west about five miles north of Davenport. The rocks shown at the outcrops and quarries around Princeton and Le Claire as well as all others north of this division line consist

FIG. 18.—A ledge of limestone showing lenses of chert (light color) along the bedding planes between the layers. Quarry one mile north of Le Grand, Marshall county.

of dolomite. The quarries at Bettendorf and Linwood, on the other hand, and in Buffalo, the southwestern township of the county, are in an impure limestone whose total carbonates range from 78.91 per cent at Buffalo to 87.78 per cent at Bettendorf, as is shown in the table of analyses on page 130. "Stone dust" from these localities is sold in several nearby counties on each side of Mississippi river.

The analysis (ref. 34) in the second line from the top of the table on page 130 is for screenings from the Bettendorf quarries east of Davenport; that in the fifth line is for screenings from Dolese Bros. at Buffalo; and that in the bottom line of the same table is for screenings at the Linwood quarry.

Analyses of Limestone in Southeastern Counties

Township	Section	Height of rock face, feet	Length of quarry face, feet	Depth of stripping, feet	Quality of material	Railroad	Highway	Impurities, per cent	Calcium carbonate, $CaCO_3$, per cent	Magnesium carbonate, $MgCO_3$, per cent
				Appanoose County						
Vermillion	SE. ¼ 26	8	250	4 – 6	Good	Yes	No	5.10	93.97	.93
Vermillion	SW. ¼ 25	5	100	4 – 6	Good	Yes	No	7.23	91.03	1.61
				Davis County						
Salt Creek	NE. ¼ 11	8	100	6	Good	1½ mi	Yes	11.22	87.61	1.17
				Des Moines County						
City of Burlington	SW. ¼ 33	40	500					66.38	29.49	4.13
				Henry County						
Center	SW. ¼ 17	20	300	4 – 5	Good	Yes	Yes	5.95	81.13	12.92
Center	Screenings (muddy at times)					Yes		27.81	68.39	3.80
Center	NE. ¼ 17	25	800	3 – 5	Good	Yes	Yes	9.21	77.36	13.43
				Keokuk County						
Van Buren	N. ½ 24	8	150	3 – 4	Good	40rd	20rd	9.57	88.40	2.03
Warren	Center 9 & 10	20	500	3	Poor	Yes	½ mi	25.48	73.29	1.23
Sigourney	NW. ¼ 2	6	100	3	Good	40rd	40rd	4.23	94.19	1.58
				Lee County						
Montrose	NE. ¼ 36	30	300	3 – 6	shale	Yes	Yes	9.06	87.36	3.58
Montrose	NE. ¼ 36				shale	Yes	Yes	36.07	55.94	7.99
Charleston	SE. ¼ 5	4	60	3 – 6	Good	1 mi	20rd	9.52	88.22	2.26
Montrose	NW. ¼ 13	30	500	3 – 6	shale	Yes	Yes	26.29	62.29	10.42
Montrose	NW. ¼ 13	30			shale	Yes	Yes	36.39	48.60	12.21
Keokuk	SE. ¼ 26	25	300	4 – 6	shaly	Yes	Yes	18.91	72.73	8.36
Keokuk	SE. ¼ 26				shaly	Yes	Yes	26.02	68.28	5.70
				Mahaska County						
West Des Moines	SE. ¼ 35	8	200	4 – 6		1 mi	Yes	8.48	89.34	2.18
Scott	W. ½ 31	8	100	4 – 6	Good	1 mi	Yes	8.26	89.61	2.13
White Oak	Center 7	10	200	3 – 4	Good	Yes	Yes			

Township	Section	Height of rock face, feet	Length of quarry face, feet	Depth of stripping, feet	Quality of material	Railroad	Highway	Impurities, per cent	Calcium carbonate, $CaCO_3$, per cent	Magnesium carbonate, $MgCO_3$, per cent
				Monroe County						
Pleasant	NW.¼ 1	8	100	3 – 4	Good	1 mi	20rd	6.29	90.63	3.08
				Van Buren County						
Van Buren	SW. ¼ 30	20	200	3 – 4	Good	1 mi	40rd	7.37	91.45	1.18
Harrisburg	4	10	150	3 – 4	Good	3 mi		4.54	90.92	4.54
Harrisburg	SW. ¼ 32	10	125	2 – 3	Good	2½mi		8.06	89.53	2.41
Henry	SW. ¼ 3	8	100	2	Good	2 mi		3.3	94.12	2.58
Farmington	NE. ¼ 5	10	200	4 – 7	Good	40rd	80rd			
				Wapello County						
Columbia	SW. ¼ 7	8	100	6 – 8	Good	1 mi	40rd	5.72	93.20	1.08
				Washington County						
Brighton	NE. ¼ 30	15	200	2 – 4		Yes	Yes	3.96	94.19	1.85

SOUTHEASTERN COUNTIES.

In Davis, Keokuk, Lee, Mahaska, Van Buren and Wapello counties a high quality of white limestone is found in abundant quantities along Des Moines and Skunk rivers and along some of their branches. Practically all of the limestone in these locations is suitable for use as raw limestone fertilizer—the problem is simply one of getting the rock crushed to the proper degree of fineness and applying it to the soil according to its needs. See the table of analyses, page 138, for details, also map, page 140, for locations.

Lee County.—In Lee county small traces of phosphate were found as is shown in the descriptions given in the following section:

Section in McManus quarry at Keokuk

		Feet
1.	Limestone, weathered, yellow to brown, fossiliferous, containing brachiopods and *Archimedes;* traces of phosphate	4
2.	Limestone, gray to blue, beds two feet thick; phosphate in cracks	4
3.	Shale, clay parting; weak reaction for phosphate	¼
4.	Limestone, thick bedded	4
5.	Shale, blue	1
6.	Limestone, thin bedded; slight traces of phosphate	6
7.	Limestone, thick bedded, gray, a few small geodes in the upper part	8
8.	Limestone, gray, thick-bedded, below main quarry floor	5

Des Moines County.—In Des Moines county, around Burlington and elsewhere, the limestone in some places is mixed with clay. But there are also localities in which the limestone is nearly pure.

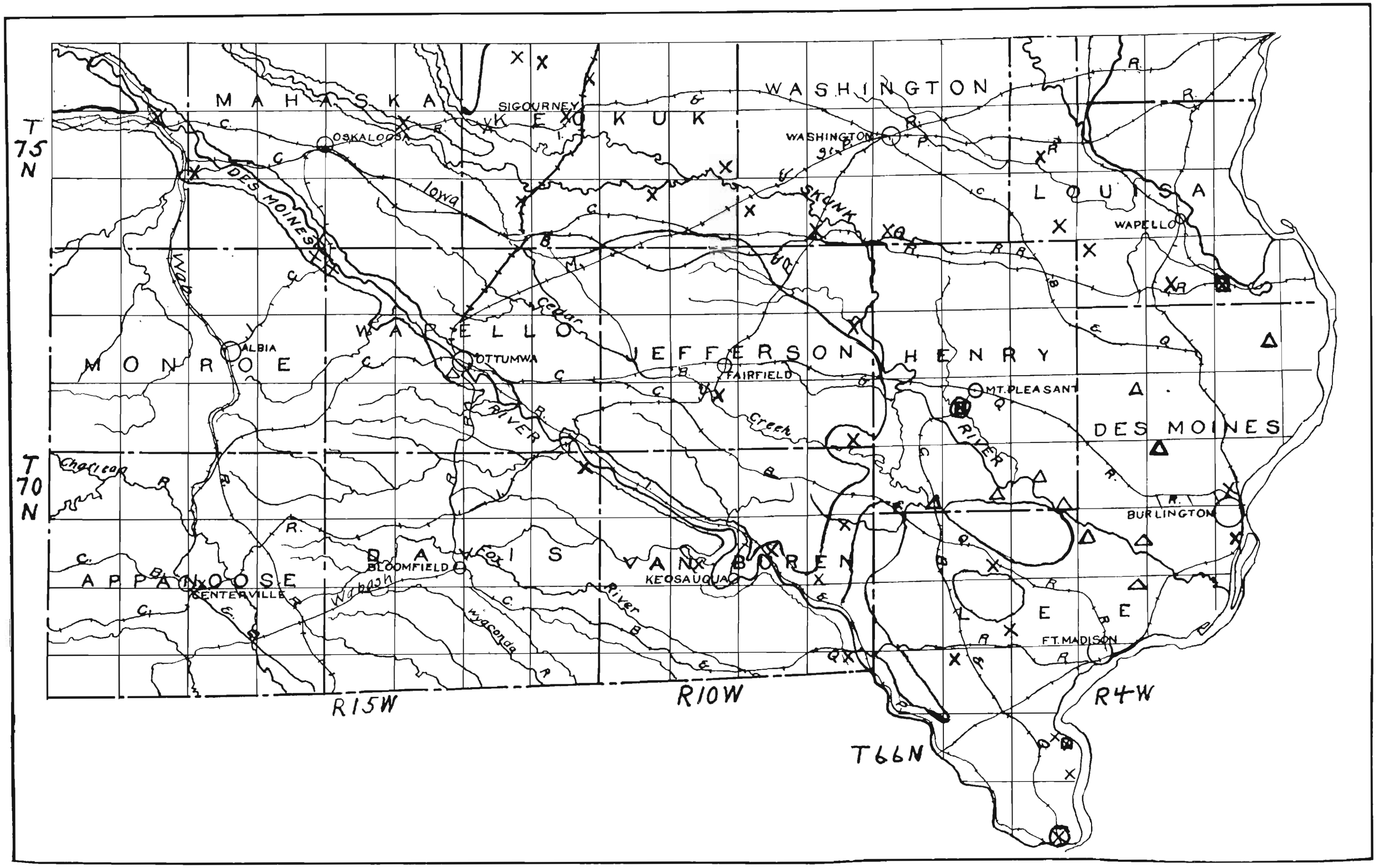
An analysis (ref. 66, p. 532) of a sample from Burlington (exact location not given), shows the specimen to contain 93.11 per cent of calcium carbonate and 0.84 per cent magnesium carbonate, total 93.95 per cent. The quality of this rock makes it extremely desirable for use as a fertilizer.

Henry County.—An analysis by Professor Harper of rock from the quarry in the southwest quarter of section 17, Center township, two and one-half miles southwest of Mount Pleasant, shows 81.13 per cent of $CaCO_3$ with 12.92 per cent of $MgCO_3$, total 94.05 per cent. Another sample from the northwest quarter of section 17, also analyzed by Professor Harper, contains 77.36 per cent of $CaCO_3$ with 13.43 per cent of $MgCO_3$, total 90.79 per cent. See the map, page 140, for locations.

Jefferson County.—The uppermost bed rock in the western three-quarters of Jefferson county is chiefly shale and sandstone which belong to the coal-producing group of sedimentary layers. The limestone occurs in a few places along the creeks and rivers in the localities shown on the map on page 140. Though no analyses of samples from this county are given in the tables, the same high grade of limestone that is found in Lee, Henry and Keokuk counties exists here.

Keokuk County.—The specimen from Warren township, 75 north, range 13 west, whose analysis is given in the table, is a sandy limestone. The western tier of townships contains numerous outcrops of sandstone, which is worthless as a fertilizer. Van Buren township is number 76 north, range 12 west, and Sigourney is the township just south of it. The total carbonates shown in the analyses are respectively, 90.43 per cent and 95.77 per cent.

Louisa County.—An analysis of a sample of limestone taken near Morning Sun (ref. 66, p. 534) shows a content of 97.02 per cent of calcium carbonate and one by Harper from the exposure south of Elrick Junction shows that the rock contains only 60.56 per cent of calcium carbonate with 34.47 per cent magnesium car-



MAP OF SOUTHEASTERN IOWA. AREAS OF LIMESTONE, DOLOMITE AND UNPRODUCTIVE AREAS ARE SEPARATED BY UNBROKEN LINES. OUTCROPS AND QUARRIES ARE SHOWN BY SAME MARKS AS IN PLATES VII AND VIII.

bonate, total 95.03 per cent, and 4.97 per cent impurities. The major part of the lime-bearing bed rock in the county is good, pure limestone.

Monroe County.—The only limestone outcrops of any size in Monroe county are in the northeast corner across Des Moines river from Eddyville. A test made from an outcrop about a mile west of Eddyville in the northwest quarter of section 1 shows the presence of 90.63 per cent of calcium carbonate, 3.08 per cent of magnesium carbonate, total 93.71 per cent, and 6.29 per cent of insoluble matter.

Wapello County.—In Washington township, sections 31 and 32, on the old coal mining property at Laddsdale, west of Eldon, is a ledge of limestone about twenty-four to thirty inches thick. As there are thick shales above and below the limestone it has no commercial value. Samples sent by the owner, Mr. W. R. Daum, were found by E. H. Wallace to contain: Impurities, 13.05 per cent; $CaCO_3$, 62.22 per cent; $MgCO_3$, 24.45 per cent; P_2O_5, 0.295 per cent; total carbonates, 86.77 per cent. See also the table of analyses on page 139.

Washington County.—Analysis shows that 94.19 per cent of calcium carbonate and 1.85 per cent of magnesium carbonate, total 96.04 per cent, with 3.96 per cent of impurities, constitute the proportions respectively in a sample obtained about a mile north of Brighton along the highway. This is in accord with the high tests made by nearly every sample secured in the southeastern counties of the state.

Wayne County.—Professor Harper's (ref. 34) analyses of samples obtained from the south half of section 36 in Wright township indicate 91.90 per cent and 77.95 per cent respectively of total carbonates. These ledges are thin and the outcrops are relatively unimportant. Limestone probably can be shipped in more cheaply than this rock can be crushed.

Analyses of Limestone in Other Counties

Township	Section	Height of rock face, feet	Length of quarry face, feet	Depth of stripping, feet	Quality of material	Railroad	Highway	Impurities, per cent	Calcium carbonate, $CaCO_3$, per cent	Magnesium carbonate, $MgCO_3$, per cent
				Decatur County						
New Buda	NW.¼ 10	15	600	3	Good	40rd	Yes	12.48	85.43	2.09
				Harrison County						
Jefferson	N. ½ 19	6	50	10 –30	Good	40rd	Yes	5.98	84.75	9.27
				Madison County						
Madison	SE. ¼ 18	30	600	12	Good	Yes	80rd	8.88	86.46	4.66
Madison	S. ½ 16					Yes	Yes	18.88	73.52	7.60
Madison	N. ½ 21					Yes	Yes			
Madison	SE. ¼ 4	12	500	6 – 8	Good	Yes	Yes	9.85	88.24	1.91
Scott	NW.¼ 6	20	300	4	Good	1 mi	Yes	17.11	81.18	1.71
Walnut	NW.¼ 10	15	200	5 –10	Good	1 mi	Yes	11.78	86.05	2.17
				Marion County						
Red Rock	SW. ¼ 25	8	100	4 – 8	Poor	Yes	40rd	95.94	4.06	1.27
Clay	SE. ¼ 4	6	50	6	Good	40rd	40rd	8.82	91.18	2.99
				Montgomery County						
Sherman	W. ½ 27	12	200	3 –10	Good	Yes	20rd	7.53	91.14	1.33
Sherman	SE. ¼ 34	12	200	3 – 8	Good	Yes				

OTHER COUNTIES.

Decatur County.—There are several outcrops of limestone near Davis City and elsewhere along the slopes of Grand River valley in Decatur county. The quality of this rock is good, the percentage of calcium carbonate reaching 85 per cent as shown in the table of analyses above. The specimens analyzed were obtained near the railroad about two miles southwest of Davis City.

It seems that small crushers might be profitably operated in Decatur county in producing pulverized limestone for local use as a soil amendment.

Harrison County.—The outcrops of limestone in Harrison county are relatively unimportant even though the quality of material is good.

Marion County.—The outcrops of limestone in Marion county are most numerous along Des Moines river valley and its larger branches. The analysis given above is of a specimen from Clay township which was procured near Harvey and several other large outcrops are found between Harvey and the former town of Flagler. A few half-covered exposures lie about three miles northwest of Knoxville, north of the railroad and southeast of Whitebreast creek. In the northeastern part of the

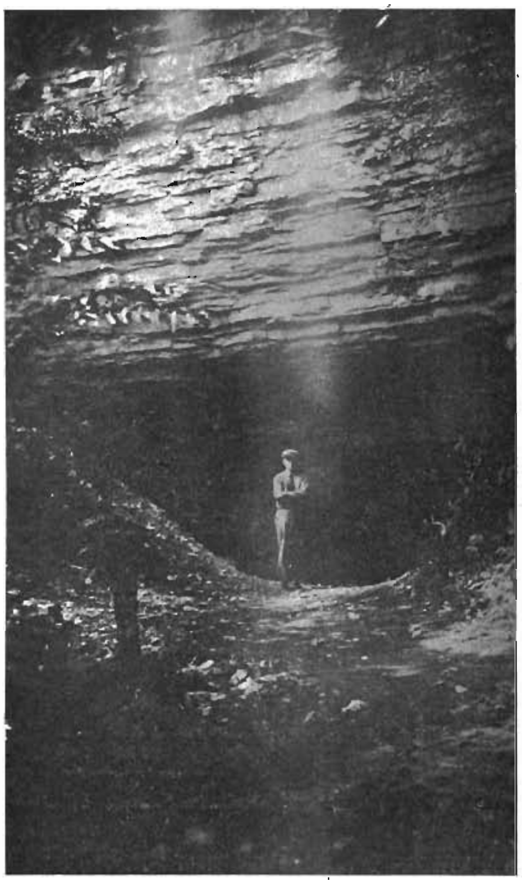


FIG. 19.—Limestone at the "Backbone" southwest of Winterset, Madison county.

county along Skunk river valley there are several outcrops of good limestone. All of the larger areas of white limestone in the county contain rock of high quality which will give excellent results when ground to a fine powder and used as fertilizer. The specimen analyzed from Red Rock township, see page 142, is a calcareous sandstone and is unfit for use as fertilizer. For other differences between sandstone and limestone see page 112.

Madison County.—Large quarries at Earlham and Peru and large outcrops in the vicinity of Winterset (see fig. 19) and in a few places in Clarke county south from Peru toward Davis City, Decatur county, and along Grand River valley to the Iowa-Missouri line, are found to produce an abundance of high grade limestone remarkably well adapted for use as a soil amendment. The

FIG. 20.—Bethany Falls limestone (Earlham). The exposure here illustrated is found on the south side of a projecting ridge of the upland in the southeast quarter of the northeast quarter of section 2 of Ward township, Clarke county.

quarries at Earlham are in Madison township and those at Peru are in Walnut township.

These ledges constitute the lower part of what is known among geologists as the Missouri limestone. This formation contains a very small amount of phosphate, as is shown in the description of an exposure in the quarry of the Peru Stone and Cement Company as follows:

Section at Peru, Madison county

		Feet
1.	Loess	3
2.	Glacial till, weathered and unweathered, partly blue	25
3.	Limestone, buff to yellow, much weathered, thick bedded, some nodules; gives weak reaction for phosphate	4
4.	Shale, a clay parting; gives weak reaction for phosphate	½ to 1
5.	Limestone, in 7 layers, compact, rust-filled cavities in upper foot; phosphate in joints and bedding planes	6
6.	Limestone, contains clay; very slightly phosphatic	1
7.	Limestone, beds 1 foot thick above to 4 inches thick below; gives weak reaction for phosphate in the cracks	5
8.	Shale, blue to black, greenish gray below; just beneath the main quarry floor	

Montgomery County.—In the vicinity of Stennett in Sherman township there are several small outcrops of limestone of good quality but the beds are so extensively intercalated with layers of clay and shale that they are in the non-commercial class.

Excepting the group of limestones extending from Earlham southward to Winterset, Peru and Davis City, there is little, if any, rock of commercial importance in southern Iowa west of Des Moines river.

New and Re-opened Quarries

When the use of ground limestone on soils becomes more general it may be necessary and profitable to re-open a large number of quarries that have not been worked for several years. The use of small crushers in producing an output of cheap pulverized limestone to meet local needs may require that new quarries be opened in many localities. The principal factors to be considered in selecting a location for a quarry are as follows:

FACTORS AFFECTING THE VALUE OF A QUARRY SITE.

1. The kind and quality of rock should be found by test to be that adapted to the uses intended.

2. The rock of the quarry should be free from lenses or layers of chert and from layers of sand and clay.

3. The area from which available stone may be obtained should be large.

4. The depth and kind of overburden or stripping to be removed should not be such as to require excessive expenditure.

5. The height of rock face or depth of quarry it will be possi-

ble to work should be sufficient for commercial development. Most successful quarries are fifteen feet high or more at the face.

6. The elevation of the quarry floor should be well above the water table or surface of the ground water.

7. The surface conditions should permit thorough drainage of the quarry and its suroundings.

8. Abundant space should be available for the disposal of waste materials.

9. It should be located as near as possible to where its product is needed.

10. It should be on or very near a highway and a railroad.

Producers of Agricultural Lime

The following firms have produced agricultural lime during the past four years:

Bartlett & McFarlane	Waterloo
Bettendorf Stone Co.	Bettendorf
Burlington Quarry Co.	19 S. 7th St., Keokuk
Cedar Valley Trap Rock Co.	Cedar Rapids
Dolese Bros.	Buffalo
Eagle Point Lime Works	Dubuque
Hale Roberts Stone Co.	Iowa Falls
Hawkeye Quarries Co.	Cedar Rapids
Keokuk Stone & Construction Co.	Keokuk
Linwood Stone & Cement Co.	Davenport
Mount Pleasant Crushed Stone Co.	Mount Pleasant
McManus Quarries Co.	Keokuk
Murphy Construction Co.	Louisville, Neb.
Peru Stone & Cement Co.	Peru
Quimby Stone Co.	Mason City
State Reformatory	Anamosa
Sugar Factory	Belmond
Sugar Factory	Mason City
Winneshiek County	Decorah

It is reported that agricultural lime is produced also at Earlham, Madison county; Gilmore City, Pocahontas county; Rutland, Humboldt county; Hurstville, Jackson county; near Arlington, Fayette county; on the Chicago, Milwaukee & St. Paul railway west of Marquette, Clayton county; and at Rock Valley in Marshall county.

At some of these places, the crushers are not operated every year and some of them run only during the summer season. At some of them the stone dust is a waste product but several of the companies have sold a thousand tons or more during one year.

The limestone waste from the sugar factories at Mason City and at Belmond is highly recommended for use as fertilizer.

Summary and Conclusions

1. Practically all of the thick beds of limestone in Iowa afford good material for use as a soil amendment and most of this rock is of high quality for this use.
2. Some areas in nearly every county in Iowa need to have limestone applied.
3. The supply of limestone is abundant and its distribution is favorable for its use wherever it is needed.
4. There is some phosphate in Iowa limestones but it is present in quantities too small to have a commercial value.
5. The marls of Iowa are neither sufficiently rich nor abundant to have much economic value.
6. There is no possibility of obtaining potash for fertilizer from the residues of Iowa lakes.
7. The gypsum deposits of Iowa are of the best quality for use as "Land plaster".
8. At present the pyrite of Iowa has no value.
9. Some of the peat of Iowa could be used as a fertilizer filler and some of it may have value as an ingredient of stock food.
10. In many localities peat may be used for fertilizer as barnyard manure is used but with less satisfactory results. Its greatest value for this purpose probably is on soils containing alkali and on sandy soils. It contains about two per cent of nitrogen and less than one per cent each of phosphorus and of sulphur.
11. The black, fine and well-rotted varieties of peat are more useful as fertilizer than the hard brown and fibrous ones, which decay too slowly.
12. The peat-producing areas of Iowa are in the north-central part of the state. Peat is found in a few other localities in river bottoms.

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THE DISTRIBUTION OF ASH AND SULFUR IN IOWA COALS AS AFFECTED BY WASHING AND FLOTATION

BY

H. L. OLIN and J. R. TROELTZSCH

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ASH AND SULFUR IN IOWA COALS

Introduction

The history of coal production in Iowa dates back to 1840 when the first mine was opened in Van Buren county near Farmington. Since that time, with increase in wealth and population of the state, has come great expansion in the mining industry, so that in 1920 according to the United States Geological Survey Iowa ranked eleventh in the list of states with a total net tonnage of 7,813,916.

Considered from the standpoint of the magnitude and importance of the industry scientific studies of the nature of Iowa coals and the possibilities of improving them for use have been few and inadequate. In general these coals are high in ash, sulfur and volatile matter, qualities that make them less desirable for domestic use at least than many of those from southern Illinois and Kentucky and from the eastern states, and in competition with them even in the local markets the Iowa fuels suffer some handicap in spite of the advantage of short freight haul. This inferiority, however, may be more apparent than real, since the method of firing is often the controlling factor that determines whether or not a coal can give good results. Consider for example two coals, one high in volatile matter, as are most of those of this state, and the other low. These may be equal in thermal value or on the ash- and moisture-free basis the first may be even higher. But with improper combustion conditions, with careless stoking or with faulty furnace design the high volatile fuel will in all probability give off much smoke and soot, will show low efficiency in generating steam and will in general be much less satisfactory than the one with a high percentage of fixed carbon. On the other hand it is quite conceivable, indeed it has been proved, that under conditions suitable for the high volatile type of fuel in question good efficiencies and smokeless combustion may be obtained—in other words the high potential heat of the raw coal is converted in a large measure into sensible heat.

The presence of ash and sulfur in large amount, however, is not so easily justified. At best ash is an inert material that must be handled both before and after the coal is burned, and when its chemical composition is such that its fusion temperature falls within certain limits troublesome clinkering in the fuel bed or on the grate manifests itself under conditions of forced draft, and this is the case particularly when the pyrite sulfur content is high. But even these difficulties may be mitigated, to some extent at least, by the use of washing processes whereby partial separation of the pure coal substance and the mineral is effected by virtue of the difference in their specific gravities.

Certain phases of the general problem of improving coal quality or of determining the best conditions for using the fuel in its raw state have been under investigation in the Division of Industrial Chemistry at the State University of Iowa since 1921. This paper, which gives the results of preliminary studies of ash and sulfur elimination, is the first of a series designed to cover the whole field so far as opportunity for research may present itself.

To a limited extent investigations of this character have already been made, the most important of which was that carried out jointly by the Iowa State and the National Surveys at the fuel testing plant established in 1904 at St. Louis in connection with the Louisiana Purchase Exposition (1). The number of Iowa coals tested, however, was limited to five, these being selected from mines in Polk, Lucas, Appanoose, Davis and Marion counties and from the standpoint of a complete survey much was left to be desired. Moreover the steam raising qualities of these coals were the chief matters for study, washing tests being quite secondary in importance, made simply in preparation for investigation of coking possibilities. Results showed equivalent evaporation from and at 212°F. ranging from 7.02 to 7.50 lbs. of water per pound of dry coal.

The quality of coke produced from these coals was in the main unsatisfactory from the standpoints both of strength and of sulfur content. It should be noted, however, that the old fashioned bee-hive oven was used and that no special pains were taken to adapt coking conditions to the high volatile coals under consideration. Researches in the constitution of coal and in the principles of coal carbonization made since that time have put the art of coke manufacture on a distinctly higher plane and it is quite probable that under modern control a much better product would be obtained—at least so far as density and structure are concerned. Unfortunately the elimination of sulfur is still one of the major problems of fuel technology yet to be solved and little improvement could be expected in this respect.

In a single producer-gas test on a Marion county coal of 17 per cent ash, one electrical horse power hour was obtained with 1.73 lbs. of dry fuel whereas under the steam boiler 4.95 lbs. were required to produce the same result.

With respect to coal washing it is interesting to note that in July, 1912, the plant of the Iowa Coal Washing Company of Lakonta, Mahaska county (2), capitalized at $40,000, began work on screenings from mines in that vicinity. The equipment and methods used as described by Kay conformed to good modern practice and results showed that from low grade material running from 25 to 35 per cent of ash, with the removal of 27 per cent as sink, a product with an ash content as low as 8 to 18 per cent was obtained or in other words the screenings were raised to the standard of the average run-of-mine coal of the state.

Outline of the Present Study

In the consideration of the possibility of improving the quality of the coals of this or any other state by removal of ash and sulfur it is evident that a laboratory study of the chemical composition and distribution of the offending constituents may be of importance in determining in advance the character of commercial scale work to be employed or that it may even define the extent to which that work can possibly succeed. In recognition of this principle the present study was undertaken in the hope that results might be secured which would lend encouragement to the subsidizing of fuel research in general with more special attention to coal washing.

It has been definitely established that sulfur occurs in bituminous coal in both the inorganic and organic states. Inorganic sulfur appears mainly as pyrite, a mineral of high density distributed throughout the coal in particles ranging in size from microscopic crystals to relatively large lumps of "brass". Because of its high specific gravity, which is about 5, it can easily be separated from coal of a gravity of the order of 1.3.

To a much smaller extent—usually not more than 0.1 per cent in freshly mined coal—sulfur is found in the oxidized form as the sulfate. This increases slowly with storage in air due to oxidation of pyrite, the reaction being influenced by temperature, moisture content and size of coal particle. It should be noted that in the salt form its density is relatively low.

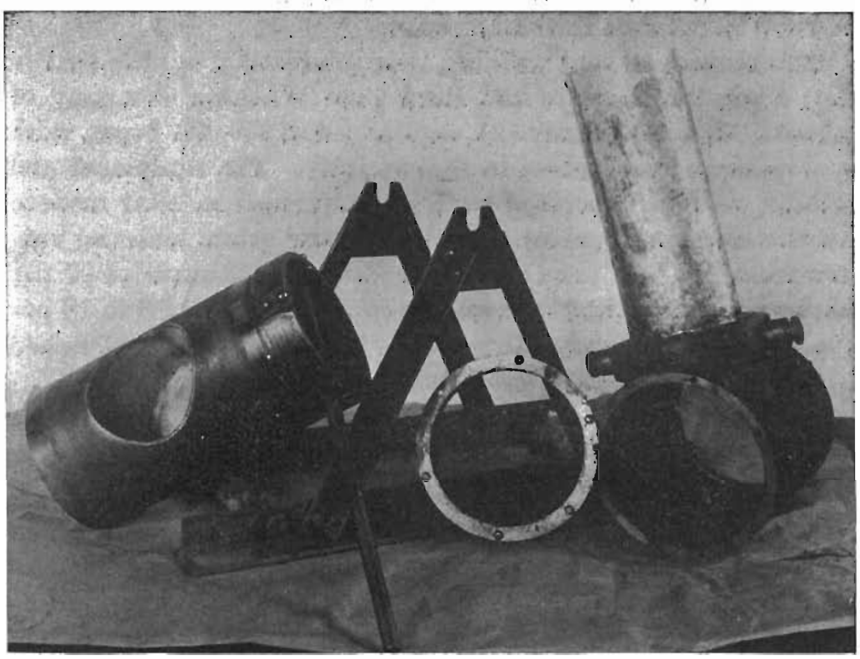

FIG. 21.—Details of sink-and-float apparatus.

Organic sulfur, i.e., that combined chemically with carbon in more or less complex arrangement, may also be classified under two heads, for according to Parr and Powell (3) it appears that it unites with two different types of coal substance and is recognized as humic and as resinic or phenolsoluble sulfur. In either case it has a direct bearing on the washing process for it is uniformly distributed throughout the vein in appreciable percentages and because its density is so close to that of the true coal substance it cannot be removed by flotation.

It is seen, therefore, that the chief value of laboratory studies of sulfur content lies in finding a value below which there can be no reduction of sulfur content by mechanical processes of separation. For example, if the coal from a given mine averages two

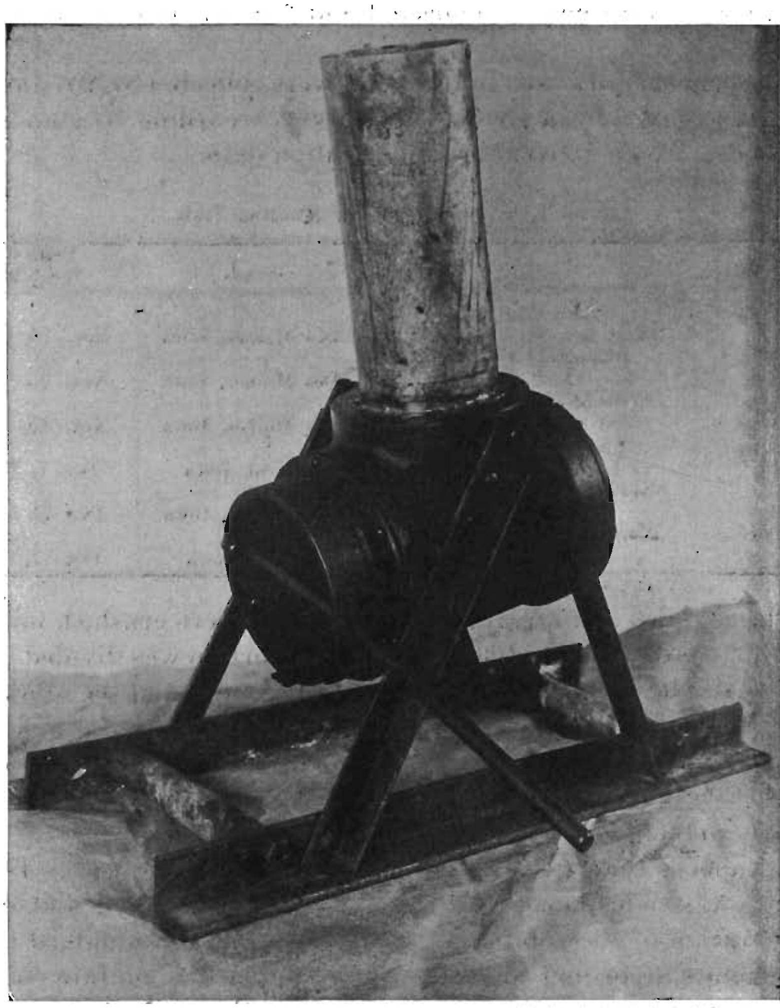

FIG. 22.—Sink-and-float apparatus assembled.

per cent total sulfur and one per cent of this is in the organic form it would of course be impossible to secure a washed product carrying less than one per cent. Moreover in no case can the pyrite be completely removed so that the minimum that can be expected in the clean coal is distinctly greater than the percentage of organic sulfur. It is true of course that small-scale laboratory apparatus gives a more perfect separation than commercial machines and processes but the results are nevertheless indicative of what may be expected and for that reason are valuable.

The coal samples used in this work were collected by Mr. James H. Lees of the Iowa Geological Survey according to standard methods. Table I gives the identification data.

Table I. Coal Samples for Washing Tests

Sample No.	Mine	Place	Date of Sampling
1	Beck Coal Co. NE.¼ Sec. 24, T. 79, R. 25	Des Moines, Iowa	Nov. 18, 1921
2	Bloomfield Coal Co. Sec. 11, T. 79, R. 24	Des Moines, Iowa	Nov. 20, 1921
3	Des Moines Coal Co., 33rd St. & Park Ave.	Des Moines, Iowa	Nov. 22, 1921
4	Sayre Coal Co., Madrid Shaft	Madrid, Iowa	Dec. 7, 1921
5	Norwood-White Coal Co., Mine No. 6	Des Moines, Iowa	Dec. 13, 1921
6	Norwood-White Coal Co., Mine No. 7	Moran, Iowa	Dec. 17, 1921

The samples on arrival at the laboratory were crushed, mixed and quartered down to 400 grams. This portion was divided into two parts, one of which was ground to 100 mesh and the other to 40. The remainder of the sample was crushed to pass a No. 4 sieve and it was this material that was used for the sink and float tests that constitute the major part of the work.

The methods of chemical analysis used need no extensive descriptions as they are all fully described in the literature. Total sulfur was determined by the Parr peroxide method and iron by titration of the solution of the fused ash with standard permanganate according to Zimmerman-Reinhardt. Sulfate sulfur determinations were made as outlined by Fraser and Yancy by extraction of the coal substance with dilute hydrochloric acid.

The pyritic iron and sulfur were measured by two methods, one direct, the other indirect. In the one case the residue from the hydrochloric acid extraction was further treated with dilute nitric acid while in the other a fresh sample was extracted with nitric acid and the sulfur percentages were corrected for sulfate. Organic sulfur was not determined in any case but was calculated as the difference between total sulfur and the sum of the hydrochloric and nitric acid solubles.

Moisture was determined by drying a one gram sample at 105°C for one hour while the ash value was obtained by igniting the dried residue.

In the sink and float tests our procedure followed closely that used in the University of Illinois studies. The average true specific gravity of the coals was first measured by the pycnometer method using water to fill the voids. A solution of zinc chloride of a specific gravity .05 higher than that of the coal was made up for use as the floating liquid and this was employed in apparatus similar in construction to that designed for similar purposes at the University of Illinois. In using this device, which is shown both knocked down and assembled in figures (21) and (22), the cylinder was filled within two inches of the top with the zinc chloride and the coal sample of 200 grams was immersed and stirred until thoroughly wetted. It was then allowed to stand undisturbed for thirty minutes to permit the heavy particles to sink, after which the valve handle was turned through 180 degrees, thereby separating the float and sink fractions. The barrel was next tilted to remove each portion in turn and the solid matter was carefully washed, dried and pulverized for analysis.

In Tables II and III are given the results of these analyses, showing the distribution and form of the iron and sulfur compounds in the unwashed coal. In every case figures given are in percentages based on moisture-free coal.

Table IV shows the distribution of impurities in the two fractions obtained in the washing process.

Table II. Iron Content of Raw Coals
Percentages

Sample Number	1	2	3	4	5	6	Mean
HCl Soluble	.99	1.12	.73	.88	.54	.24	.75
Pyrite iron	2.61	1.62	2.67	2.84	3.15	1.52	2.40
Pyrite +HCl soluble	3.60	2.74	3.40	3.72	3.69	1.76	3.15
Total by analysis of ash	3.80	2.85	3.42	3.95	3.72	1.75	3.25

Table III. Sulfur Content of Raw Coals
Percentages

Sample Number	1	2	3	4	5	6	Mean
Pyrite plus HCl soluble	3.10	2.34	3.38	3.55	3.65	1.75	2.96
HCl soluble (sulfate)	.17	.29	.42	.55	.20	.15	.29
Pyrite sulfur	2.93	2.05	2.96	3.00	3.45	1.60	2.66
Pyrite sulfur calculated from pyrite iron	2.97	1.86	3.05	3.24	3.60	1.74	2.74
Organic sulfur by difference	2.51	.68	1.99	2.08	2.68	1.25	1.86
Total sulfur by bomb	5.61	3.02	5.37	5.63	6.33	3.00	4.82

Table IV. Distribution of Iron and Sulfur in Float and Sink Fractions
Percentages

Sample Number	1	2	3	4	5	6	Mean
Moisture in original	9.84	6.42	5.56	5.96	2.48	7.56	6.30
Percentage of float	72.10	81.80	66.10	73.00	83.50	84.10	76.60
Percentage of sink	27.90	18.20	33.90	27.00	17.50	15.90	23.40
Ash							
Original	13.61	11.91	12.84	12.22	12.72	9.97	12.21
Float	9.40	8.88	19.74	7.90	7.33	6.83	8.35
Sink	26.42	35.23	32.45	38.82	46.15	38.90	36.33
Percentage Removed	54.20	53.80	85.80	85.70	63.50	62.00	67.50
Sulfur							
Original	5.61	3.02	5.37	5.63	6.33	3.00	4.83
Float	3.50	1.78	3.60	3.53	4.07	1.75	3.04
Sink	7.75	6.68	9.13	11.50	14.50	9.02	9.76
Percentage Removed	38.58	40.30	57.60	55.15	40.10	47.75	46.58
Iron							
Original	3.80	2.85	3.42	3.95	3.72	1.75	3.25
Float	2.50	1.65	2.25	2.21	1.68	1.02	1.89
Sink	7.49	6.10	6.05	8.95	14.80	6.12	8.25
Percentage Removed	55.00	39.00	59.98	61.20	69.60	55.60	56.73

Little comment on the figures submitted is necessary other than to stress the fact that the mean sulfur value of the float portions as shown in Table IV is well above that for mean organic sulfur given in Table III which may be taken as the possible minimum. In other words sulfur elimination even under the most favorable conditions is not an efficient process. Figures taken from Table IV show that in order to lower the sulfur content of the average coal from 4.83 to 3.04 per cent and the average ash from 12.21 to 8.35 per cent, reductions of 46.5 and 67.5 per cent respectively, it is necessary to discard 23.4 per cent of the original tonnage. Of this 23.4 per cent, however, 10.3 per cent is ash and sulfur so that only 13.1 per cent of the original tonnage is discarded or converted into what may be classified as low grade material. Rather wide variation is observed in individual coals and this points to the necessity of studying each coal separately before definite conclusions concerning the advisability of attempting large-scale washing can be reached.

We may say in conclusion that this study has covered but a small part of the field but it is nevertheless indicative of what might profitably be done for all the coals of the state as opportunity presents itself and this could then be followed by carload washing tests employing semi-plant size machinery.

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TRILOBITES OF IOWA AND SOME RELATED PALEOZOIC FORMS

BY

OTTO THEODORE WALTER

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TRILOBITES OF IOWA

Introduction

The study of the trilobites of Iowa and of some of the related forms is an attempt to bring together all the work of previous writers and collectors who have contributed in any way to our knowledge of these Paleozoic Arthropods. No work of this kind, including all the trilobites of the Paleozoic of Iowa, has ever before been attempted. The notes and lists made by the authors of the various county reports and of other workers have been more or less abundant but they have been scattered and withal only incidental to the geologic problems under investigation by them.

Slocom,[1] however, forms an outstanding exception to this general statement for he made an excellent beginning in this work by his investigations of the "Trilobites of the Maquoketa Beds of Fayette County, Iowa". In this report twenty species of trilobites are described and twelve of these were found by him to be new.

The nucleus of the material available for the present study was the Samuel Calvin collection and to some extent the C. A. White collection, both at the State University of Iowa. The former especially represents many years of careful collecting and embodies much reliable information concerning exact horizons and localities. In addition to the Calvin collection the writer has had free access to an excellent collection belonging to Professor T. J. Fitzpatrick; to a fairly complete collection of Maquoketa fossils belonging to Mr. A. G. Becker and to his late father Dr. Fredrick Becker; to the collections of Mr. Richard Herrmann in the Herrmann Museum at Dubuque; to the collections of the Davenport Academy of Science and of St. Ambrose College, both of Davenport; and to the collections of the State Historical Department at Des Moines.

A circular letter was addressed to many institutions and individuals in the state asking for opportunity to study any Iowa

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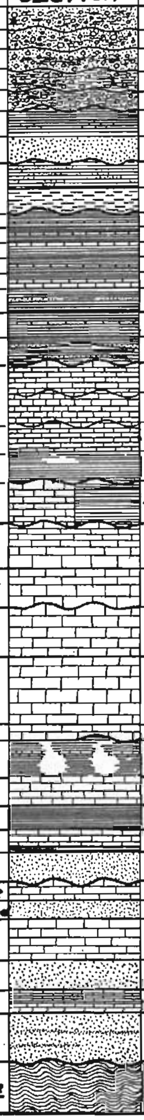
1 Slocom, Field Mus. Nat. Hist., No. 171, Geol. Ser., vol. 4, No. 3, pp. 43-83, plates 13-18, 1913. Also Iowa Geol. Survey, vol. XXV, pp. 183-250, plates XIV-XIX, 1916.

trilobite material in their possession or care. Without exception a courteous response and a willingness to co-operate in the investigation mark the replies received.

During the summer of 1921 the writer in company with Dr. A. O. Thomas engaged in an intensive collecting trip throughout the northeastern part of the state, visiting nearly all the horizons from the Cambrian to the Devonian and nearly all the localities from which trilobites have ever been recorded in county reports and other papers, as well as many new localities. This trip added greatly to a more refined knowledge of the mode of preservation, occurrence and distribution of many of our trilobites. Later in the season three weeks were spent in the vicinity of Dubuque collecting in the Platteville and Galena. Again during the summer of 1922 the writer in company with Mr. Ben H. Wilson made an extensive collecting trip through the southeastern part of the state visiting the younger Paleozoic systems and localities from which trilobites have been reported. Some of these localities are Mount Pleasant, Fort Madison, Burlington, Montrose and Keokuk. The Devonian outcrops in the vicinity of Iowa City, Solon and Linn Junction have been visited on several occasions.

Seventy-nine species of trilobites have been established for the state. Nineteen, or twenty-four per cent, of these are new. But the writer feels fully convinced that further collecting in Iowa will not only add more new species but also will reveal additional species already known outside of the state and thus perhaps double the number of species now known from Iowa. There also remains an open field for the study of Ostracods, Phyllocarids and Echinocarids. Fragmentary remains of the last have been encountered on numerous occasions. Phyllocarids are known from the Sweetland Creek shales, the stratigraphic position of which is somewhat problematical at the present time. Ostracods are exceedingly numerous at certain horizons throughout the Paleozoic of the state.

In the main the classification of trilobites as it appears in the English edition of the Zittel-Eastman Textbook of Paleontology, volume 1, 1913, has been followed. However, in those instances where revisions of old genera have been made, or where new genera have been added since the publication of Zittel's textbook the revised classification is adopted and the new generic names are used in order to bring the classification up to date.



SYSTEM	SERIES	FORMATION	COLUMNAR SECTION	Thickness Feet	Character of Rocks
Pleistocene	Wisconsin				
	Iowan				
	Illinoian				
	Kansan				
	Nebraskan				
Cretaceous	Upper Cretaceous	Colorado		150	Shales, with soft chalky limestones
		Dakota		100	Sandstone
Permian		Fort Dodge		50	Sandy shale and sandstone
				30	Gypsum
Pennsylvanian	Missouri	Wabaunsee		108	Shale and limestone
		Shawnee		233	Limestone and shale
		Douglas		26	Limestone and shale
		Lansing		34	Limestone and shale
		Kansas City		131	Limestone and shale
	Des Moines	Pleasanton			Shale and sandstone
		Henrietta		750	Shale and sandstone
		Cherokee			Shale, sandstone, coal.
Mississippian	Meramec	Ste. Genevieve		0–40	Limestone
		St. Louis Spergen Warsaw		35–105	Limestone
	Osage	Keokuk Burlington		150–215	Limestone
	Kinderhook			150	Shale and sandstone
Devonian	Upper Devonian	State Quarry — Lime Creek		40–120	Limestone Shale
		Cedar Valley		100	Limestone, shaly limestone. Some dolomite in the northern counties.
		Wapsipinicon		60–75	Limestones, shales and shaly limestones.
Silurian	Niagaran	Gower		120	Dolomite
		Hopkinton		220	Dolomite Very fossiliferous in places.
	Alexandrian			0–40	Limestone and dolomite.
Ordovician	Cincinnatian	Maquoketa		200	Dark shales, shaly limestones, and locally, beds of dolomite.
	Mohawkian	Galena		340	Dolomite chiefly. In places unaltered limestone.
		Decorah		0–40	Shales with thin beds of limestone
		Platteville		90	Marly limestones and shales.
	Canadian	St. Peter		80–160	Sandstone
		Prairie du Chien — Shakopee		20–80	Dolomite
		Prairie du Chien — New Richmond		20	Quartzitic sandstone
		Prairie du Chien — Oneota		150	Dolomite
Cambrian	Croixan	Jordan		100	Coarse sandstone
		St Lawrence		50	Dolomite, sandy
		Dresbach			Sandstone, with bands of glauconite
Algonkian	Huronian	Sioux Quartzite			Quartzite

FIG. 23.—Chronological table of the Paleozoic rocks of Iowa. Adapted from Jesse V. Howell, Iowa Geol. Survey, vol. XXIX, Ann. Reports for 1919 and 1920, p. 20.

The writer has refrained as much as possible from establishing new species on inadequate material. Erection of species on pygidia alone is ill-advised and has been resorted to in only a few cases. As a general rule it is unwise to give generic or specific rank to forms the cephalic characters of which are uncertain or entirely wanting. A perusal of the literature on trilobites reveals far too many instances in which species and even genera based on pygidia do cause confusion. In the opinion of the writer this practice should be resorted to with extreme caution.

It has been deemed inadvisable to give family and generic definitions except in the case of *Proetides,* a new genus, and of *Conaspis,* which is not given in ordinary texts such as Zittel, Grabau and Shimer, and others.

The bibliography listed for the various species is not intended to be complete or exhaustive except in cases where it was necessary to give the full synonymy of those forms whose generic reference has been changed since the founding of the species. In all other cases only as much of the bibliography is quoted as seemed relevant to an accurate understanding of the Iowa material and its history. A more extended bibliography seems to the writer not only superfluous but also an unnecessary repetition in view of the fact that Vogdes'[2], Bassler's[3] and Weller's[4] bibliographies are readily available to students of trilobites.

In cases where a species was formerly reported from the state but where the specimen was not collected or seen by the writer the original description is used here for the sake of completeness. In cases where the material was identifiable but too poor or fragmentary for description a similar method was pursued, and in those cases where earlier descriptions are deemed adequate, even though good material was at hand, the earlier descriptions have been freely drawn upon and due credit has been given in all cases.

Results of the study

1. The study has resulted in establishing for the state seventy-nine species of trilobites, one species of an arachnid, one species

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2 Vodges, Bibliography of Paleozoic Crustacea: California Acad. Sci., San Francisco, 1913. Also Paleozoic Crustacea: Trans. San Diego Soc. Nat. Hist., San Diego, Cal., July, 1917.

3 Bassler, Bibliographic Index of American Ordovician and Silurian Fossils: Smithsonian Institution, U. S. National Mus. Bull. 92, vols. 1 and 2, 1915.

4 Weller, Bibliographic Index of North American Carboniferous Invertebrates: United States Geological Survey, Bull. 153, 1898.

of a cirriped, and one species of a decapod crustacean. Of the seventy-nine species of trilobites, nineteen, or twenty-four per cent, are new. From one to eight species in each system of rocks except the Pennsylvanian and the Permian were found to be new. In the former system only two species of trilobites were encountered and the latter or Permian system is unfossiliferous in Iowa with the exception of such fossils as occur in the pebbles of a basal conglomerate below the gypsum near Fort Dodge. The arachnid is new also and the cirriped from the Lime Creek beds is here described as new by Dr. A. O. Thomas.

2. Of these seventy-nine species found in the state thirty-nine represent Iowa types and the remaining forty were originally described from specimens found outside of Iowa. The present location of the types is denoted under each species.

3. The seventy-nine species are distributed through thirty-eight genera. Of these genera *Proetides* is new and thirteen are recorded for the first time as occurring in the state.

4. The following new trilobite-yielding localities have been added: The Eau Claire formation about half a mile south of Lansing; a *Dikelocephalus minnesotensis* horizon three miles west of Lansing; an *Isotelus* zone in the southeast quarter of the northwest quarter of section 9, Madison township, Winneshiek county; a *Ceraurus* zone in the Platteville along Sny Magill creek, Clayton county; an *Eoharpes* zone in the Platteville limestone at Boyle's quarry near McGregor and in the Platteville limestone near Dubuque; the *Griffithides wilsoni* horizon in the Pella beds at Mt. Pleasant, Ottumwa, Fremont and Ollie; the *Griffithides scitulus* horizon in the Henrietta limestone at Des Moines.

5. Many of the trilobites have a definite stratigraphic value as horizon markers of exposed strata and can now be so used in the state. A few examples are cited as an illustration: *Dikelocephalus minnesotensis* is limited to a narrow zone near the base of the St. Lawrence limestone; *Saratogia wisconsensis* and *Ptychaspis striata* are fairly common but in Iowa are limited to the Eau Claire formation; *Calymene mammillata* is found only in the Lower Maquoketa near Graf; *Calymene gracilis* definitely marks the upper layers of the Upper Maquoketa at Pattersons Springs

near Brainard and elsewhere; the different species of *Isotelus* are limited to the *Isotelus* zone of the Lower Maquoketa; *Encrinurus ornatus* is the type fossil of the Anamosa-LeClaire formation; *Proetus prouti* has a comparatively wide areal distribution in the Devonian but stratigraphically it is limited to the basal Cedar Valley; *Goldius thomasi* is limited to a narrow zone in the Owen substage of the Lime Creek shales; *Cyphaspis brandonensis* definitely marks the Independence shale; *Griffithides wilsoni* is an excellent index fossil of the Pella beds. *Phillipsia tuberculata* is a trilobite peculiar to the Burlington limestone and is the first trilobite ever reported in Iowa from this highly fossiliferous formation; *Griffithides scitulus* is a guide fossil of the Des Moines shaly limestone and *Phillipsia major* is a guide fossil of the Tarkio limestone.

6. Panderian organs, which are only rarely observed in trilobites, have been found on two Iowa specimens, namely *Isotelus gigas* and *Ectenaspis beckeri.*

Acknowledgments

The writer wishes at this time to express his sincere appreciation of the assistance of Mr. A. G. Becker of Clermont. With enthusiastic interest he made available for study his fine collection of Maquoketa fossils as well as that of his late father, Dr. Fredrick Becker. He not only cheerfully gave valuable information but rendered most valuable personal service in conducting collecting excursions to the famous localities in Fayette county, with which he is most intimately familiar.

The writer is also much indebted to Dr. G. M. Ehlers for the loan of specimens from the paleontologic collection at the University of Michigan, to Mr. Edgar R. Harlan, curator of the State Historical Department at Des Moines, for the loan of a specimen of *Phillipsia tuberculata* and to Mr. G. A. Larson of Des Moines for his recent gift to the University of several fine specimens of *Griffithides wilsoni* from the Pella beds at Ottumwa.

Dr. W. H. Norton of Cornell College generously loaned a fine set of *Encrinurus ornatus,* collected at Mt. Vernon, and to him is credited a beautiful new species of *Proetus* from Linn and Janesville.

The writer has been greatly favored by the courtesy and interest of Prof. T. J. Fitzpatrick, who placed his entire collection of fine and rare trilobites at the writer's disposal, giving exact information concerning horizons and localities. Much credit is due his generous spirit in aiding the progress of this work.

Grateful acknowledgment is due Father Ulrich Hauber, of St. Ambrose College at Davenport, who spent several delightful days in the field with the writer collecting material which he presented to the State University of Iowa for study; and for the delightful hospitality which the writer enjoyed at St. Ambrose College during his stay at Davenport.

The writer is greatly indebted to Mr. Ben H. Wilson of Mount Pleasant for his untiring devotion to our work. He examined many private, college and museum collections for material that would enhance and add to the completeness of the investigation. Especially does the writer wish to express his gratitude to Mr. Wilson for the helpful and successful trip taken with him in the summer of 1922 to all the noted trilobite localities in southeastern Iowa, with which Mr. Wilson is well acquainted.

An expression of admiration is here recorded for the pioneer work of Mr. Richard Herrmann of Dubuque and his family who, side by side with a business career, have found inspiration in studying "the yesterdays" of human and geologic history. They have gathered around them directly and indirectly and with untiring patience and effort a large body of valuable and interesting facts as well as a great variety of museum specimens—constituting the Richard Herrmann Museum—the trilobites from which were freely placed at the writer's disposal.

The writer also wishes to acknowledge the splendid spirit of coöperation shown by Dr. Charles D. Walcott, Dr. Percy E. Raymond, Mr. Arthur Ware Slocom, and Dr. Aug. F. Foerste in the identification of specimens submitted to them. Their help has contributed greatly to bringing the classification up to date.

In having made the acquaintance, through correspondence, of the able scholar and paleontologist, Dr. George H. Girty, the writer feels that he has been especially favored. The Carboniferous fossils which were submitted to Doctor Girty for verification or identification were taken up one by one with the most thorough and painstaking efforts and discussion was invited. It has been a peculiar pleasure indeed to consider difficult problems with one who left nothing to guesswork but who exhausted every possibility to arrive at positive scientific truth.

In addition acknowledgment is due the different members of the staff of the Department of Geology of the State University of Iowa, all of whom have contributed directly and indirectly with material, counsel and advice to the work in progress, and to the students of the paleontology classes, who have most enthusiastically contributed to the writer for study their findings on their various field trips. Further mention of these students is made in the discussion of the species.

Grateful acknowledgment and recognition of her efficiency is given to Miss Jane E. Roberts, former librarian, who coöperated most cheerfully for a period of two and one-half years in securing many valuable and indispensable publications from reference libraries and from various institutions.

And finally I wish to pay tribute to Dr. A. O. Thomas, a scholar, friend and untiring co-worker. His counsel, leadership and interest in the preparation of this work have not only been a source of continual pleasure and inspiration throughout a period of three years but also have taught the writer the method and secret of scientific investigation.

The classification and terminology is copied from Slocom's report which appeared in volume xxv of this series.

Classification and Terminology.

The classification here used is that prepared by Prof. Charles E. Beecher and given in the English edition of Zittel's Textbook of Paleontology. For definitions of the various orders and families the reader is referred to that work.

In order to make clear in what sense various terms are used by the writer, the following glossary is given. The letters or figures in parentheses refer to text figure 24.

Annulations: The ringlike divisions of the axis of the pygidium. (13)

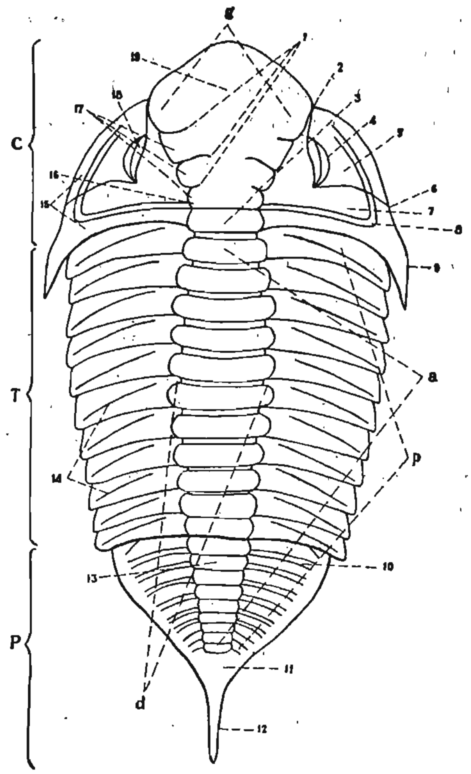

FIG. 24.—Diagrammatic figure of a trilobite. Drawing after Slocom by David Tracy Jones.

Anterior: Situated in front.

Anterior limb of the facial suture: The portion of the facial suture lying in front of the eye. (2)

Axis: The median longitudinal lobe of a trilobite. (a)

Carapace: The hard shell covering the dorsal surface of a trilobite.

Caudal spine: A spine at the posterior extremity of the pygidium. (12)

Cephalon: The head of a trilobite. (C)

Cheeks: The two lateral portions of the head or cephalon of a trilobite, divided into fixed (7) and free (5) cheeks by a facial suture.

Compound eyes: Eyes commonly present upon the free cheeks of trilobites; they are made up of a large number of small facets. (4)

Cranidium: The portion of the head or cephalon of a trilobite lying between the facial sutures, comprising the glabella and the fixed cheeks.

Distal: Away from the median line..

Dorsal: Pertaining to the back.

Dorsal furrows: The furrows or depressions bounding the axial or medial longitudinal lobe of a trilobite; same as the axial furrows. (d)

Doublure: The infolded margin of the trilobite test.

Facial suture: The suture in the head or cephalon of a trilobite separating the fixed from the free cheeks. (2, 6)

Fixed cheek: The portion of the cephalon or head of a trilobite lying between the glabella and the facial suture. (7)

Free cheek: Lateral portion of the cephalon or head of a trilobite, lying between the facial suture and the lateral cephalic border. (5)

Frontal lobe: That portion of the glabella anterior to the first lateral furrows. (19)

Genal angles: The postero-lateral angles of the cephalon or head of a trilobite.

Genal spines: The posterior prolongation into spines of the genal angles of a trilobite. (9)

Glabella: The central or axial portion of the cephalon or head of a trilobite. (g)

Holochroal eyes: Compound eyes of a trilobite whose visual area is covered with a continuous horny integument.

Hypostoma: The under lip of a trilobite.

Lateral furrows: The transverse furrows or grooves of the trilobite glabella, sometimes continuous across the glabella and sometimes greatly modified. (1) These furrows define the lobes of the glabella. (17)

Marginal border: The thickened or otherwise differentiated external border of the cephalon and pygidium of a trilobite. (15)

Marginal furrow: The groove or depression lying just within the marginal border of the cephalon and pygidium of a trilobite. (8)

Occipital furrow: The posterior transverse groove or furrow of the glabella of a trilobite, lying in front of the occipital segment. (16)

Occipital lobes: Small, lateral lobes of the occipital segment present in some trilobites, which are morphologically different from the lateral lobes of the glabella.

Occipital or neck segment: The posterior transverse segment of the trilobite glabella, lying between the posterior margin and the occipital furrow. (3)

Ocular ridges: Ridges extending from near the anterior extremity of the glabella to the eyes in some trilobites. The eye lines.

Palpebral lobes: Lobes of the fixed cheeks within the margins of the eyes. The eye lobes. (18)

Pleurae: The two lateral longitudinal lobes of a trilobite, applied chiefly to the thoracic region and the pygidium. (p)

Pleural grooves: Grooves on the pleuræ of the thoracic segments. (14)

Pleural ribs: The fused segments in the lateral lobes of the pygidium. (10)

Post-axial region: The flattened area occupying the median portion of the pygidium of some trilobites, posterior to the elevated axis. (11)

Post-cephalic margin: The posterior margin of the head or cephalon.

Posterior cheek furrow: The marginal furrows or grooves present in some trilobites, which extend across the cheeks from the extremities of the occipital furrow of the glabella towards the genal angles. (8)

Posterior limb of facial suture: That portion of the facial suture extending from the posterior extremity of the eye to the posterior or lateral margin of the cephalon. (6)

Proximal: Toward the median line.

Punctate: Having minute depressions or pits.

Pustulose: Covered with pustules or blister-like prominences.

Pygidium: The tail or posterior region of the trilobite test. (P)

Schizochroal eyes: Compound eyes of the trilobites in which the visual area is occupied by small openings for the separate facets.

Segments: The transverse divisions of the thorax or pygidium.

Test: The hard outer covering of the trilobite.

Thorax: The central segmented region of the body of trilobites. (T)

Ventral: Pertaining to the under surface.

TRILOBITES OF THE CAMBRIAN

Order **HYPOPARIA** Beecher

Family **AGNOSTIDAE** M'Coy

AGNOSTUS PARILIS Hall

Plate X, figs. 10, 11.

Plate XII, fig. 1.

1863. *Agnostus parilis* Hall, 16th Rept. New York State Mus. Nat. Hist., p. 179, pl. 10, figs. 23, 24.
1892. *Agnostus parilis* Vogdes, American Geologist, vol. 9, p. 394, pl. X, fig. 4.

Description.—Very small in size; head shield semioval in outline, truncate posteriorly, surface strongly convex curving abruptly to the sides and more gently toward the anterior margin. Margin narrow but well defined, increasing in width anteriorly. A small node is present on each postero-lateral angle. The central area of the posterior third of the shield is defined by a faint parabolic curve whose posterior extremities divide the posterior margin into three subequal parts.

The pygidium is similar in general form to the head shield. An elongate V-shaped impression extends backward on each side of the central area from the anterior margin to about one-third the length of the shield. The antero-lateral angles are obliquely truncate.

The surface of both head and tail shields is smooth.

Average length of a cephalon 3.5 mm., width across the posterior margin 3.2 mm.

Position and locality.—Eau Claire formation, about one-half mile southeast of Lansing. (Field notes of T. J. Fitzpatrick.)

Remarks.—Our specimens agree quite well in general form and size with those described and figured by Hall, but differ in being proportionally shorter and in lacking the median node on each shield. These differences may be variations of minor importance or they may be the result of the mode of preservation, though both Hall's and our specimens occur in a buff or drab-colored sandstone.

Order OPISTHOPARIA

Family OLENIDAE

Genus CONASPIS Hall

Description of genus.—"Glabella subconical, medium sized eye-lobes, rather strong postero-lateral limbs, narrow fixed cheeks, and with facial sutures extending almost directly forward from the eye lobes so as to form a narrow frontal limb; the frontal rim is usually well defined and cut obliquely by the facial sutures." (Walcott, Cambrian Geol. and Pal., Vol. II, No. 13, p. 357, 1914.)

CONASPIS MICROS n. s.

Plate XI, figs. 5, 6.
Plate XII, fig. 2.

Description.—Cranidium small, elongate, depressed convex, gently arched longitudinally. Facial sutures converging abruptly in front of the eye-lobes to the dorsal furrows opposite the antero-lateral angles of the glabella, thence converging less abruptly they pass around the antero-lateral angles of the frontal limb and cut the same in line with the dorsal furrows opposite the palpebral lobes. Glabella prominent, depressed convex, subconical, gently arched longitudinally, sides straight and diverging posteriorly. Entire surface smooth. Occipital groove transverse and well defined. Occipital segment broad, flattened and strongly arched. Fixed cheeks very narrow within the eye-lobes, confluent with the dorsal furrows at the antero-lateral angles of the glabella; frontal limb comparatively narrow and elongate, faintly thickened near the dorsal furrow, arched transversely and sloping gently forward. The median length is somewhat greater than that of the occipital segment. Palpebral lobes narrow, elongate and bounded proximally by a fine groove. Posterior limb of fixed cheek unknown.

Free cheeks depressed and faintly sulcate about the base of the narrow orbital ridge, thence sloping abruptly to the marginal groove; border thickened and continued at the genal angles into a nearly straight spine.

Pygidium unknown.

Dimensions.—Length of an average sized cranidium 5 mm., width of same across palpebral lobes 4 mm.

Position and locality.—Eau Claire formation, one-half mile southeast of Lansing (Prof. T. J. Fitzpatrick).

Remarks.—*Conaspis micros* occurs in association with *Saratogia wisconsensis* and *Ptychaspis striata.* Some of the thin slabs of buff-colored sandstone contain the small cranidia in great abundance. The species closely resembles *Conaspis anatinus* (Hall) but differs from the latter in having proportionally longer palpebral lobes and a narrower but longer frontal limb, whose sides are in direct line with the dorsal furrows.

In *C. anatinus* the frontal limb is as wide as the base of the glabella. Several curved cheek spines, more or less perfect and attached to parts of free cheeks, are associated with the cranidia. They are similar in general contour to those of *Conaspis anatinus* (fig. 35, Pl. VII, 16th Ann. Rep. New York State Cab. Nat. Hist.)

Family **CERATOPYGIDAE**

Saratogia wisconsensis (Owen)

Plate XI, figs. 7-10.

1852. *Crepicephalus? wisconsensis* Owen, Rept. Geol. Survey Wisconsin, Iowa and Minnesota, pl. I, fig. 13 (illustrates a cranidium; upper figure).
1863. *Conocephalites wisconsensis* Hall, 16th Ann. Rept. New York State Cab. Nat. Hist., p. 164, pl. 7, figs. 39-41; pl. 8, figs. 22-24, 27, 28.
1863. *Conocephalites wisconsensis* Shumard, Trans. Acad. Sci. St. Louis, vol. 2, p. 103.
1863. *Conocephalites latifrons* Shumard, Trans. Acad. Sci. St. Louis, vol. 2, p. 101.
1867. *Conocephalites wisconsensis* Hall, Trans. Albany Inst., vol. 5, pp. 130, 151, pl. 2, figs. 39-41; pl. 3, figs. 23, 24, 27, 28.
1883. *Conocephalites wisconsensis* (Owen) Chamberlin, Geol. Wisconsin, vol. 1, p. 131.
1893. *Anomocare wisconsensis* Vogdes, Bibliography of Paleozoic Crustacea: California Acad. Sci., vol. IV, p. 271.
1899. *Ptychoparia (Lonchocephalus) wisconsensis* Walcott, U. S. Geol. Survey, Monogr. 32, pt. 2, p. 461, pl. 64, figs. 1, 1a (not 1b or 1c).
1916. *Saratogia wisconsensis* Walcott, Smithsonian Misc. Coll.

vol. 64, No. 3, p. 198, pl. 34, figs. 5, 5a-c. Eau Claire formation (pygidium not figured).

Description.—Cranidium large, depressed convex, gently arched longitudinally. Glabella subconate, very gently rounded or nearly truncate in front, transverse behind, sides straight and diverging from front to back; surface along axial line sloping gently forward, sides sloping more abruptly from the median line to the dorsal furrows; width at the occipital groove nearly equal to the length. One pair of very faint lateral furrows originates at the dorsal furrows opposite the palpebral lobes and extends obliquely backward becoming obsolete before reaching the median region of the glabella. Occipital groove shallow but well defined at the sides, nearly obsolete in the middle. Occipital segment strongly arched, wider in the center than at the sides and bearing a long, stout and slightly arcuate median spine directed almost horizontally backward. Fixed cheeks narrow opposite the glabella; posterior limb narrow, directed obliquely backward in such a way that a straight line projected from it would cut the anterior portion of the palpebral lobe; anterior border somewhat wider than the anterior width of the glabella, sloping downward in a gentle curve for more than one-half its width to a broad submarginal groove, thence continuing anteriorly into a flattened horizontal border. Favorably preserved specimens show flexuous lines in the submarginal furrow. The facial sutures expand along a gentle curve from the anterior margin of the palpebral lobes to the submarginal groove then converge to the anterior border. Palpebral lobes long, crescentic, bounded proximally by a parallel groove.

Free cheek moderately convex, surface sloping in a curve from the eye to the marginal groove; border thickened and continued into a long, slender, inwardly curved spine at the genal angles and a very short spine in front.

Pygidium transversely subelliptical, anterior margin describing the arc of a great circle, posterior margin the arc of a smaller circle, slightly emarginate posteriorly, antero-lateral angles obtusely rounded. Length is to width as 1 to 2.5. The outer margin is somewhat thickened, nearly horizontal, decreasing in width posteriorly. The axis is very prominent, conical, rising abruptly above the pleuræ, occupying one-fourth the anterior width of the shield; sides straight and tapering uniformly to a raised obtusely rounded termination within the marginal groove. A rounded, abruptly tapering ridge connects the last segment with the posterior margin. There are five rounded transverse segments the first four of which decrease regularly in size, the fifth or terminal segment being about twice as wide as the fourth. The pleural lobes slope gently and evenly from the dorsal furrows to the marginal grooves. There are three broad, flattened annulations exclusive of the anterior articulating ring; all end at the marginal groove. The anterior annulation is faintly sulcate, the sulcus originating on the posterior margin at the dorsal furrow, passing obliquely forward to the center of the annulation and thence outward medially to the end.

There is a wide range in size of both cranidia and pygidia. An average sized cranidium of the specimens at hand is 13.5 mm. long exclusive of the occipital spine, 10.2 mm. wide across the palpebral lobes, and 11 mm. wide across the frontal border. The median length of a large specimen, exclusive of occipital spine, is 27 mm. A pygidium of average size is 10.5 mm. long and 23.5 mm. wide.

Position and locality.—Upper Cambrian, Eau Claire formation, Lansing, Iowa. Prof. T. J. Fitzpatrick collected the specimens about half a mile down the river from the town.

Remarks.—The specimens upon which the foregoing description is based were collected from approximately the same position and locality in Iowa as that given by Walcott (op. cit., p. 199) for this species. Figure 11, Plate XI, is a good illustration of the associated fauna. The pygidium is referred to this species only tentatively, none having thus far been found in actual conjunction with the thorax and cephalon. Two types of pygidia are associated on the slabs from this locality. The larger type has a definite, somewhat thickened and moderately wide horizontal border and agrees well in size with *S. wisconsensis*. The second type because of its smaller size and other differences discussed under that species is referred to *Ptychaspis striata*.

Family ILLAENIDAE Corda

Genus ILLAENURUS Hall

ILLAENURUS QUADRATUS Hall

1863. *Illaenurus quadratus* Hall, 16th Rept. New York State Mus. Nat. Hist., p. 176, pl. 7, figs. 52-57.
1916. *Illaenurus quadratus* Walcott, Smithsonian Misc. Coll. vol. 64, No. 5, p. 406, pl. 45, figs. 1, 1a-e. Walcott points out that the thorax has eleven segments.

That this species has been found in the Upper Cambrian of Iowa is somewhat doubtful. Associated with *Illaenurus calvini* there is but one incomplete cranidium which in any degree resembles *I. quadratus*. The latter differs from the former in having a proportionally shorter and wider cranidium, diverging less anteriorly, and in having eleven instead of ten thoracic segments.

Further field work in the Upper Cambrian of Iowa will undoubtedly prove its presence here since it is reported from similar formations in Wisconsin and Minnesota.

ILLAENURUS CALVINI n. s.

Plate XI, figs. 15-20.

1921. *Illaenurus calvini* Walter, Up. Camb. Trilobites: Abstr. Bull. Geol. Soc. Am., vol. 32, p. 128 (brief notice).

Description.—Body broad, oval-elongate, anterior and posterior margins broadly rounded, sides very gently rounded. Trilobation distinct. Length is to width as 8 to 5. Cephalon large, nearly semicircular on outline, twice as wide as it is long; genal angles rounded. Glabella undefined. Cranidium large, flattened and smooth, the part in front of the palpebral lobes being keystone shaped and somewhat longer than one-half the total length. Occipital segment narrow, faintly but clearly defined between the indistinct dorsal furrows along the articulating margin. Dorsal furrows undefined. Palpebral lobes marginal, crescentic and located slightly posterior to the middle of the cranidium. The width across the palpebral lobes is approximately equal to the width across the anterior extremity. Fixed cheeks extended posteriorly into long, narrow, flattened limbs, ending a short distance within the genal angles.

Free cheeks large, subtriangular, very gently convex, somewhat longer than wide, and continuous with the antero-lateral margin of the glabella. Genal angles rounded and faintly produced.

The facial sutures originate on the posterior margin of the cephalon just within the genal angles and describe a slightly sinuous curve to the posterior margin of the palpebral lobes in front of which they diverge toward the anterior margin, cutting the same approximately in line with the outer margin of the eye lobes.

Thorax subquadrate, nearly as wide as it is long, subequally trilobate, composed of ten segments; sides gently rounded. Axis broad, occupying one-half the width of the thorax, separated from the pleural lobes by broad shallow dorsal furrows. Pleural lobes narrow, having a serrate outer margin due to the slightly recurved tips of the segments. A shallow groove extends diagonally across each segment from the inner anterior to the outer posterior margin. The segments are longest and widest in the center, decreasing in size toward the anterior and posterior ends.

The pygidium is flattened, much smaller than the cephalon and transversely biconvex in outline. The anterior margin describes the arc of a large circle, the posterior margin that of a smaller circle. An axis is faintly visible.

Dimensions.—No. 9002, length of cranidium 13 mm., width of same across palpebral lobes 9.7 mm.; No. 9000, length of thorax 11.4 mm., width of same 13.6 mm. Length of pygidium 5 mm.

Position and locality.—Upper Cambrian, St. Lawrence limestone, on Fire-bell Hill, Lansing.

Remarks.—Most of the material upon which the description of this species is based was collected nearly thirty years ago by the late Dr. Samuel Calvin. In the Iowa Geological Survey, volume IV, page 58, Professor Calvin calls attention to these specimens in the following words: "There are occasional fragments of an *Illaenurus,* differing from *Illaenurus quadratus* Hall, in the form and other characters of the glabella. In general the trilobites are represented only by impressions of dismembered portions of the dorsal exoskeleton, but in two specimens of *Illaenurus* the glabella and thoracic segments retain their normal, relative position."

The species occurs in association with *D. minnesotensis* and *Aglaspis thomasi*. Cranidia, free cheeks and pygidia are found rather commonly. Entire specimens are exceedingly rare.

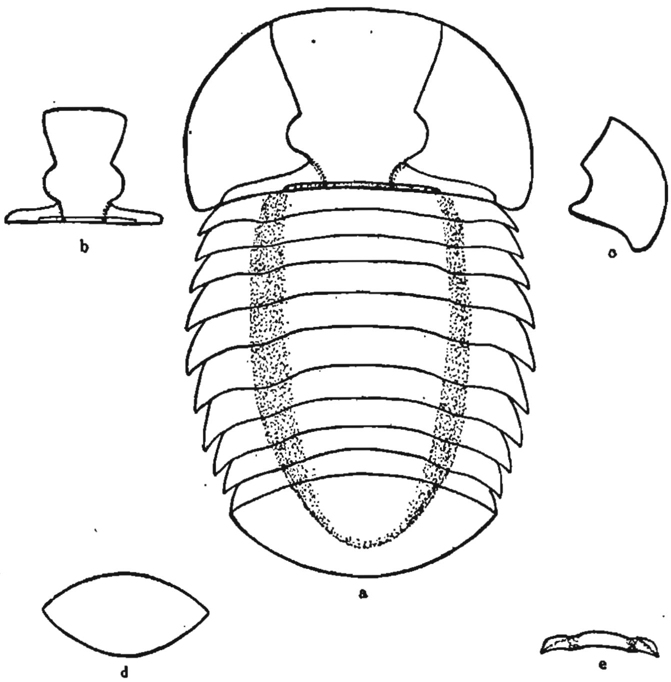

FIG. 25.—Restoration of *Illaenurus calvini;* a, complete specimen much enlarged; b, cranidium, note narrow occipital segment; c, free cheek, very broad with rounded genal angle; d, outline of a nearly featureless pygidium; e, thoracic segment.

Illaenurus calvini differs from *I. quadratus* in having a proportionally longer cranidium, a greater divergence in front of the eye-lobes, in being narrower between the proximal ends of the posterior limbs of the fixed cheeks, in having ten instead of eleven thoracic segments, and in the presence of long postero-lateral extensions of the fixed cheeks.

The species is named in honor of the late Professor Calvin. Figure 25 is a restoration of the species.

Family DIKELOCEPHALIDAE

DIKELOCEPHALUS MINNESOTENSIS Owen

Plate X, figs. 1-9.

1852. *D. minnesotensis* Owen, Rep. Geol. Surv. Wisconsin, Iowa and Minnesota, p. 574, pl. 1, figs. 1, 2; pl. 1 A, figs. 3, 6.
1914. *D. minnesotensis* Walcott, Cambrian Geol. and Pal., Smithsonian Miscellaneous Collections, vol. 57, No. 13, p. 369; pl. 60, figs. 1-8; pl. 61, figs. 1-3, 5-7; pl. 62, figs. 4-6; pl. 66, fig. 1.

The body form, as restored by Owen, 1852, is subquadrate, the sides are subparallel, the posterior margin is broken by the presence of two postero-lateral caudal spines. Body depressed away from the central axis.

The head is broadly crescentic in outline, the long genal spines forming the horns of the crescent. The even concave posterior margin is interrupted centrally by the recurved upward arching of the occipital ring.

The cranidium is roughly four sided, being narrowest about its midlength, wider across the palpebral lobes and frontal shield, and widest across the posterior limbs of the fixed cheeks.

The glabella is quadrangular, longer than wide, moderately to strongly convex, evenly rounded in front, less rounded in back, sides parallel. It is divided by the two furrows traversing it into one large well-rounded anterior and two narrow posterior lobes. The occipital furrow is moderately impressed and almost straight. The posterior glabellar furrow is more deeply impressed; it arises near the midlength of the marginal border and curves backward to the middle line where it is separated from the occipital furrow by a distance equal to the width of the occipital ring, thus forming a middle lobe which is laterally expanded. The anterior lobe is well rounded in all directions and partly divided on each side by a submedian sidefurrow which extends about one-third the distance across. Very rarely another even fainter side furrow may be observed anterior to the last.

The facial suture is sigmoid, arising at the lateral margin of the frontal shield in line with or somewhat in front of the anterior extremity of the glabella; it proceeds along a slightly curved line to the narrowest part of the fixed cheek and is continued around the palpebral lobe, thence abruptly outward along the posterior limb of the fixed cheek, ending at a distance from the dorsal furrow equal to the average width of the glabella.

The fixed cheeks are extended in front of the glabella into a broad slightly arched and rounded frontal shield. Thus the cephalon has the form of an inverted shovel with a broad shallow groove crossing it near the posterior margin parallel to the free edge. The cheeks are most constricted a little in front of the palpebral lobe, thence they spread out opposite the occipital furrow and extend laterally as narrow, flattened, knife-blade-like posterior limbs bearing a deep submarginal furrow which is continued into the free cheek.

The free cheek is subtriangular in shape and extends posteriorly into a long flattened spine. The even contour of the posterior margin is broken by the posterior limb of the fixed cheek. The posterior half of the inner margin gives rise to a deep sinus for the eye. The anterior half is curved in accordance with the outer margin of the frontal shield, in front of which it is continued as a spine. The outer margin is of even contour, having a faint submarginal depression. The area around the sinus is convex, sloping abruptly toward the flattened outer area.

The hypostoma is broad, the central portion is oval-elongate to subcircular, the margins are expanded, bearing a submarginal groove which ends in a pit on each side of the central portion near the posterior end.

The thorax is subquadrate, axis convex and narrow, pleural lobes depressed, sides subparallel, dorsal and intersegmental furrows well defined.

Thoracic segments composed of well arched axial rings one-fifth the width of the thorax and continued in front as a narrow similarly arched elliptical plate. They are continued obliquely outward and backward as pleural segments which are raised and narrow near the axis, but wider where they flatten out distally until they end in recurved sword-shaped tips. An intrasegmental furrow of diminishing proportions begins at the inner anterior margin and extends diagonally across to the outer posterior margin. This same character is continued into the pygidium, becoming less recognizable toward the extreme posterior end of the axis.

The pygidium is transverse, wider than long by a length usually equal to or greater than that of its axis. Axis strongly arched throughout, composed of five segments including the large terminal segment, which often shows faint transverse furrows across its anterior half. The pleural lobes are convex near the axis, sloping down into a flattened area to the margin. The sides are gently rounded, produced into a spine at the postero-lateral angle and have a broadly rounded posterior margin between the spines. The lateral lobes are marked by five divided segments whose furrows are confluent distally with the flattened margin. The intrasegmental furrows begin at the inner anterior margin and after curving abruptly to the middle continue centrally along the downward slope. Posteriorly the furrows are so faint that they are hardly distinguishable. The surface is marked by fine concentric inosculating lines.

Dimensions.—Specimen No. 9017, a cranidium, median length 36 mm.; width across palpebral lobes 41 mm.; width between the extremities of the posterior limbs of the fixed cheeks 63 mm.; length of glabella 29 mm. Number 9016, a pygidium, median length 35 mm.; greatest width 62 mm.; length of axis 28 mm.

Horizon and locality.—Nearly all of the material of this species now in the University collection comes from the St. Lawrence limestone on Fire-bell Hill, Lansing. There is another exposure at the same horizon three miles west of Lansing on a hillside north of the road and about twenty feet above it. Here slabs were found which contained the impressions of a number of thoracic segments.

Remarks.—Most of the material is preserved in a greatly depressed and flattened state. This has a tendency to distort the natural proportions, especially those of the glabella, which is usually wider across the middle lobe than it should be. In an unusually well preserved cranidium, No. 9005, from Baraboo, Wisconsin, the transverse and longitudinal convexity is well shown and the sides of the glabella are parallel. This genus contains some of the largest species of the Dikelocephalinæ, the giants of Cambrian trilobites. The University collection contains a fragmentary pygidium, No. 9262, which if fully restored would have a width of 22 cms.

Ptychaspis striata Whitfield

Plate XI, figs. 11-14. Plate XII, figs. 3, 4.

1863. *Ptychaspis granulosa* Hall, 16th Rept. New York State Cab. Nat. Hist., p. 173, pl. 6, figs. 33, 37, 38, not *Ptychaspis granulosa* (Owen).
1878. *Ptychaspis striata* Whitfield, Ann. Rept. Geol. Surv. Wisconsin, p. 55.
1880. *Ptychaspis striata* Whitfield, Ann. Rept. Geol. Surv. Wisconsin, 1879, p. 51.
1882. *Ptychaspis striata* Whitfield, Geology of Wisconsin, vol. IV, p. 186.

Description.—Cranidium subtrapezoidal in outline; anterior border narrow, thickened slightly, broadly rounded and deflected almost 80 degrees from horizontal; facial sutures faintly subangular, extending in a straight line from the postero-lateral angles to the eyes, thence more directly forward, rounding the antero-lateral angles in a broad curve. Glabella prominent, subsemicylindrical, longer than wide, rising strongly above the dorsal furrows and cheeks, sides straight and parallel, anterior margin broadly rounded. The anterior glabellar lobe is globose, occupying more than one-third the glabella. Two pairs of lateral furrows cross the glabella; the first pair curves gently backward from the dorsal furrows, becoming shallower over the median area; the second pair is stronger and directed more obliquely backward at the sides. The occipital groove is straight, shallow medially, deeper at the sides, becoming much larger as it continues along the posterior margin of the fixed cheeks. Occipital segment strongly arched, equaling in width the median glabellar lobes.

Fixed cheeks large, depressed convex transversely, rising abruptly from the anterior border to the palpebral lobes and increasing in width to the posterior margin. Palpebral lobes very small and situated opposite the anterior lateral glabellar furrows. The anterior two-thirds of the cranidium is marked by strong wavy striæ roughly parallel to the margin.

Free cheeks strongly convex, sides sloping abruptly to a deep marginal groove, which becomes shallower anteriorly and does not communicate with the posterior marginal groove at the genal angles. Border greatly thickened and marked by several conspicuous striæ produced posteriorly into a strong spine. The surface of the cheeks from the eye toward the marginal groove is marked by striæ similar to those found on the cranidium.

Pygidium transversely elliptical, anterior margin describing the arc of a large circle, posterior margin that of a much smaller circle, the two arcs meeting at the sharp antero-lateral angles. Border slightly thickened and narrow throughout. Axis prominent, semiconical, tapering gradually to a raised obtusely rounded termination well within the margin. Segments four, all well defined by deep intersegmental grooves. The pleural lobes are narrowly depressed near the axis, thence slope strongly to the marginal furrow; each is marked by three flattened annulations, which bear a distinct median sulcus throughout their entire length.

Dimensions.—Number 9234, length of cranidium 8.5 mm., greatest width of same 14.2 mm. Specimen 9235, length of pygidium 8.5 mm., width of same 18.5 mm.

Position and locality.—Upper Cambrian, Eau Claire formation, one-half mile southeast of Lansing (Prof. T. J. Fitzpatrick).

This species is associated with *Saratogia wisconsensis* in thin slabs of fine-grained buff-colored sandstone. It is about equally abundant with the latter. The pygidium is referred to this species with doubt. From *S. wisconsensis* it differs in having but four instead of five axial segments, a very narrow marginal border, more abruptly sloping pleural lobes and all the annulations distinctly sulcate.

SAUKIA PYRENE Walcott

Plate X, figs. 12, 13.

1914. *Saukia pyrene* Walcott, Cambrian Geology and Paleontology, vol. II, No. 13, p. 382, pl. 67, figs. 18-29.

Description.—Cranidium subquadrate; anterior margin thickened, broadly rounded and set off from the glabella by a narrow but deep submarginal furrow; posterior margin transverse; dorsal furrow well defined. Glabella subquadrate, widest opposite the posterior part of the palpebral lobes, narrowing in the region of the second and third glabellar furrows, thence widening toward the anterior end. Occipital segment transverse, moderately arched; occipital furrow well defined and curved slightly forward; first glabellar furrow also well defined but not as prominent as the occipital furrow; curved slightly backward; second glabellar furrow very faint, subparallel to first and continued entirely across; third glabellar furrow represented on each side by a short, faint, forwardly directed furrow which is equidistant from the anterior glabellar margin and the second furrow.

Palpebral lobes prominent, about half as long as the glabella, bearing a strong intermarginal furrow which is directed inward, meeting the dorsal furrow opposite the third glabellar furrow.

Remarks.—As far as known this is the first record of this genus in Iowa. It must be considered a very rare fossil because a continued three day search on the part of Doctor Thomas and the writer in the *Dikelocephalus* layer of the St. Lawrence limestone at Lansing revealed only this one fragmentary cranidium. It is likely, however, that it is present in the collections of others who have collected from time to time in this same locality, but its rather small size and scarcity as well as its surficial resemblance to *D. minnesotensis* may have caused it to be overlooked. It is hoped that eventually better specimens will be found. This cranidium is similar in most respects to *Saukia pyrene* Walcott 1914 but there are several minor differences: the anterior margin of the cranidium is somewhat wider and thicker, the glabella is relatively shorter and wider and the second or middle glabellar furrow extends entirely across.

Dimensions.—Length of cranidium 8 mm., length of glabella 5.5 mm., greatest width of glabella 4.6 mm.

This species is associated with *Dikelocephalus minnesotensis* and *Illaenurus calvini.*

ARACHNIDA OF THE CAMBRIAN

Class **ARACHNIDA**

Subclass **Merostomata** Woodward

Order **SYNXIPHOSURA** Packard

Family AGLASPIDAE Walcott

AGLASPIS THOMASI Walter

Plate XI, figs. 1-4.

1924. *Eurypterus thomasi* Walter, Iowa Acad. Sci., Proc., vol. XXIX, pp. 127, 128.

Description.—The carapace is subcircular in outline, anterior margin well rounded, posterior margin broadly concave, sides diverging gently posteriorly and somewhat produced at the postero-lateral angles. The outer edge bears a faint submarginal groove which is wider and more shallow from front to back. The compound eyes are prominent, reniform, situated approximately in the middle and as far apart as the distance of each is from the lateral margin. Their greatest length is two millimeters. A shallow groove beginning at a point nearly midway between the eyes and the posterior margin extends to the postero-lateral angles. The entire surface, as preserved, is flattened and smooth. Length 8 mm., width across postero-lateral angles 13 mm.

An impression of the under side of a fragmentary tergite of the Aglaspid type occurs in the same layers of limestone in which the carapace was found. This specimen is flattened, its anterior and posterior margins are subparallel and entire, describing a broad sigmoid curve; the outer antero-lateral angle is rounded and the postero-lateral angle is produced into a short spine. A low rounded ridge begins proximally about midlength and extends outward and slightly backward, becoming obsolete some distance before reaching the outer margin. The obverse of this ridge very likely represents the groove which limits the posterior margin of the overlapping tergite. The entire surface is crowded with minute porelike pits which open obliquely on the surface. They are smallest and most numerous over the low ridge and largest along the posterior half of the proximal end. A narrow zone along the anterior margin is entirely smooth.

Position and locality.—Upper Cambrian, St. Lawrence limestone, on "Fire-bell Hill," Lansing. Collected by the writer. Museum numbers, 9008, 9009.

Remarks.—*Aglaspis thomasi* occurs in association with the dismembered parts of *Dikelocephalus minnesotensis* and *Illaenurus calvini.* It is of special interest because it represents the first species of this genus ever recorded from the Cambrian of Iowa. In general outline of cephalothorax it resembles *A. eatoni* Whitf. but differs from the latter in having the eyes more centrally located and in possessing apparently no nodes either on the posterior margin of the cephalic shield or on the abdominal segments.

The writer is greatly indebted to Dr. C. D. Walcott for the generic classification of *A. thomasi.* The species is named in honor of Dr. A. O. Thomas.

TRILOBITES OF THE ORDOVICIAN

Order **HYPOPARIA** Beecher

Family **HARPEDIDAE** Barrande

Genus Harpes Goldfuss

Sub-genus Eoharpes Raymond

Eoharpes cf. E. ottawaensis (Billings)

Plate XIII, figs. 1, 2.

1865. *Harpes ottawaensis* Billings, Paleozoic Fossils Canada, vol. I, p. 183, fig. 166.
1897. *Harpina,* cf. *H. ottawaensis* Billings (sp.), Clarke, Pal. Minnesota, vol. 3, pt. 2, p. 757, fig. 79.
1902. *Harpina ottawaensis* Weller, Pal. New Jersey, vol. III, p. 191, pl. 14, figs. 1, 2.
1909. *Eoharpes ottawaensis* Bassler, Bull. Virginia Geol. Surv. 29, p. 111, fig. 10.
1910. *Eoharpes ottawaensis* Raymond, 7th Rept. Vermont State Geol., p. 215, pl. 32, fig. 2.

Description.—border of the cephalon including the genal spines horseshoe-shaped in outline. The spines converge gently throughout most of their length but curve strongly inward at their extremities. The brim is widest anteriorly, narrowing uniformly posteriorly; the outer and inner margins are slightly thickened and smooth but the area between is thickly pitted. A single row of larger pits extends around the outer and inner margins respectively, each being just within the smooth zone.

Specimen 9205, comprising the border and genal spines, is 32 mm. long and 26 mm. wide. The breadth of the brim at the anterior end is 5 mm.

Position and localities.—Platteville limestone, Boyle's quarry, McGregor (Mr. A. G. Becker). Platteville limestone, Dubuque, about three hundred yards upstream from the high bridge and six to eight feet above low water mark of Mississippi river.

This very interesting trilobite, though recorded from Minnesota, had not been found in Iowa until the summer of 1921 when Mr. Becker found two specimens near McGregor. The larger of these has been described above. After seeing Mr. Becker's specimens it was the good fortune of the writer to find one specimen at Dubuque which is, however, less perfectly preserved than either of the other two. It is hoped that more material will be found which will show not only the cephalic border but the entire body so that there may be no doubt concerning the identity of the species. The material at hand agrees strikingly well with the specimen figured by Raymond (op. cit., 1910).

Family **BATHYURIDAE**

BATHYURUS SPINIGER (Hall)

Plate XIII, figs. 6, 7.

1847. *Acidaspis spiniger* Hall, Pal. New York, 1, p. 241, pl. 64, fig. 5.
1884. *Bathyurus spiniger* Clarke, Geol. Minnesota 3, pt. 2, p. 723, figs. 38-40.
1910. *Bathyurus spiniger* Raymond, Ann. Carnegie Mus., 7, p. 48, pl. 15, figs. 4-6.

This species is represented in the University collection by an incomplete partly exfoliated cranidium, No. 9188, from the Platteville limestone along Sny Magill creek, Clayton county. The anterior border is broadly rounded in outline, moderately wide, gently concave and slightly thickened at the edge. The glabella is oval-elongate and strongly convex transversely; its anterior margin extends to the concave border and is sharply rounded, the sides are very gently convex, the base is transverse and separated from the occipital segment by a prominent smooth groove. The surface of the glabella is tuberculate, the tubercles of the anterior half being smaller and more numerous than those of the posterior half. Two pairs of shallow glabellar furrows are discernible by the absence of tubercles on them. The first pair originates at the dorsal furrows about midlength of the glabella and is directed obliquely inward for a short distance; the second pair originates approximately opposite the palpebral lobes and extends parallel to the first pair for a short distance, whence it turns abruptly backwards but does not open into the occipital groove. The length of the glabella is 12 mm.

Associated in the same formation with this species is a hypostoma of a *Bathyurus,* No. 9186, which is here provisionally referred to *B. spiniger.*

Position and locality.—Specimens Nos. 9186 and 9188 were collected by Professor Thomas and the writer in the Platteville limestone on Sny Magill creek, Clayton county.

Family **ASAPHIDAE**

Ectenaspis beckeri (Slocom)

Plate XIII, figs. 8, 9. Plate XXVII, fig. 22.

1913. *Megalaspis beckeri* Slocom, New Trilobites From The Maquoketa Beds of Fayette County, Iowa: Field Museum of Natural Hist., Publication 171, vol. IV, No. 3, p. 50, pl. XIV, fig. 5.
1916. *Megalaspis beckeri* Slocom, Iowa Geol. Survey, vol. XXV, p. 196, pl. XV, fig. 5.
1920. *Ectenaspis beckeri* Raymond, Bull. Mus. Comp. Zool., vol. LXIV, No. 2, p. 292.

Description.—General form subelliptical in outline; sides broadly rounded and steeply sloping; head produced into a long, pointed and slightly upturned process. Pygidium narrowly rounded. Trilobation distinct on the thorax, less distinct on the pygidium. The length is nearly 2.4 times the greatest width.

The cephalon is subtriangular elongate; posterior and lateral margins gently incurved. The sides are compressed and nearly vertical. The occipital region is gently convex between nearly obsolescent dorsal furrows. The glabella is defined from the rest of the dorsal surface by its somewhat greater convexity. In front of this the surface is depressed and continued into an elongate, pointed and slightly upturned process. The palpebral lobes are prominent and extend obliquely inward as broadly rounded ridges which gradually diminish in size until lost in the convexity of the glabella. The occipital furrow is wanting in the central area; laterally it is present as a broad shallow groove which extends well into the free cheeks.

The facial sutures originate on the posterior margin on a level with the fulcrum, converging slightly to the eyes; in front of the eyes they converge more abruptly to the anterior extremity.

The eyes are not preserved but probably they reached a height considerably above that of the glabella.

The free cheeks are very elongate subtriangular in outline, forming the sides of the head; they are widest opposite the occipital region, becoming gradually narrower toward the anterior extremity; posteriorly they are continued into genal spines which extend to the sixth thoracic segment.

Thorax subquadrate, sides gently rounded, trapezoidal transversely, moderately trilobate and composed of eight segments. The width is to the length about as 3.5 to 2. The axis is low and broadly rounded, occupying more than one-third the width of the thorax. It is bounded laterally by shallow subparallel dorsal furrows which approach each other along gentle outward curves from front to back. The segments are smooth and flat and of uniform breadth throughout. The intersegmental grooves are narrow and shallow. Pleuræ flattened for one-half their width, thence abruptly deflected to the margin. Each segment bears a strong sulcus which begins proximally on the anterior margin, thence passes diagonally outward over the fulcrum, becoming obsolete upon the sides. Distally the segments are flattened and strongly imbricated, each bearing a "Panderian organ" near the anterior margin midway between the fulcrum and the outer edge.

Pygidium subtriangular in outline; sides nearly straight, produced posteriorly into a narrow, obtusely rounded extremity. Axis low and broadly rounded, tapering at first strongly then very gradually to an obtusely rounded extremity well within the margin. The pleuræ curve abruptly to the nearly vertical lateral margin. Eight obsolescent annulations may be counted upon the surface from which the crust has been removed. A strong furrow is present posterior to the articulating ring. The length is to the width as five is to six. The surface is covered with fine pustules.

Dimensions of the type specimen.—Length of body 88.5 mm., length of cephalon 42 mm., length of thorax 22 mm., length of pygidium 25.2 mm.

Position and locality.—Lower Maquoketa, Elgin beds, Clermont and Postville Junction (Slocom).

Remarks.—The specimen above described is the type which has been so well described by Slocom and named in honor of the finder, Mr. A. G. Becker, whose kindness made it possible for the writer to study and figure this very valuable and unique form. That the species is exceedingly rare is evidenced by the fact that repeated visits to the type locality by Mr. Becker as well as an intensive search by Doctor Thomas for more material have been unsuccessful. Therefore the type specimen in possession of Mr. Becker and the "nearly complete cranidium" found by Slocom in the Lower Maquoketa beds at Postville Junction represent nearly all the known material of this species to date. The statement by Raymond (op. cit., p. 293), that there were two specimens of the trilobite on the same slab of limestone could not be verified.

While collecting in the Platteville limestone near Eagle Point, Dubuque, the writer found an incomplete pygidium, No. 9185, which appears to belong to this species and which is much larger than that of the holotype. It preserves well the specific characters and has the concave marginal border strongly produced posteriorly.

VOGDESIA VIGILANS (Meek and Worthen)

Plate XVI, figs. 1-5.

1875. *Asaphus vigilans* M. & W., Geol. Surv. Illinois, vol. VI, p. 497, pl. 23, fig. 6. From Carroll county, near Mount Carroll, and near Oswego, in Kendall county, Illinois, in the Cincinnati shales of the Lower Silurian.

1887. *Illaenus (Nileus) minnesotensis* Foerste, Fifteenth Rep. Geol. and Nat. Hist. Surv. Minnesota, p. 478, fig. 1.
1897. *Nileus vigilans* Clarke, Pal. Minnesota, III, pt. 2. p. 712, figs. 17-19. From Lower Trenton (Black River), Minneapolis; Galena shales, Wykoff, Pleasant Grove, Minn.
1904. *Nileus vigilans* G. E. Finch, Notes on the Position of the Individuals in a Group of *Nileus vigilans* Found at Elgin, Iowa: Proc. Iowa Acad. Sci., 1903, vol. XI, p. 179.
1910. *Vogdesia vigilans* Raymond, Notes on Ordovician Trilobites, Ann. Carnegie Mus., vol. 7, No. 1, p. 70.
1913. *Nileus vigilans* Slocom, New Trilobites from the Maquoketa Beds of Fayette County, Iowa: Field Museum Nat. Hist., Publication 171, Geol. Series, vol. IV, no. 3.
1916. *Nileus vigilans* Slocom, Trilobites From The Maquoketa Beds of Fayette County, Iowa: Iowa Geol. Surv., vol. XXV, p. 199, pl. 15, figs. 9-15.
1920. *Nileus (Vogdesia) vigilans* Raymond, The Appendages, Anatomy and Relationships of Trilobites: Mem. Conn. Acad. Arts Sci., vol. VII, p. 102, Dec., 1920.

"Body convex, trilobation very obscure, subelliptical in outline, lateral margins nearly parallel. Surface smooth to the naked eye, but under a magnifier the extremities are seen to be ornamented with transverse impressed lines. These lines are most distinct on the doublure and anterior portion of the glabella and rather indistinct on the pygidium. Free cheeks finely punctate.

Cephalon sublunate in outline, somewhat depressed on the anterolateral margin, convex, frontal slope inflated but not projecting. Margin marked by a slight recurved elevation; genal angles obtusely rounded; free cheeks large, produced in front of the cranidium nearly or quite to the median line. Eyes small for the genus but prominent, situated at points each one-third the transverse diameter of the cephalon, and about their own diameter from the posterior margin. The facial sutures originate on the posterior margin of the cephalon at about one-third the distance from the dorsal furrows to the genal angles, curve obliquely forward over the palpebral lobes, thence in sigmoid curves to the anterior margin, where they meet. Glabellar furrows, dorsal furrows and occipital ring and furrow are obsolete on the surface of the test, but on casts the location of the dorsal furrows is indicated on each side by pits at the posterior margin of the cephalon. These pits are connected by a shallow occipital furrow which runs parallel to the posterior margin until near the median point, where it arches forward.

Thorax composed of eight broad, flat segments, trilobation very obscure; axis about three-fourths the entire width, depressed convex; pleural lobes curving regularly to the lateral margins; segments arched slightly forward on the axial lobe, somewhat curved backward. On enrolled specimens this backward curve appears greater than it really is on account of the flattening of the anterior portion of the pleuræ, which originates at the dorsal furrows and gradually widens distally. On the anterior border at the dorsal furrow of each segment are small projections which point forward and fit into corresponding notches of the preceding segment. The segments are without grooves on the test, but on the casts a shallow groove connects the dorsal furrows.

Pygidium somewhat narrower but longer than the cephalon, depressed convex, sloping equally to the margins, trilobation and segmentation wanting on the surface of the test but faintly discernible on the casts.

Remarks.—The Maquoketa specimens, above described, appear to correspond in practically all points to the orginal description and are from a similar horizon to the type. The Galena and Trenton specimens referred to this species and described by Clarke appear to differ as follows: The facial sutures reach the margin of the cephalon in front of the eyes, while in the Maquoketa specimens the sutures reach the anterior margin near the median line of the cephalon. The front part of the cranidium is more inflated in the Maquoketa specimens.

Locality and horizon.—This species was described originally from the Cincinnati shales of Carroll and Kendall counties, Illinois. It has been collected by the writer from the Lower Maquoketa beds at Clermont, Elgin, and Bloomfield, and from the Upper Maquoketa bed at Pattersons Springs near Brainard."

This interesting species, which has been so adequately described by Slocom and whose life habits have been discussed by Finch and by Raymond, is one of the beautiful and fairly common forms of the Maquoketa beds of northeastern Iowa. Members of this rather gregarious and usually well preserved species are commonly found enrolled but in the slab of limestone found by Mr. G. E. Finch and containing fifteen specimens the majority were straight or nearly so.

In the University collection there are twenty complete or nearly complete specimens and numerous free cheeks, cranidia and pygidia. The following localities are represented: No. 9135, Lower Maquoketa, Dover Mills; No. 9250, Clermont; No. 9252, northwest quarter of section 11, Springfield township, Winneshiek county; No. 9253, Upper Maquoketa, section 19, Clermont township, Fayette county; No. 9190, Lower Maquoketa, Elgin.

VOGDESIA GIGAS Raymond

Plate XV, Figs. 4, 5.

1920. *Vogdesia gigas* Raymond, Bull. Mus. Comp. Zool., Harvard College, vol. LXIV, No. 2, p. 292, July, 1920.

"This species differs from *V. vigilans* only in that the type is twice as large as the largest known specimen of the latter, the eyes are farther from the anterior margin, and the test is slightly if at all punctate.

Measurements.—Specimen, if extended, about 120 mm. long. The cephalon is 34 mm. long and 58 mm. wide; the eye is 8 mm. long and 8 mm. from the posterior margin. The pygidium is 36 mm. long and 55 mm. wide, with no trace of an axial lobe. The thorax is estimated to be about 50 mm. long, each of the eight segments being 7 mm. wide in the enrolled state.

Horizon and locality.—This species is known from a single specimen collected by the writer near the base of the Maquoketa on a creek four miles west of Clermont, Iowa. Holotype, M. C. Z. 1,589." After Raymond. 1920.

Remarks.—No complete specimens of *V. gigas* have been observed by the writer but Doctor Thomas collected a nearly complete specimen, No. 9165, and the writer found a little more than the left half of a specimen, No. 9164, in the Lower Maquoketa on the Patrick Leehy farm near Clermont. One pygidium, No. 9261, from the Lower Maquoketa at Dover Mills, also is referred to this species.

BASILICUS cf. B. BARRANDI (Hall)

Plate XVI, fig. 11.

1851. *Asaphus barrandi* Hall, Geol. Lake Superior Land Dist., Foster and Whitney's Rept., p. 210, pl. 27, figs. 1 A-D; pl. 28.
1897. *Ptychopyge ulrichi* Clarke, Geol. Minnesota, 3, pt. 2, p. 709, figs. 12, 13.
1914. *Basilicus barrandi* Raymond, Bull. Mus. Comp. Zool., 58, p. 261, pl. 1, figs. 4, 5; pl. 2, figs. 1, 7.

This species is represented in the University collection by a rather poorly preserved specimen, No. 9193, showing the pygidium in conjunction with eight thoracic segments. The thorax is convex and one-third wider than long. The axis is prominent, originating on a level with the pleuræ and rising considerably above them; anteriorly it occupies more than one-third the width of the thorax, thence diminishes abruptly and uniformly in size toward the pygidium where it occupies considerably less than one-third the width of the thorax. The segments are broad and gently rounded, each bearing a short and wide diagonal groove adjacent to each dorsal furrow and extending forward and upward from the posterior margin of the segment. The pleural lobes are flattened for one-half their width, thence descend abruptly to the margin. The proximal half of each segment is depressed and subequally divided by a broad shallow groove which begins in front at the axis and is thence directed outward in a gentle curve, ending near the posterior margin on the upper part of the sloping sides. The segments are flattened distally, ending in a blunt point which is directed backwards.

The pygidium is subtriangular, the length is to the width as 2 is to 3, the anterior margin is nearly transverse, the lateral margins converge rapidly to the sharply rounded posterior end. On each side of the axis there is a narrow flattened triangular area which descends abruptly to the broad shallow concave margin. Five annulations are discernible on the pygidium. These are smaller and increasingly oblique from front to back. The axis is well defined throughout; opposite the first two annulations it tapers abruptly, thence more gradually to a somewhat raised and obtusely rounded termination just above the concave border. The annulations appear to have been worn away.

The length of the thorax and pygidium is 78 mm., the greatest width across the thorax is 63 mm.

Position and locality.—Specimen No. 9193 was found in place in the Platteville limestone, along the Chicago, Milwaukee and St. Paul Railway right of way four miles north of Dubuque. Collected by C. C. Barnes.

Remarks.—The above described specimen represents all the material thus far recorded of the genus *Basilicus* from this state. Dr. Percy E. Raymond identified the specimen as probably belonging to *B. barrandi;* its poor state of preservation does not permit a more accurate determination.

BRACHYASPIS ALACER (Billings)

Plate XIV, figs. 1-8.

1866. *Asaphus alacer* Billings, Cat. Sil. Foss. Anticosti: Geol. Surv. Canada, p. 26, fig. 9 A.
1882. *Asaphus susae* (Calvin in MS.) Whitfield, Geol. Wisconsin, vol. 4, p. 236, pl. 5, fig. 3; pl. 10, fig. 8.
1883. *Asaphus susae* Chamberlin, Geol. Wisconsin, vol. 1, p. 160, fig. g.
1903. *Asaphus* (*Isotelus*) *susae* Calvin, Iowa Geol. Surv. vol. XIII, p. 46 (footnote).
1912. *Brachyaspis alacer* Raymond, Trans. and Proc. Roy. Soc. Canada, 3rd ser., 5, sec. 4, p. 119.

"Body, when entire, more or less oval, the anterior and posterior extremities almost alike in form, the anterior border a little more sharply rounded than the other, and the sides of the body along the edges of the thorax straight. In profile, the body rises gradually from the middle of the caudal plate, along the thorax, and to the anterior border of the eyes; in front of which it abruptly declines to the front margin of the head. Proportional width and length about as ten and twelve. In the specimens figured, the breadth is apparently somewhat greater, being as nine is to twelve, owing to the partial overlapping of two of the thoracic segments.

Cephalic shield crescent-form; the occipital line having a much longer curvature than the outer border, and the length, along the median line, equal to two-fifths of the transverse diameter, the sides of the head extending backward some distance behind the central portion, and the genal angles rounded. Surface very convex in middle, and nearly level on the top between the eyes, which are very distant, large and exceedingly prominent, strongly reniform, situated less than their length from the occipital border, and their visual surfaces highly convex. Facial sutures rounding outward in front of the eye for half the distance, then rounding rapidly inward and uniting in the middle just above or on the margin, in a very obtuse point. Behind the eye they are directed backward and outward, reaching the posterior border at a point about one-third the width of the lateral lobe from the dorsal furrow; the posterior lateral limbs being about twice as long as wide.

Thorax short, strongly lobed longitudinally, and consisting of eight short articulations, which are nearly flat on their exposed surfaces from front to back, and their free extremities rounded. Axis convex, about once and a half as wide as the lateral lobes, and very slightly narrowed posteriorly. Lateral lobes horizontal for a short distance outside of the dorsal furrow, the flattening scarcely visible on the anterior segment, but gradually increasing in length to the sixth segment, when it again diminishes posteriorly. Beyond the horizontal part, the segments are abruptly bent downward, and the articulating face of the free pleura extends almost the entire width of the rib.

Pygidium depressed convex, transversely subelliptical, the length a little more than half the width, posterior margin almost regularly arcuate, and more strongly curved than the anterior border; so that a line drawn across the plate from the two outer angles would cross at about the anterior third of the length. Lobation very indistinct, the dorsal furrows being scarcely perceptible except near the anterior margin, and the articulation only faintly traceable. A perceptibly depressed furrow extends along the sides just within the margin.

Formation and locality.—In the limestones of the Trenton group at Apple River, just across the Illinois line.'' Whitfield 1882.

Position and locality.—Specimens Nos. 9166-9168 are from the upper part of the Galena-Platteville near Florenceville, Iowa. They belong in the Calvin collection (H. Saulisbury). No. 9171, an incomplete cranidium, was collected by the writer in the Lower Maquoketa shale, on the Patrick Leehy farm near Clermont.

Remarks.—The abrupt deflection of the head in front of the eyes differentiates this species from all other trilobites of this state. The Iowa material agrees fully with Whitfield's description, except that the anterior border of the cephalon is a little more broadly rounded than the posterior border of the pygidium. When naturally preserved the surface of the pygidium slopes evenly to the margin but in exfoliated specimens the margin is concave and marked by numerous subparallel lines. Whitfield's figure 8, Plate 10, is in striking agreement with our specimen No. 9166, but his figure 3, Plate 5, which he says in explanation of Plate 10 is of the same specimen, has a much more broadly rounded posterior pygidial margin than any one of Calvin's specimens which Calvin used as the types of his *Asaphus susae*.

HOMOTELUS GRATIOSUS Raymond

Plate XVII, figs. 6, 7.

1897. *Asaphus* (*Isotelus*) *susae* Whiteaves, Pal. Foss. Canada, 3, pt. 3, p. 231.

1912. *Onchometopus susae* Raymond, Proc. and Trans. Roy. Soc. Canada, ser. 3, 5, sect. 4, p. 118, pl. 2, figs. 1, 2.
1920. *Homotelus gratiosus* Raymond, Bull. Mus. Comp. Zool., 64, No. 2, p. 291.

"Cephalon nearly semicircular, evenly convex, with large, elevated eyes. Cranidium absent from the type, but on other specimens depressed, smooth, glabella not outlined. Fixed cheeks smooth, genal angles rounded. Eyes large, near the middle of the cephalon.

The axial lobe of the thorax is wide for a *Homotelus*, being nearly one-half the total width.

Pygidium short and wide, nearly semicircular, with the axial lobe outlined at the anterior end only.

Measurements.—Length of cephalon, 25 mm., width, 51 mm., the eye is 10 mm. long. Total width of thorax at middle, 48 mm., width of axial lobe, 23 mm. Length of pygidium, 26 mm.; width 46 mm.

This species differs from *Homotelus florencevillensis*, which occurs at the same horizon, in having the eyes much farther forward and larger, as well as in the shorter and wider shields. It differs from the other known species of the genus in the same particulars.

Horizon and locality.—The holotype, a gift of Mr. A. G. Becker and Mr. John H. Bradley, Jr., M. C. Z. 1,573, was found near the top of the Maquoketa at Pattersons Springs, near Brainard, Iowa." After Raymond 1920.

Homotelus florencevillensis (Calvin)

Plate XIII, figs. 3, 4, 5.

1894. *Isotelus susae* Clarke, Geol. Minnesota, 3, pt. 2, p. 708, text figs. 10, 11. Not *Asaphus susae* (Calvin in MS.) Whitfield, Geol. Wisconsin, vol. IV, p. 236, pl. 5, fig. 3, pl. 10, fig. 8, 1882.
1903. *Isotelus florencevillensis* Calvin, Iowa Geol. Survey, vol. XIII, p. 46. (In a footnote Calvin offers the name *Isotelus florencevillensis* because the name *Isotelus susae* used by Clarke for this form is preoccupied by *Isotelus susae* Whitfield which is a different form.)
1920. *Homotelus florencevillensis* (Raymond), Bull. Mus. Comp. Zool., vol. LXIV, no. 2, p. 291, July, 1920. *Homotelus florencevillensis* is here compared to *H. gratiosus* Raymond 1920, which occurs at the same horizon.

Description.—The general shape of the body is broad, depressed, gently and evenly convex, its outline is nearly oval, the sides of the thorax are straight, the cephalon is somewhat less broadly rounded than the pygidium. The width is to the length as five is to eight, or the width is equal to the median length of the head and thorax combined.

The cephalon is subcrescentic in outline, having a very broad curvature along the posterior margin, which is somewhat produced medially. The surface is evenly depressed convex except the narrow outer margin, which descends almost vertically. The length is to the width as one is to two. The cranidium is marked by shallow dorsal furrows which converge toward the palpebral lobes then diverge again to the end opposite the anterior angle of the eyes. The facial sutures originate on the posterior margin approximately half way between the genal angles and the dorsal furrows, whence they curve forward and inward to the eyes, in front of which they diverge, forming a sharp curve at the anterolateral angles of the cranidium, whence they continue centrally and unite in an obtuse point. The distance between the eyes is equal to a little more than twice their distance from the posterior margin of the cephalon. The free cheeks slope gently to the margin.

The thorax is twice as wide as it is long, composed of eight segments. The surface is generally depressed except the nonarticulating portions of the pleuræ which slope strongly to the margin. Dorsally the segments are flattened on the axis and the proximal half of the pleuræ, which are marked by a faint wide groove. The width of the axis is to the width of the thorax as two is to five.

The pygidium is depressed convex, transversely subelliptical, the surface curving evenly to the margin, which is narrow and nearly horizontal posteriorly and still narrower and more sloping anteriorly. The length is to the width as three is to five. The axis is defined along the anterior margin only.

Dimensions.—Length of entire specimen, No. 9161, 83 mm.
Width of same 52 mm.
Length of cephalon 26 mm.
Length of thorax 27 mm.
Length of pygidium 31 mm.

Position and locality.—Specimens Nos. 9161-9163 were collected by Dr. Samuel Calvin from the Maquoketa shales on the river above Florenceville. Number 9134, a very small but nearly perfect specimen, was collected by the writer in the *Isotelus* zone, Elgin member of the Maquoketa at Dover Mills.

Remarks.—Specimen No. 9161 is made the basis of the foregoing description. It is one of the forms referred to by Calvin in the footnote on page 46 of the Iowa Geological Survey, volume XIII. Specimen No. 9134 is doubtfully assigned to this species. It is a very young specimen which is similar in nearly all respects to the above described adult form but differs from it in possessing very short genal spines, a small median tubercle at the base of the glabella, and in having a narrow marginal area of the free cheeks nearly flattened instead of nearly vertical. These characteristics are very likely characteristics of youth. Dr. Percy E. Raymond[5] agrees with the writer in the assignment of this specimen.

ISOTELUS GIGAS DeKay

Plate XV, figs. 1-3. Plate XXVII, fig. 21.

1824. *Isotelus gigas* DeKay, Annals Lyceum Nat. Hist. New York, vol. 1, p. 176, pl. 12, fig. 1; pl. 13, fig. 1.
1832. *Isotelus gigas* Green, Mon. Tril. North America, p. 71, cast 21, 22.
1894. *Isotelus gigas* Clarke, Geol. Minnesota 3, pt. 2, p. 701, figs. 6-8; p. 706.
1910. *Isotelus gigas* Raymond, Ann. Carnegie Mus., 7, p. 53, pl. 15, figs. 1, 2.
1914. *Isotelus gigas* Raymond, Bull. Mus. Comp. Zool. 58, p. 248, pl. 1, figs. 1, 2; pl. 2, figs. 2-5; pl. 3, fig. 3.
1916. *Isotelus gigas* Slocom, Iowa Geol. Survey, vol. XXV, p. 192.

Description.—Body form subelliptical in outline, moderately convex, trilobation distinct in the thorax only, outer marginal configuration of the head and tail shields similar. Length equals approximately two times the width.

Cephalon subtriangular in outline, bearing prominent depressed marginal borders which increase in width from genal

5 Dr. Percy E. Raymond, personal correspondence, August, 1922.

angles forward; posterior margin gently concave. Length is to width as 2 to 3. Cranidium evenly convex with the general surface of the cephalon and gently arched longitudinally. Greatest convexity opposite the palpebral lobes. Anterior margin depressed, forming a shallow concave groove with the free cheeks. Palpebral lobes subsemicircular, rising gently from the dorsal furrows and becoming nearly horizontal distally. Glabellæ are continuous with the lateral margins of the cranidium and defined by the dorsal furrows back of the eyes only except in depressed specimens where they diverge in front of the eyes, becoming continuous with the depressed marginal borders.

The facial sutures originate on the posterior margin of the cephalon nearly midway between the dorsal furrows and the genal angles, from whence they converge in a curve to the eyes; in front of the eyes they diverge in an arcuate curve toward the marginal borders, thence run subparallel to the anterior margin, meeting in a distinct angle in front of the glabella within the anterior limbs of the free cheeks. Free cheeks large, rounded at the genal angles, produced anteriorly into narrow limbs which meet in front of the glabella, broadly depressed about the eyes thence sloping abruptly to the borders. Eyes prominent, lunate, situated slightly less than their own length in front of the posterior margin of the cephalon.

Thorax subquadrate, composed of eight segments, distinctly trilobate; dorsal furrows broad and shallow. Axis broad, depressed convex, not tapering but with sides gently rounded. Segments directed slightly forward on the sides, thence passing over the median area in a gentle posterior curve. Width of the axis is to the total width of the thorax as 3 to 8. Pleural lobes flattened to depressed convex for about one-half their width from the axis, thence descending abruptly to the margin. Each segment bears a broad groove which passes obliquely outward from the dorsal furrows to the descending portion. Beginning with the anterior margin at the fulcrum each segment is flattened distally toward the posterior margin.

Pygidium subtriangular in outline, anterior margin transverse across the axis, oblique at the sides. Marginal border broad, depressed and of uniform width from the articulating ring backward. Length is to width nearly as two is to three. Axis faintly defined at the anterior margin and at the nearly obsolete, narrow but obtusely rounded extremity well within the depressed border. General surface gently and evenly convex from the axial line outward. Depressed specimens show the axis better than normally preserved ones. Nearly all traces of segmentation are lost in young as well as old specimens.

Surface markings none.

Dimensions.—Specimen 9154, length 175 mm., width at the genal angles 96 mm., length of cephalon (estimated in part) 60 mm., length of thorax 46 mm., width of thoracic axis 36 mm., length of pygidium 69 mm., width of same 92 mm.

Position and locality.—Number 9154 is from the Elgin member of the Maquoketa at Florenceville, collected by Professor Calvin. Number 9150, an even larger specimen than No. 9154, but much exfoliated and showing the Panderian organs, appears to come from the Elgin member of the Maquoketa at Dover Mills. The exact locality is unknown, but the matrix in which the specimen is preserved is identical with that of the *Isotelus* zone at Dover Mills. Number 9151 was collected by the writer from the Lower Maquoketa shales in the southeast quarter of the northwest quarter of section 19, Madison township, Winneshiek county. Number 9155, a specimen showing a hypostoma, was collected by Professor Calvin in the Elgin member of the Maquoketa about one-half mile east of Nordness, Winneshiek county.

Remarks.—*Isotelus gigas* is distinguished from *I. maximus* and from *I. iowensis* by the long subtriangular cephalon and pygidium, the outline of the anterior portion of the cranidium and the absence of genal spines. In *I. gigas* the cranidium is greatly extended and the antero-lateral margins converge uniformly, meeting in a distinct angle. In *I. maximus* the cranidium is less extended; the antero-lateral margins approach each other more abruptly until near the center whence they curve abruptly forward to meet in a short sharp angle. In *I. iowensis* the anterior part of the cranidium is distinctly rounded, forming the anterior margin of the cephalon. The outline and general proportions are quite similar to those of *I. iowensis* though the pygidial axis of the latter is much more distinct and shows traces of segmentation. Both the cephalic and pygidial shields of *I. maximus* are proportionally shorter and wider than those of *I. gigas.*

Owing to careful investigations of this and allied species by Raymond, Slocom and others it is found to be less common than it was thought to be by the earlier writers in this state. Careful collecting has revealed fewer specimens of *I. gigas* than of other members of this genus such as *I. iowensis* and *I. rejuvenis.*

Isotelus iowensis Owen

Plate XVI, figs. 6-10.

1852. *Isotelus iowensis* Owen, Rep. Geol. Surv. Iowa, Wisconsin and Minnesota, p. 577, pl. IIa, figs. 1-7.
1913. *Isoletus iowensis* Slocom, Field Mus. Nat. Hist., Geol. Ser., vol. 4, p. 48, pl. XIII, figs. 1, 2.
1916. *Isoletus iowensis* Slocom, Iowa Geol. Survey, vol. XXV, Annual Rep. 1914, p. 193, pl. XIV, figs. 1, 2.

"The general form and contour of the cephalic shield closely resembles that of *I. gigas* DeKay; but the facial sutures do not converge in front to form a distinct angle, but describe three parts of a circle as in *Asaphus expansus.* The eyes are reticulated and the middle lobe of the caudal shield is defined (though sometimes somewhat indistinctly), but the segments are only obscurely pronounced. The glabella is but obscurely defined, and the genal angles are produced into spines. The thorax consists of eight segments.

"From *I. megistos,* it differs in the eyes being set closer together; in the spines being longer, extending as low as the caudal shield; the pygidium more regularly elliptical, and its axial lobe more distinctly defined.

"From the bituminous limestone, mouth of Otter creek, Turkey river, Iowa."

The original description, of which the above is practically a copy, is so incomplete that it seems advisable to redescribe the species in more detail.

Body subelliptical, length about twice the greatest breadth, moderately convex, trilobation not well developed. Entire surface finely punctate, the punctæ being larger and more pronounced on the free cheeks and less conspicuous on the marginal borders than on other parts of the test.

Cephalon semioval in outline, marginal border defined by a marginal furrow which originates on the genal spines as an angular groove and develops into a shallow concave furrow gradually widening to the front of the glabella. Dorsal furrows shallow, converging toward the median line in passing the palpebral lobes, then diverging to about their original distance apart. Cranidium moderately convex, greatest convexity just in front of the eyes, concave where the marginal furrow crosses it. The anterior margin of the cranidium forms the margin of the cephalon. Fixed cheeks very small, not well defined. Free cheeks large, with long genal spines, convex near the eyes, not produced in front of the glabella. The facial sutures originate on the posterior margin of the cephalon about midway between the dorsal furrows and the lateral margins, from whence they converge forward in a sigmoid curve to the crest of the eye lobes, which they follow, thence forward and outward in an arcuate curve, meeting the anterior margin of the cephalon in front of the anterior angles of the eyes; here the sutures bifurcate, one fork following the anterior margin until it meets the fork from the other side in a continuous curve or slight angulation, never in a distinct angle; the other fork passes over the margin and curves across the doublure to the base of the hypostoma. Hypostoma forked posteriorly, only slightly constricted at the base, greatest width about three-fifths the length. Compared with *I. gigas* the forks point more directly backward making the notch between them narrower. Eyes lunate, prominent, situated less than their own length in front of the posterior margin of the cephalon, rather near together for the genus. A rather indistinct posterior cheek furrow extends across the fixed cheeks. Occipital ring and furrow obsolete.

Thorax composed of eight segments. Dorsal furrows shallow, ill-defined; axial lobes depressed convex, not tapering, occupying more than one-third but less than one-half the width of the thorax; pleural lobes curving gently upward from the dorsal furrows, then more abruptly downward to the lateral margins; each segment arching gently forward on the axial lobe, and curving slightly backward towards the extremities of the pleuræ. A shallow concave furrow crosses the axial lobe, originating on the posterior margins at the dorsal furrows. A more pronounced subangular furrow originates on the anterior margin of each pleura at the dorsal furrows and passes diagonally outward and backward about three-quarters the length of the pleura. The distal portion of each pleura is distinctly flattened anteriorly. The flattening occupies nearly the entire width at the rounded extremity of the pleura but gradually narrows towards the dorsal furrow until it disappears.

Pygidium slightly narrower and longer than the cephalon, rather more convex, with a marginal border of uniform width. Axial lobe tapers abruptly near its anterior margin, thereafter only moderately to its prominent, rounded termination, no annulations visible. The segmentation of the pleural lobes is obscure although three or four segments may be distinguished on young individuals. All markings are more distinct on young than on older individuals.

Measurements.—The figured specimen (Field Mus. No. P 11241) measures: Cephalon 36.5 mm. long, 63.5 mm. wide, thorax 33 mm. long. Another (Field Mus. No. P 6969) measures: Cephalon 21 mm. long, 36 mm. wide, thorax 18.5 mm. long, 36 mm. wide. Pygidium 24.4 mm. long, 34 mm. wide, entire length 63.9 mm.

Remarks.—Specimens of this species have been usually referred to *I. maximus* Locke, but the writer is convinced that they belong to Owen's species as the Field Museum collection contains one nearly complete individual and quantities of less complete ones that were collected at the type locality which agree with Owen's description. The character which most easily distinguishes *I. iowensis* from *I. maximus* is the position of the facial sutures. In *I. iowensis* they follow the anterior margin of the cephalon and unite in a curve or indistinct angle. In *I. maximus* the sutures run subparallel to the anterior margin and meet in a distinct angle so that the free cheeks are produced in front of the glabella, while in *I. iowensis* the cheeks terminate in front of the eyes. Owen describes the genal spines as extending the entire length of the thorax, but his original figures show the spines much shorter. In the specimens before the writer the length of the spines seems to be a variable character.

Locality and horizon.—"*Isotelus* Zone" near the base of the Lower Maquoketa beds near where Otter creek empties into Turkey river at Elgin, and at Clermont. An hypostoma, undoubtedly belonging to this species, was found on a slab at the top of the Upper Maquoketa beds at Pattersons Springs." After Slocom 1916.

Isotelus iowensis is similar in most respects to *Isotelus rejuvenis* Raymond, with which it is commonly associated, but it differs from the latter in having somewhat larger eyes, a shorter and wider pygidium which is more nearly smooth in adult specimens and a more densely punctate surface. In addition Raymond[6] in-

6 Raymond, personal communication, August 15, 1922.

forms the writer that if the ratio of length of pygidium divided by the width of same is less than 80 it is *I. iowensis* and if the ratio is greater than 80 it is *I. rejuvenis*.

The hypostoma from the Elgin member of the Maquoketa at Elgin, figured by Slocom, 1916, Plate XIV, figure 2, is No. 9147 in the University collection. All of the material at the University is from the Elgin member. Number 9140 is an impression of a nearly perfect specimen collected by Professor Calvin at Clermont. Numbers 9142, a hypostoma, 9143, a glabella, and 9148, two small pygidia, are all from the *Isotelus* zone at Dover Mills. Numbers 9144, a small nearly complete specimen, and 9145, a large free cheek showing genal caeca, are from Elgin. Number 9158, the ventral side of a cephalon, is from the southeast quarter of the northwest quarter of section 19, Madison township, Winneshiek county. Besides this there is a great deal of uncatalogued material in the collection.

ISOTELUS REJUVENIS Raymond

Plate XVII, figs. 8, 9.

1920. *Isotelus rejuvenis* Raymond, Bull. Mus. Comp. Zool., Harvard College, vol. LXIV, No. 2, p. 294, July, 1920.

"Entire specimen elongate oval, narrow, strongly convex. Cephalon large, with short genal spines which in uncrushed specimens have their outer surfaces nearly vertical. The facial sutures follow the same course as in *I. iowensis,* being very close to, and parallel to the anterior margin. The eyes are very small, elevated, situated a trifle more than their own length in front of the posterior margin. The glabella is faintly outlined, constricted between the eyes, and nearly smooth.

Thorax as in *I. iowensis,* the dorsal furrows shallow, and the axial lobe more than one-third and less than one-half the total width.

Pygidium elongate, narrow, with steep sides. The axial lobe is narrow, faintly outlined except in young specimens, and without rings except for the one on the anterior end. The pleural lobes show traces of several pairs of ribs, two of which at the anterior end are very distinct.

Measurements.—The holotype is 105 mm. long; the cephalon is 38 mm. long and 62 mm. wide; the pygidium is 46 mm. long and 55 mm. wide.

This species differs from *Isotelus iowensis* in having smaller eyes, a longer and narrower pygidium with two pairs of ribs at the anterior end, and in having a less densely punctate shell.

Horizon and locality.—The species has so far been found only in the lower part of the Maquoketa at Clermont and Elgin, Iowa, at both of which places it is rather common in association with *I. iowensis.* The holotype, M. C. Z. 1,586, was collected by the writer on a creek about four miles west of Clermont." After Raymond 1920.

Remarks.—Doctor Percy E. Raymond informed the writer that one of the principal differences between the pygidium of this species and that of *I. iowensis* is the proportion of length to width. If the length divided by the width is less than 80 it is *I. iowensis,* if it is greater than 80 it is *I. rejuvenis.* In the University of Iowa collection there is a slab of limestone, No. 9141, from the Elgin member of the Maquoketa at Elgin which contains five or six imperfectly preserved specimens. Number 9146, a pygidium with eight thoracic segments in place, and No. 9153 are from the Elgin member of the Maquoketa at Dover Mills. Numbers 9149 and 9150, two pygidia, are from the same horizon in section 19, Clermont township, Fayette county. The collection also contains considerable uncatalogued material of this species.

Family **ILLAENIDAE**

ILLAENUS AMERICANUS Billings

Plate XVII, fig. 1.

1847. *Illaenus crassicauda* Hall, Pal. New York, vol. I, p. 24, pl. 4 (bis), fig. 13, (not Wahlenberg).

1859. *Illaenus americanus* Billings, Canad. Nat. and Geol., vol. 4, p. 371.

1861. *Illaenus taurus* Hall, Geol. Surv. Wisconsin; Rept. Progress, p. 49.

1865. *Illaenus americanus* Billings, Paleozoic Fossils, vol. 1, Geol. Surv. Canada, p. 329, figs. 316a-d, 318.

1868. *Illaenus taurus* Meek and Worthen, Geol. Surv. Illinois, 3, p. 320, fig. 2. Galena, Illinois.

1894. *Illaenus americanus* Clarke, Geol. Minnesota 3, pt. 2, p. 714, figs. 20-23. Galena limestone.

1908. *Illaenus taurus* Rowley, Missouri Bur. Geol. and Mines, 2nd ser., vol. 8, p. 57, pl. 15, fig. 1. Trenton limestone (*Receptaculites oweni* horizon), Pike county, Missouri.

Description.—Pygidium transversely subelliptical in outline, strongly convex, length to width as 3 to 5; posterior margin smooth, broadly and evenly rounded, anterior margin transverse medially, obliquely truncated laterally. Axis short, subconate, strongly rounded anteriorly and tapering rapidly to an obsolete termination at the pleural geniculation; width slightly less than one-third the width of the shield. Pleural lobes depressed or flattened near the axis, thence sloping abruptly along a gentle curve to the margin. Surface markings none.

Dimensions.—Specimen 9173, length along median curvature 16 mm., width 27 mm.

Position and locality.—Galena dolomite, in quarries on West Fourteenth St., Dubuque.

Remarks.—The specimen described is an internal cast collected by the writer. It represents all the material of this species at the University though it has been reported by Leonard (Iowa Geol. Survey, vol. XVI, p. 254) from the Upper Platteville about ten to fifteen feet below the Galena dolomite, along a small creek about one mile southwest of Elkader. Savage (Iowa Geol. Survey, vol. XV, p. 462) also reports an undetermined species of *Illaenus* in a zone about fifteen feet below the top of the Galena-Platteville along Turkey river at Clermont. This specimen very likely was *Illaenus americanus* since it appears to be limited to a very definite vertical horizon not only in this state but in the adjacent states of Minnesota, Wisconsin, Illinois and Missouri as well.

BUMASTUS BECKERI Slocom

Plate XVIII, figs. 10, 11.

1913. *Bumastus beckeri* Slocom, Field Mus. Nat. Hist., Geol. ser., vol. 4, p. 54, pl. XIV, figs. 1-4.
1916. *Bumastus beckeri* Slocom, Iowa Geol. Survey, vol. XXV, Ann. Rep. 1914, p. 201, pl. XV, figs. 1-4.

"*Type specimens.*—Holotype in collection of Mr. A. G. Becker, one paratype in collection of State University of Iowa, and the other No. P 16708 Field Museum.

Description.—Body oblong, slightly ovate, width at the genal angles about half the entire length. Dorsal furrows nearly obsolete on the cephalon and thorax and entirely so on the pygidium. Surface, except in the region of the palpebral lobes, dorsal furrows and the anterior central portion of the glabella, marked with indented, transverse lines, more or less parallel to each other and to the transverse divisions of the test. These lines are conspicuous and close together on the doublure, somewhat less so on the cephalon and anterior segments of the thorax. On the posterior segments and pygidium they are inconspicuous and discernible only with a magnifier.

Cephalon strongly convex, semicircular in outline; the location of the dorsal furrows indicated by two almost imperceptible grooves leading up to longitudinally elongate depressions situated just in front of a line joining the anterior edges of the eyes and somewhat nearer to the eyes than to the median line of the cephalon. These depressions appear as sublunate grooves on the casts, but on the surface of the test only as a slight flattening. The regular curvature of the cephalon, aside from the flattening just referred to, is interrupted only by the palpebral lobes. Eyes far apart, situated at about half their length from the posterior margin of the cephalon. Facial sutures originate on the posterior margin of the cephalon on a level with the lower edges of the eyes, from whence they pass forward and upward around the eyes, thence obliquely downward to the antero-lateral margin of the cephalon. Free cheeks small, genal angles obtusely rounded. Occipital ring not discernible on either test or cast.

Thorax composed of ten segments, smooth and flat, gradually narrowing to the almost obsolete dorsal furrows, at which points they bend backward and downward to the lateral margins; the axis occupies about two-thirds of the width of the thorax; dorsal furrows appear on the casts as two parallel grooves.

Pygidium strongly arched, transversely oval, length about two-thirds the width, no trace of the dorsal furrows.

Five specimens were used by the writer in making this description. The holotype is an enrolled specimen having a portion of the front of the cranidium missing. It is in the private collection of Mr. A. G. Becker. A paratype consists of a complete cephalon attached to nine complete thoracic segments and a portion of the tenth. This specimen was collected by Professor Calvin and is a part of the geological collection of the State University of Iowa. The other paratype is a pygidium attached to the seven posterior thoracic segments. It belongs to the Field Museum collections (Field Mus. No. P 16708). Two somewhat distorted natural casts (Field Mus. No. P 16854) also were used in making this description. These casts were presented to the Field Museum by Mr. Becker. The dimensions of the type specimens are as follows:

Holotype: Cephalon 18 mm. long, 31.5 mm. wide; pygidium 15 mm. long, 26.4 mm. wide; distance around the coiled specimen 74.5 mm. Allowance for the convexity of the cephalon and pygidium would make the length, if the specimen were unrolled, about 60 mm. Specimen from the State University of Iowa: Cephalon 19.6 mm. long, 32.3 mm. wide and 18 mm. thick. Specimen P 16708: Pygidium 11 mm. long, 19 mm. wide, length of pygidium and the seven posterior segments of the thorax 33 mm.

Remarks.—Specimens of this species have been referred to *B. orbicaudatus* Billings by Calvin, Savage and others in the various Iowa reports. *B. orbicaudatus* was originally described from a pygidium only and a complete specimen was afterwards figured by Billings. Referring to this description and figure, it is evident that *B. beckeri* is quite distinct from *B. orbicaudatus.* The cephalon and pygidium are much longer in proportion to their width, and the dorsal furrows are much more distinct in *B. orbicaudatus.* The orbicular axis of the pygidium, which is the distinguishing character of *B. orbicaudatus,* is missing in *B. beckeri. B. beckeri* seems to be most closely related to *B. billingsi* Raymond and Narraway, from the Trenton limestone of Canada, but it is considerably narrower in proportion to its length, the trilobation is much less pronounced and no mention is made in the description of *B. billingsi* of any transverse lines on the test.

The specific name is given in honor of Mr. A. G. Becker, whose collection contains the holotype.

Locality and horizon.—All specimens observed are from the Lower Maquoketa beds of Clermont." After Slocom 1916.

Dismembered parts and occasional complete specimens of *B. beckeri* are found in the Lower Maquoketa of Fayette county. Number 9256, a lot of six cranidia and one pygidium, is from the Patrick Leehy farm near Clermont, collected by Professor Thomas and the writer. Numbers 9257a, a paratype used by Slocom, and 9257b were collected by Professor Calvin at Clermont. Number 9258, a very large well preserved specimen was collected by Professor Thomas at Clermont.

Bumastus milleri (Billings)

Plate XVII, fig. 2.

1859. *Illaenus milleri* Billings, Canadian Nat. and Geol. vol. 4, p. 375, fig. 10.

1897. *Bumastus trentonensis* Clarke, Geol. Minnesota 3, pt. 2, 1897, p. 718, figs. 30-35. Trenton limestone, Minneapolis and St. Paul, Minn.; Dixon, Illinois; Platteville, Wisconsin.

1908. *Bumastus milleri* Raymond and Narraway, Ann. Carnegie Mus., 4, 1908, p. 249, pl. 61, figs. 9, 10; pl. 62, figs. 3-5.

This species is represented in the University collection by an incomplete cranidium, No. 9191, from the Platteville limestone along Sny Magill creek in Clayton county. The specimen is quite globose and almost completely exfoliated, showing a very faint trace of the dorsal furrows, which end opposite the anterior portion of the eyes in a pair of small oval-elongate impressions. The eyes and free cheeks are missing.

It is not surprising that this species should be found in this state since it is reported by Clarke, above referred to, at a similar horizon in three adjoining states.

Position and locality.—Number 9191, Platteville limestone, along Sny Magill creek, Clayton county.

BUMASTUS species

Plate XVIII, fig. 12.

A number of years ago while collecting in the Maquoketa shales at Graf, Iowa, the writer found the impressions of an incomplete *Bumastus*, No. 9159, associated with *Diplograptus peosta* in a thinly laminated bituminous shale. The entire specimen, including the pygidium and five complete and two incomplete thoracic segments, is entirely flattened except the terminal parts of the pleural segments, which descend abruptly. The axis of the thorax is faintly outlined and occupies nearly two-thirds of the entire width of the thorax. The pygidium is subsemicircular in outline; the length is to the width nearly as one is to two; the anterior margin is gently curved. It bears no traces of an axis or of annulations.

It is hoped that more and better material of this form will be found so that the specific identity of the only *Bumastus* thus far found in this locality can be determined.

Position and locality.—Lower Maquoketa shale, in zone 4 of

Professor Thomas' "Section of the railway cut near Graf, Iowa."[7]

THALEOPS OVATA Conrad

Plate XVII, figs. 3-5.

1843. *Thaleops ovata* Conrad, Proc. Acad. Nat. Sci. Philadelphia, vol. I, p. 332.
1882. *Illaenus ovatus* Whitfield, Geol. Wisconsin, vol. IV, p. 238, pl. 5, figs. 1-2.
1897. *Thaleops ovata* Clarke, Pal. Minnesota, vol. III, pt. 2, p. 716, figs. 17-19.
1913. *Thaleops ovata* Slocom, Field Mus. Nat. Hist., Geol. Ser., vol. 4, p. 56, pl. XIV, figs. 6-8.
1916. *Thaleops ovata* Slocom, Iowa Geol. Survey, vol. XXV, Annual Rep. 1914, p. 204, pl. XV, figs. 6-8.

"Body broadly ovate, widest at the base of the cephalon, distinctly trilobed, length about equal to the width at the eye lobes.

Cephalon broadly semicircular on the anterior margin, very highly convex. Dorsal furrows clearly defined on the posterior third of the cephalon, obsolete in front. Glabella convex between the dorsal furrows, not defined in front. Eyes small, pedunculate, extending laterally and horizontally. Occipital segment and furrow very faintly marked, rounded backward. Free cheeks small, produced laterally at the genal angles into blunt spines. The facial sutures rise rapidly from the posterior margin to the summit of the eye lobes, thence round gradually forward to the anterior margin, which they intersect in front of the dorsal furrows.

Thorax wider than long, tapering, composed of ten smooth, slightly convex segments. Axial lobe depressed convex, narrower than the lateral lobes, segments arched forward. Pleuræ flat for more than half their width from the axis, then bent downward, segments strongly recurved toward their extremities.

Pygidium nearly flat on top and curving abruptly to the margins, short, subquadratic. The posterior margin forms a very broad curve, width about twice the length. Axis prominent, narrower than the thoracic axis, tapering slightly and terminating bluntly in an elevated extremity, which is faintly bilobed; axis entirely surrounded by the dorsal furrows; annulations of the axis nearly obsolete.

The surface of the cephalon is covered with epidermal punctæ

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7 A. O. Thomas, Iowa Acad. Sci., vol. 21, pp. 225-229, 1914.

except in the dorsal furrows and on the palpebral lobes. On the cheeks and anterior portion of the glabella the punctæ are vertical and isolated, on the posterior surface of the glabella they are oblique and crowded. The surface of the thorax appears to be smooth. Doublure marked with prominent lines parallel to the anterior margin. Pygidium sparsely punctate on the posterior margin but on the anterior portion the punctations are deep, coarse, and arranged in transverse rows.

The foregoing description is based on a practically complete specimen from the Platteville beds at Mineral Point, Wisconsin, in the paleontological collection of the University of Chicago. The Fayette county specimens have been compared with the Platteville specimen and agree so well that they must be considered to be specifically identical, although previously *T. ovata* has been found only at lower geological horizons.

This species is represented in the Field Museum collections from Fayette county by a nearly complete cranidium from the Lower Maquoketa at Clermont and another from the Upper Maquoketa at Pattersons Springs." After Slocom 1916.

This species is represented in the University collection by a cast of a nearly complete individual, No. 9251, which is somewhat distorted. This specimen comes from the Platteville limestone at Beloit, Wisconsin. The following specimens are all from the Platteville limestone about one mile southwest of McGregor along the road to Pikes Peak: No. 9194, a complete pygidium; No. 9195, a pygidium in conjunction with the thorax; Nos. 9196 and 9197 are two cranidia. The species has been recorded also from Decorah by Clarke, 1897, page 718, referred to above.

Family **LICHADIDAE**

Amphilichas rhinoceros Slocom

Plate XVIII, figs. 7, 8.

1913. *Amphilichas rhinoceros* Slocom, Field Mus. Nat. Hist., Geol. Ser., vol. 4, p. 58, pl. XV, figs. 5-6.
1916. *Amphilichas rhinoceros* Slocom, Iowa Geol. Survey, vol. XXV, Ann. Rep. 1914, p. 206, pl. XVI, figs. 5-6.

"Type specimen No. P 11181 Field Museum.

Glabella large, occupying nearly the entire width of the cranidium, depressed convex posteriorly, inflated in front, subpentangular in outline, rounded anteriorly, greatest width just in front of the eyes; the single pair of glabella furrows originates on the lateral margins; curves gently inward and backward for about half the length of the glabella, thence backward subparallel until these furrows join the occipital furrow. They thus divide the glabella into a median and two lateral lobes. Median lobe broad in front, posterior half only slightly convex, anterior half abruptly inflated, length about two and one-half times the width at the occipital furrow. Lateral lobes undivided, margins subparallel, width about equal to that of the median lobe, moderately convex except in front where they bend outward and downward to the lateral margins; greatest elevation near the dorsal furrows in line with the palpebral lobes, where large nodes rise abruptly from the dorsal furrows but elsewhere gradually; these nodes form the bases of the two long lateral spines. The occipital segment forms a wide depressed transverse band, widest in the middle and gradually narrowing towards the dorsal furrows; posterior margin slightly concave, with a well developed doublure. Dorsal furrows, as well as glabella and occipital furrows, narrow but well defined. Fixed cheeks small, depressed, convex, aside from the palpebral lobes, which rise abruptly; the only portion of the palpebral lobes observed is that attached to the fixed cheek. This is elevated, lunate in form with the convex side toward the dorsal furrows. The marginal border of the cephalon is represented by only a single, somewhat crushed fragment, but this fragment indicates that there was a narrow marginal border similar to that of *A. bicornis* Ulrich. Eyes and free cheeks not preserved. Surface of the cephalon finely papillose, with tubercles of various sizes more or less regularly arranged thereon. Two of the larger of these tubercles occur along the median line of the glabella, one on each lateral lobe, and three form a transverse row on the occipital segment; aside from these tubercles, the inflated anterior portion of the glabella supports a pair of recurved hornlike processes, 2.5 mm. in diameter and 29 mm. long (measured on the outer side of the curve); these processes diverge somewhat and curve upward, then backward. Another pair of processes of about the same size occurs, one on each lateral lobe of the glabella, near the dorsal furrow, in line with the eyes. Exact length of the lateral pair of processes not known.

Thorax and pygidium unknown.

The specimen (Field Mus. No. P 11181) on which the above description is based consists of a nearly complete cranidium of which the inner surface of the test is exposed with one of the anterior horns complete and in natural position and one of the lateral ones bent outward with the end missing. The dimensions are as follows: Length of cranidium, along the median line, 32 mm.; greatest width of glabella (in front of eyes) 42 mm.; width of median glabella lobe on anterior margin 18 mm.; width at occipital furrow 11.5 mm.; width of lateral lobes 11.5 mm.; width of occipital segment on median line 7 mm.; width at dorsal furrows 5.5 mm.

Remarks.—In general form and proportion the cranidium above described approaches *A. bicornis* Ulrich, from a similar horizon in Minnesota, but is distinguished from that species by the number and position of the hornlike processes as well as by the variation in size of the surface tubercles; also in a side view of the glabella of *A. bicornis* the outline of the surface is convex, while in *A. rhinoceros* the outline near the middle is concave, due to the inflation of the anterior portion.

Locality and horizon.—Upper layers of the Lower Maquoketa beds at Elgin.'' After Slocom 1916.

No additional material of this very rare and interesting species has been found to date since Slocom's work on *A. rhinoceros.*

AMPHILICHAS CLERMONTENSIS Slocom

Plate XVIII, fig. 9.

1913. *Amphilichas clermontensis* Slocom, Field Mus. Nat. Hist., Geol. Ser., vol. 4, p. 59, pl. XV, fig. 7.

1916. *Amphilichas clermontensis* Slocom, Iowa Geol. Survey, vol. XXV, Ann. Rep. 1914, p. 207, pl. XVI, fig. 7.

''Type specimen No. P 11257 Field Museum.

Cephalon subtriangular, broadly rounded anteriorly, much shorter in proportion to the width than *A. rhinoceros.* Glabella convex, greatest elevation just in front of the center, to which point it rises gradually from the posterior and lateral margins and much more abruptly anteriorly; subpentangular in outline, widest in front of the eyes; a single pair of glabella furrows originates on the lateral margins, curves abruptly inward and upward, then converges backward until it meets the occipital furrow, forming a large median lobe and two smaller lateral lobes. Median lobe very broad anteriorly, more than twice the width at the occipital furrow. It comprises nearly two-thirds of the glabella. Lateral lobes undivided, margins subparallel, conforming to the general convexity of the glabella, abruptly bent downward anteriorly. Occipital segment a flat or slightly concave transverse band, widest at the juncture of the occipital and glabella furrows, narrowing slightly to the median line and more so laterally. Occipital and glabella furrows narrow but distinct. Surface smooth to the naked eye, but a magnifier shows it to be covered with variously sized pustules. No nodes or spines interrupt the regular curvature of the cephalon.

Thorax and pygidium unknown.

The specimen here described (Field Mus. No. P 11257) consists of an incomplete glabella. The cheeks and marginal border are entirely missing. The median lobe and one lateral lobe are nearly complete, and the other lateral lobe is somewhat less so. The occipital, one dorsal and the glabella furrows are well indicated and the median portion of the occipital segment is intact. While the specimen leaves much to be desired, yet the generic characters are well shown and the specific characters fairly well.

The dimensions are as follows:

Length of glabella on median line (exclusive of occipital segment)	24.5 mm.
Greatest width of glabella (in front of the eyes)	30 mm.
Width of glabella at occipital furrow	26 mm.
Width of median glabella lobe on anterior margin, about	24 mm.
Width of median glabella lobe on occipital furrow	11.5 mm.
Width of lateral glabella lobes	8.5 mm.
Length of lateral glabella lobes	17 mm.
Width of occipital segment on median line	3.5 mm.
Width of occipital segment behind glabella furrows	4.2 mm.

Amphilichas clermontensis is distinguished from the other members of this genus by the much greater width of the glabella in proportion to its length and by its more nearly arcuate curvature both longitudinally and transversely. In surface ornamentation it resembles *A. circullus* from the Trenton, but in form it is quite distinct from that species.

Locality and horizon.—Lower Maquoketa Beds, Clermont." After Slocom 1916.

The specimen described by Slocom represents all the known material of this species. The collecting trip in northeastern Iowa added no representative of this rare species.

Remarks.—Foerste[8], who has made a very thorough study of the American Lichadidae, has suggested that *A. rhinoceros* and *A. clermontensis* of Slocom probably belong to his new genus *Acrolichas.* The genus *Acrolichas,* according to Foerste, differs

[8] The Generic Relations of the American Lichadidae. By Aug. F. Foerste, Am. Jour. Sci., vol. XLIX, pp. 26-50, with 2 text figs. and 4 plates, Jan., 1920.

from *Amphilichas* of Europe primarily in the character of the pygidium. The axial lobe of the pygidium of the latter is somewhat constricted near the middle, widening toward both ends, whereas on the former, the typical American genus, the axial lobe of the pygidium tapers posteriorly to a point which ends in the notch between the posterior pair of lateral ribs.

Since the pygidia of Slocom's species are not known and since the cranidia of the two genera under consideration are almost identical it seems best to retain these species under the generic name *Amphilichas* until further investigation reveals pygidia which will show undoubted *Acrolichas* characters. That these species will very likely be placed with *Acrolichas* is foreshadowed by the fact that Dr. Foerste shows quite clearly that *Acrolichas* is typically American and *Amphilichas* typically European in geographical distribution.

Family **ODONTOPLEURIDAE** Burmeister

Genus Ceratocephala Warder

Ceratocephala maquoketensis n. s.

Plate XVIII, figs. 2, 3.

Description.—Size very small, strongly trilobate, the lateral margins of the head and thorax bordered with spines. Pygidium unknown.

Cephalon subcrescentiform in outline, depressed convex, produced into long narrow divergent spines at the genal angles; entire margin thickened into a narrow encircling ridge which bears about twelve spines on each free cheek between the genal angles and the anterior limb of the facial suture. A marginal sulcus extends parallel to the marginal ridge from the genal angles to the anterior end of the cephalon and is narrower in front of the glabella. Glabella prominent, depressed below the fixed cheeks posteriorly, subrectangular, widest across the basal lobes, and well defined by the dorsal furrows; median lobe elongate, transversely elliptical and widest in front, parallel-sided posteriorly and extending from the anterior marginal sulcus to the occipital groove. There are two pairs of isolated lateral lobes; the first pair is oval elongate subparallel to the long axis of the glabella; the second pair is much larger, rounded posteriorly, pointed anteriorly, and directed obliquely outward and forward. The two anterior lateral furrows are deep, directed obliquely inward, somewhat wider and shallower where they pass backward along the median lobe. The second lateral furrows are larger than the first, also directed obliquely backward, shallower along the median lobe and continuing posteriorly to the occipital groove. A pair of small indistinct occipital lobes is present at the antero-lateral angles of the occipital segment. Occipital segment broad, gently arched, bearing a strong median tubercle and two divergent spines from the postero-lateral angles. (The specimen being an internal cast of the dorsal crust the length of these occipital spines can not be measured without destroying a part of the thorax.) Occipital groove wide, shallow and smooth.

Fixed cheeks prominent, rising strongly above the posterior surface of the glabella to the eyes; sloping gently forward toward the anterior margin from the eyes and abruptly backward and downward to the deep groove which extends along the posterior limb of the fixed cheeks from the dorsal furrows to the genal angles. A narrow sharp occular ridge, bounded on each side by equally narrow grooves, connects the eyes with the antero-lateral angles of the median glabellar lobe. The eyes are small, strongly elevated and situated about their own length in front of the posterior margin of the cephalon.

The facial sutures originate at the genal angles, pass a short distance forward parallel to the outer margin of the free cheeks, curve sharply inward and continue obliquely to the eyes; in front of the eyes they describe a gentle arcuate curve cutting the anterior margin of the cephalon in a straight line in front of the inner margin of the eyes. Entire surface, except grooves, strongly tuberculate.

The thorax is represented by eight complete segments and the pleural portion of the ninth. The axis is well defined, narrow, moderately convex, less than one-third the width of the thorax exclusive of the marginal spines; the sides are straight, tapering gently posteriorly. The segments are rounded and covered with spinelike tubercles; those near the dorsal furrows are small and irregularly arranged; the remaining tubercles are larger, arranged in five longitudinal rows so that the tubercles of one row alternate in position on the segment with those of the adjacent row. The tubercles of the median row are located on the anterior margin of each segment.

The pleural lobes are flattened throughout their entire width. Each segment is continued laterally into a pair of long slender divergent spines which extend obliquely backward. A narrow well defined sulcus near the anterior margin divides each segment into a larger posterior portion and a smaller anterior portion; the former bears a row of five tubercles, the latter from seven to nine smaller ones. The base of each pleural spine bears a number of similar tubercles.

Dimensions.—Specimen No. 9233, median length of cephalon 3 mm., width between the genal angles 7 mm., width between the ends of the genal spines 11.5 mm., length of eight thoracic segments 4 mm., width of thoracic axis 2.2 mm.

Position and locality.—Elgin member of the Maquoketa, Florenceville. Collected by Mary L. Calvin (Mrs. S. Calvin).

Remarks.—The incomplete type specimen described above represents all the known material of this species. The surface markings of *C. maquoketensis* stand in such striking contrast to the other Ordovician species of this genus that a comparison seems hardly necessary.

Order **PROPARIA**

Family **ENCRINURIDAE**

ENCRINURUS PERNODOSUS Slocom

Plate XVIII, figs. 4, 5, 6.

1913. *Encrinurus pernodosus* Slocom, Field Mus. Nat. Hist., Geol. Ser., vol. 4, p. 61, pl. XVI, figs. 5-7.
1916. *Encrinurus pernodosus* Slocom, Iowa Geol. Survey, vol. XXV, Ann. Rep. 1914, p. 209, pl. XVII, figs. 5-7.

"Type specimens Nos. P 17038 and P 16930 Field Museum.

Body ovate in outline, trilobation distinct, without genal or caudal spines.

Cephalon sublunate in outline, anterior margin inflated, width more than twice the length. Glabella subhemispherical, width somewhat less than the length, slightly protruding beyond the anterior margin; three pairs of indistinct lateral glabella furrows define the lateral lobes; these furrows rapidly decrease in depth from the dorsal furrows and become obsolete among the tubercles; a well-defined furrow originates on the dorsal furrows about midway between the anterior lateral glabella furrows and the anterior marginal furrow and bends slightly forward in crossing the anterior lobe of the glabella; anterior glabella lobe large, comprising nearly half the glabella, lateral lobes quadrangular, decreasing rapidly in size posteriorly; occipital segment narrow, resembling the axial portion of one of the thoracic segments in size and form; occipital furrow narrow, angular, well-defined; dorsal furrows deep, angular, diverging somewhat from the occipital furrow to the anterior marginal furrow; cheeks subtriangular in outline, depressed conical in form, sloping gradually to the palpebral lobes; eyes small, pedunculate, holochroal; facial sutures originating at the genal angles, passing directly to the palpebral lobes, which they cross, thence obliquely forward, crossing the dorsal furrows and subparallel to the furrow crossing the glabella, until they meet the rostral plate, where they bend abruptly forward to the anterior margin; free cheeks large, more than twice the size of the fixed cheeks; marginal borders well-defined by the marginal furrows, those of the posterior margin narrow, those of the lateral margins wide, gradually narrowing to the anterior margin; genal angles rounded, ending in a large tubercle. Surface of the glabella covered with large rounded tubercles, that of the cheeks near the dorsal and lateral marginal furrows tubercular, other portions covered with elongated pits radiating from the eyes; surface of the occipital segment and marginal borders finely granulose. Hypostoma broadly elliptical, convex.

Thorax composed of eleven segments; axis convex, about the same width as the pleuræ; tapering slightly posteriorly, pleuræ curving regularly to the lateral margins; surface of the thoracic segments finely granulose, ornamented with indistinct nodes; these vary from two to four on the axis and one or two on each pleura; no pleural grooves.

Pygidium triangular, convex, width somewhat greater than the length, rounded posteriorly, no caudal spines. Axis convex, conical, occupying about one-third the anterior margin of the pygidium, with many annulations, which diminish in size and distinctness posteriorly so that the number visible depends to a great extent on the amount of abrasion to which the specimen has been subjected; most of the annulations bear two to four rounded nodes, having decided pits in their apices. Pleuræ composed of seven distinct ribs, which curve slightly upward and then downward and backward to the margins; each rib ornamented with two or more rather indistinct nodes near the dorsal furrows and with a prominent knoblike distal end.

Dimensions of the type specimen:

Length of cephalon	10 mm.
Width of cephalon at genal angles	17.5 mm.
Length of glabella exclusive of occipital segment	8.4 mm.
Width of glabella on anterior margin	8.0 mm.
Width of glabella on occipital furrow	5.0 mm.
Entire length of body measured on a coiled specimen	32.0 mm.
Length of pygidium (Field Mus. No. P 16930)	8.2 mm.
Width of pygidium	9.6 mm.
Width of axis at anterior margin	3.6 mm.

The species is known from the holotype (Field Mus. No. P 17038) in which the cephalon, about two-thirds of the thorax and most of the pygidium are preserved, from five detached pygidia and from one specimen in which the entire pygidium is attached to all but the anterior segment of the thorax.

In general form and proportions the species here described resembles *E. variolans* Brongniart, from the Wenlock Limestone of England, but the tubercles are much larger, the transverse furrow on the glabella is missing and the annulations of the pygidia are fewer in number. *E. sexcostatus* Salter possesses the transverse furrow, but that seems to be about the only resemblance with this species.

Locality and horizon.—The holotype is from the top of the Lower Maquoketa beds at Bloomfield. The species has been found at a similar horizon at Clermont and Elgin, and at a somewhat lower horizon at Clermont.'' After Slocom 1916.

No additional material of this species has been found.

Cybeloides iowensis Slocom

Plate XVIII, fig. 1.

1913. *Cybeloides iowensis* Slocom, genotype, Field Mus. Nat. Hist., Geol. Ser., vol. 4, p. 64, pl. XVI, figs. 1-4.
1916. *Cybeloides iowensis* Slocom, Iowa Geol. Survey, vol. XXV, Ann. Rep. 1914, p 213, pl. XVII, figs. 1-4.

''Type specimens Nos. P 16631, 16633 and 17039 Field Museum. Body depressed convex, distinctly trilobed, outline, aside from the spines, subovate, tapering rather rapidly to a small pygidium. Surface finely granular with many more or less prominent rounded nodes.

Cephalon short, width nearly three times the length, outline sublunate with the anterior lateral margins inflated. Glabella convex, inflated anteriorly, somewhat longer than wide, widest across the lateral lobes; median lobe clavate, narrow at the occipital furrow, gradually widening for about half its length then abruptly widening until its greatest width is reached, rounded in front; lateral lobes longitudinally oval; longitudinal glabella furrows originating in deep pits on the occipital furrow, converging slightly, then curving forward and outward; the positions of the lateral glabella furrows are indicated by three pits in the longitudinal furrows; occipital ring prominent, more elevated than any other part of the cephalon, wide between the glabella furrows, abruptly narrowing towards the dorsal furrows, bearing a large median node with a smaller one on each side of it; occipital furrow shallow and ill-defined in the median portion, deepened into pits near the dorsal furrows. Surface of the glabella finely granular with many prominent rounded nodes arranged in more or less uniform transverse rows; the two largest nodes are close together near the anterior margin and point forward. On the median line of the glabella just in front of a line connecting the anterior pair of glabella pits is a circular, well-marked pit. Cheeks large, depressed convex, not rising as high as the glabella, genal angles produced into long spines, which extend backward more than half the length of the thorax. Marginal borders convex; posterior marginal furrows narrow and deep, lateral marginal furrows not well-defined. The facial sutures originate on the lateral margin just in front of the genal angles, pass almost straight to the palpebral lobes, after crossing which they extend forward for a short distance, then curve abruptly toward the median line and again forward to the anterior margin. Eyes small, pedunculate and very prominent, situated on a line with the anterior pair of glabella pits near the dorsal furrows; a pair of ocular ridges connects the eyes with the anterior lobe of the glabella. Surface of the cheeks inside the marginal borders reticulated, or covered with rows of pits; surface of the marginal borders granular like the glabella, many nodes irregularly distributed over the cheeks; these nodes average somewhat larger than those on the glabella; the larger ones are on the posterior margin and point backward instead of outward.

Thorax composed of twelve segments, rather rapidly tapering posteriorly, distinctly trilobed; axis convex, less than one-third the width of the thorax; the pleural lobes curve gently for about half their width and then more abruptly to the lateral margins. Each segment is divided unequally by a furrow extending nearly from one margin of the thorax to the other. The posterior portion, which is the wider, bears numerous nodes, four of which occur on the axis and two or more on each pleura. The nodes on the pleuræ are much larger than those on the axis and their location on different segments is not always uniform. The five anterior segments terminate at the lateral margins of the thorax, but the seven posterior ones are abruptly bent backward at the lateral thoracic margins and are produced into spines. The spines of the sixth segment extend more than one-third their length beyond the pygidium; the spines of the other segments are considerably shorter.

Pygidium small but too poorly preserved in the specimens at hand for a detailed description.

The dimensions of the type specimens are as follows:

Length of the holotype along the axis 23.6 mm. Length of body, including pleural spines, 31.3 mm.; width at genal angles 19.6 mm.; length of cephalon, including genal spines, 16 mm.; length of glabella 7.8 mm.; width of anterior portion of glabella 4.7 mm., across lateral lobes, 5.3 mm.; length of thorax 12.8 mm.

Width of paratype at genal angles 27.8 mm.; length of glabella 10.7 mm.; width of posterior portion 8.0 mm., across lateral lobes, 8.7 mm.

This description is based upon the holotype (Field Mus. No. P 16631), a nearly complete specimen, a practically complete cephalon (Field Mus. No. P 17039), somewhat larger than the holotype, and a detached free cheek with eye (Field Mus. No. P 16633).

Localities and horizon.—The holotype was collected by the writer from the top of the Lower Maquoketa beds at Elgin, the two paratypes from a similar horizon at Bloomfield. More or less complete cranidia are not uncommon at a similar and somewhat lower horizon at Clermont." After Slocom 1916.

In the University collection there is one cranidium of *C. iowensis,* No. 9259, from the Elgin member of the Maquoketa at Dover Mills and Doctor Thomas found a well preserved nearly complete specimen, No. 9263, in the same horizon on the Leehy farm near Clermont.

Family CALYMENIDAE

CALYMENE FAYETTENSIS Slocom

Plate XIX, figs. 4, 5, 6.

1913. *Calymene fayettensis* Slocom, Field Museum of Natural History, Geology, vol. IV, p. 67, pl. 16, figs. 8-9. Lower Maquoketa shale, Clermont, Elgin, Bloomfield.
1916. *Calymene fayettensis* Slocom, Iowa Geol. Survey, vol. XXV, p. 216, pl. 17, figs. 8-9.

The general form and outline of this species is quite similar to the other members of this genus. The glabella is moderately convex and only slightly elevated above the cheeks; the width across the posterior glabellar lobes is somewhat less than the median length. The dorsal furrows are well defined throughout. The eyes are situated about opposite the second glabellar furrows. The axial segments of the thorax are arched gently forward and provided on either side with a rounded node adjacent to the dorsal furrow. The proximal third of each pleural segment of the thorax bears on the anterior margin an elongate triangular lobe the point of which is directed forward on the crest of the convexity when the body is rolled up. The axis of the pygidium is marked by seven annulations and each pleural lobe by five or more. The annulations of the latter are marked distally by a faint median groove. All parts of the surface are covered by fine papillæ and numerous small rounded tubercles.

For a detailed description see Slocom, op. cit., 1913.

This species is similar to *C. senaria* in many respects and was so referred until Slocom erected this new species. Only by a close comparison can certain differences between the two species be distinguished. In *C. senaria* the anterior lateral glabellar furrows are more distinct but the lateral nodes on each thoracic axial segment as well as the small rounded tubercles on the general surface are wanting. Slocom[9] in comparing the two species states: "the glabella in *C. senaria* is shorter and more convex, the pleural segments of the pygidium do not have a longitudinal furrow." On comparing the length of the glabellae with the

[9] Slocom, op. cit., 1913, p. 68.

median length of the cephala of twenty undoubted *C. senaria* from the Waynesville, Ohio, area the ratio is found to be as 8 to 12 and for eight *C. fayettensis* from Iowa the ratio is as 8 to 11.2. This small difference in length of glabella is of small specific value. All of the *C. fayettensis* at hand have the longitudinal furrow on the pleural segments of the pygidium but this character appears also to be common to *C. senaria* for out of twenty-five specimens of the latter examined eleven had the furrows and fourteen were without them. Those specimens which do not show the furrows seem to be somewhat worn.

Position and localities.—Maquoketa shales, Elgin and Clermont members, at Clermont, Elgin, Dover Mills, Ossian and numerous other localities in northeast Iowa.

Cranidia of this species are fairly common but complete specimens are rare.

Calymene senaria, where it is mentioned in the various county reports dealing with the Ordovician, is here referred to *C. fayettensis,* except that mentioned for Pattersons Springs (Iowa Geol. Survey, vol. XV, p. 479) which is *C. gracilis.*

CALYMENE GRACILIS Slocom

Plate XIX, figs. 7, 8.

1913. *Calymene gracilis* Slocom, Field Museum of Natural History, Geology, vol. IV, p. 69, pl. 18, fig. 9. Limestone layers of the Upper Maquoketa beds at Patterson's Springs near Brainard, Iowa.

1916. *Calymene gracilis* Slocom, Iowa Geol. Survey, vol. XXV, p. 219, pl. 19, fig. 9. Horizon and locality same as preceding.

The following description is after Slocom 1913:

"Body small, in form and general proportions similar to other species of the genus. The surface of the test appears smooth to the naked eye but under a magnifier it appears very finely papillose.

Cephalon sublunate, width of the genal angles somewhat less than twice the length of the median line, about as 7 to 4. Anterior border flat, projecting obliquely forward and upward, not recurved, separated from the glabella by a deep, narrow, marginal furrow. The dorsal furrows, in passing forward from the occipital ring, diverge slightly near the posterior glabellar lobes, then converge until they meet the anterior marginal furrow. Here the dorsal furrows become nearly obsolete on account of a large rounded node on each fixed cheek, opposite the anterior lobe of the glabella. Glabella convex, elevated above the cheeks, shorter than is usual in this genus, widest at the posterior lobes where the width is equal to the length, including the occipital ring, much narrower anteriorly; anterior lobe transverse, width less than one-third the length; first lateral lobes well defined, about the width of the anterior lobe and terminating about the same distance from the median line; second lateral lobes large and node-like; posterior lateral lobes much larger, forming a pair of conspicuous nodes at the base of the glabella. Lateral furrows well defined but not crossing the glabella. The first pair transverse; second pair somewhat larger but bent slightly backward; posterior pair broader and deeper, curved backward towards but not reaching the occipital furrow. At about two-thirds of their length from the dorsal furrows they bifurcate and the shorter fork extends toward the median line of the glabella, forming a well-defined node between the second and posterior lobes. The facial sutures originate just in front of the genal angles, curve forward and inward over the palpebral lobes and thence forward to the anterior margin. Occipital ring prominent, slightly wider in the middle, separated from the rest of the glabella by a well-defined occipital furrow. Cheeks only moderately convex aside from the palpebral lobes, which are long for this genus and rise very abruptly from the dorsal furrows; lateral marginal borders wide and well rounded, posterior border much narrower; all are defined by deep marginal furrows.

Thorax known only by a few detached segments which indicate that it was narrow and elevated.

Pygidium subtriangular, terminating in a rounded obtuse angle, strongly elevated and trilobed. Axis convex, marked by six or seven annulations; it tapers gradually and is truncated posteriorly so that the dorsal furrows instead of meeting at a point posteriorly are joined by a short transverse furrow; the pleural lobes slope abruptly from the dorsal furrows to the margins; each lobe consists of five segments, faintly grooved on their distal portion; the segments merge into a smooth, undefined marginal border.

The type specimen is a perfect cranidium with the following dimensions: Length on median line 7.8 mm.; length including genal angles 9.0 mm.; width 14.0 mm.; length of glabella including occipital ring 5.4 mm.; length of glabella without occipital ring 4.5 mm.; width of glabella at anterior lobe 3.5 mm.; width of glabella at posterior lobe 5.4 mm. A detached pygidium gives the following measurements: Length 3.4 mm.; width 6.4 mm.; thickness 4.8 mm.''

Position and locality.—Brainard member of the Maquoketa at Pattersons Springs near Brainard.

Remarks.—During the summer of 1921 the writer visited the type locality and collected numerous slabs of highly fossiliferous limestone immediately underlying the Niagaran limestone. Cranidia, pygidia and other parts of the body of *C. gracilis* are very common. Associated with these fragments there is a calymenid hypostoma which is here referred to this species since at this horizon no other *Calymene* is found to which this hypostoma could belong. *Calymene gracilis* can be readily distinguished from all other *Calymene* by its small size, the relatively high palpebral lobes and the node which is situated on each fixed cheek in apposition to the frontal lobe, causing the dorsal furrow to be obsolete in many specimens. The uppermost layers of the Maquoketa were examined in many places in northeastern Iowa but *C. gracilis* was found in the type locality only.

Calymene mammillata Hall

Plate XIX, figs. 1, 2, 3.

1861. *Calymene mammillata* Hall, Rep. Supt. Geol. Surv. Wisconsin, p. 50. In the shales above the Galena limestone, Maquoketa creek, 12 miles west of Dubuque, Iowa.

1862. *Calymene mammillata* Hall, Geol. Wisconsin, vol. 1, p. 432, figs. 1, 2 (no description).

The original description of this species by Hall is here copied.

''Form of the entire body unknown. Cephalic shield broadly semielliptical, the posterior margin nearly straight, the anterior border extended in front of the glabella in a broadly rounded, thickened projection, which is abruptly recurved at the margin, and marked on each side by a mammilliform tubercle about half way between the antero-lateral angle of the glabella and the edge of the border. The glabella is proportionally small, broad at base, rounded in front, lobed at the sides by three pairs of transverse furrows; the posterior lobes extend about one-third across the glabella, and are directed backwards, forming two rather large tubercles; the two anterior pairs are small, and extend but a short distance from the margin of the glabella. The centre of the glabella is prominent, the sides nearly parallel to the anterior angles, which are slightly extended laterally; occipital furrow distinct, bent forward in the middle. Cheeks very prominent, giving great depth to the furrows which divide them from the glabella; the lateral borders thickened with a rounded margin. On the inside of the projecting border, in front of the glabella, there are two large rounded tubercles, which form a conspicuous feature.

Pygidium semielliptical, the central lobe or axis not very prominent, marked by seven annulations besides the terminal one, which is nearly as long (wide) as the three preceding, obtusely rounded posteriorly: the lateral lobes are broad, nearly twice the width of the central lobe at its junction with the last thoracic segment; marked by six broad flattened ribs, which become obsolete before reaching the margin; the anterior five are divided in the middle or on the outer half of their length, by a narrow sulcus.

Surface of the whole crust of the body, so far as seen, covered with fine rounded papillæ."

Remarks.—This trilobite is so distinctive that it is not likely to be mistaken for any other species of *Calymene*. The unusually large, broadly rounded, thickened, upward projecting brim in front of the glabella, the two mammilliform tubercles on the inside of the brim anterior to the dorsal furrows, the exceptionally deep dorsal furrows between the glabella and fixed cheeks, the small frontal lobe with its node-like projection on each antero-lateral angle and the characteristic surface markings are features which distinguish this species from all other *Calymene*. The average median length of the cephalon is about 15 mm., and the width across the genal angles is twice the length. The axis of the pygidium is well defined throughout, broadly rounded behind and bordered by the dorsal furrow, which widens into a broad shallow groove in the region of the sixth to the eighth segments.

Associated in the same beds with the cranidia and the pygidia of *C. mammillata* there is a calymenid hypostoma which, because of its association, is here tentatively referred to this species. The hypostoma is considerably longer than wide and the anterior third is abruptly expanded from the nearly straight or gently curved sides to form a semicircular enlargement with a recurved margin. The posterior part is produced into a short fork and the central area is broadly convex and bordered by a groove on each side.

Position and localities.—This species has been successively recorded from this same locality by Hall (op. cit.), James, Calvin and Bain, and Thomas.[10] And the writer has collected numerous cranidia, pygidia and a hypostoma from here. Savage (Iowa Geol. Survey, vol. XVI, 1905, p. 601) reports a pygidium from the Maquoketa shale at Bellevue, Iowa, which he refers to this species. As far as now known *C. mammillata* has not been recorded from any localities outside of the state of Iowa[11] and within the state it is limited in its occurrence to the Maquoketa shales. The type specimens are now in the American Museum of Natural History and according to Whitfield (Bull. Am. Mus. Nat. Hist., vol. XI, pt. I, 1898, p. 68) they consist of "a large, partly exfoliated cranidium and a pygidium, imbedded separately" and "four unfigured types in the series." Their museum catalogue number is 1408.

CALYMENE CALLICEPHALA Green

1832. *Calymene callicephala* Green, Mon. Tril. North America, p. 30, cast 2.

This species has been reported from the Maquoketa shales at Graf, Iowa, by Joseph F. James.[12] Other geologists who have collected in this locality either before or since 1890 have failed to note the occurrence of *C. callicephala.* There seems to be a good deal of doubt concerning the status of this species. Bassler[13] suggests that the specific name *callicephala* be abandoned since Green's cast of the type can not be identified with any of the species of *Calymene.* In all probability therefore the *C. callicephala* of James is a *C. mammillata.*

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10 James, American Geologist, vol. 5, 1890, p. 353. Calvin and Bain, Iowa Geol. Survey, vol. X, p. 435. Thomas, Iowa Acad. Sci., Proc., vol. XXI, p. 229.

11 James (op. cit., 1890, p. 353) reports *C. mammillata* from Wisconsin without, however, giving any locality. It is possible that this is an error. In the Geology of Wisconsin, Hall lists this species and gives the only figures which have ever been published of the type but no locality is mentioned. From this record James may have assumed that the species occurs in Wisconsin.

12 James, Am. Geol., vol. V, p. 353, 1890.

13 Bassler, Bibliographic Index of American Ordovician and Silurian Fossils: vol. I, p. 166.

Family CHEIRURIDAE

CERAURUS PLEUREXANTHEMUS Green

Plate XIX, fig. 9.

1832. *Ceraurus pleurexanthemus* Green, Mo. Amer. Jour. Geol., vol. I, p. 560, pl. 4, fig. 10.
1847. *Ceraurus pleurexanthemus* Hall, Pal. New York, vol. I, p. 242, pl. 65, figs. 1 a-1 n except 1d, 1h, 1i, 1m.
1847. *Ceraurus pleurexanthemus* S. A. Miller, Cincinnati Quar. Jour. Sci., vol. I, p. 132.

Thus far this species is but poorly represented in the trilobite fauna of this state. Slocom, in his very careful study of the trilobites of Fayette county, did not observe this species there. The writer met with a similar experience. But the Platteville limestone along Sny Magill creek, Clayton county, yielded one well preserved but incomplete head, No. 9180, showing nearly all the specific characters of the cephalon. The glabella is clavate, moderately convex, rising to the height of the strongly arched occipital segment. Three pairs of short glabella lateral furrows are present on each side, the posterior pair opening into the occipital groove and delimiting a pair of small circular basal lobes. The eyes are situated somewhat closer to the dorsal furrows than to the posterior margin of the cephalon. The genal angles are produced into long curved flaring genal spines. The surface of the glabella and free cheeks is irregularly covered with small tubercles of different sizes. The marginal border and the genal spines are finely granulose.

FIG. 26.—A large and well preserved specimen of *Ceraurus pleurexanthemus* from Boyle's quarry near McGregor. No. 9289. Collected by Miss Florence S. Chapin.

Position and localities.—Number 9180, Platteville limestone, about three and one-half miles southwest of McGregor, along Sny

Magill creek, Clayton county. This species apparently ranges throughout the Platteville of Iowa.

Since the above was written a nearly complete specimen was found in the Platteville limestone at Boyle's quarry near McGregor by Miss Florence S. Chapin. This specimen was briefly described by Dr. A. O. Thomas at the annual meeting of the Iowa Academy of Science at Cedar Falls, May, 1925. Museum No. 9289. See text figure 26.

CERAURUS MILLERANUS Miller and Gurley

Plate XX, fig. 7.

1894. *Ceraurus milleranus* Miller and Gurley, Bull. III, Illinois St. Mus. Nat. Hist., p. 80, pl. 8, fig. 10.
1913. *Ceraurus milleranus* Slocom, Field Mus. Nat. Hist., Geol. ser., vol. 4, p. 71, pl. 17, figs. 1-3.
1916. *Ceraurus milleranus* Slocom, Iowa Geol. Survey, vol. XXV, Ann. Rep. 1914, p. 221, pl. XVIII, figures 1-3.

"Type specimen No. 6062 University of Chicago.

General outline of the carapace, exclusive of the spines, subovate, abruptly narrowed posteriorly; moderately convex, trilobation distinct.

Cephalon semielliptical, width nearly three times the length; dorsal furrows well marked. Glabella convex, narrower than the cheeks at the occipital ring, gradually widening anteriorly until its width about equals its length, abruptly bent downward at the frontal margin; anterior lobe constituting about one-third the length of the glabella; the three pairs of lateral furrows are short and about equidistant, forming three pairs of small convex lateral lobes; the two anterior pairs of furrows extend slightly forward, but the posterior pair is transverse for a part of its course and then bends abruptly backward until it meets the occipital furrow isolating the posterior lateral lobes. Occipital segment arched upward, higher than the anterior portion of the glabella, greatest height at the posterior margin, sloping gradually into the occipital furrow. This furrow is narrow and deep behind the posterior lateral glabella lobes but wider and shallow in its median portion. Cheeks convex with well-defined rounded marginal borders, posterior angle produced into spines, which point backward; eyes prominent, globular, placed near the center of the cheeks; the palpebral lobes bear a pit near the base on the side nearest to the dorsal furrows; the facial sutures originate on the lateral margins about in line with the occipital furrow, curve forward and inward to the palpebral lobes, which they traverse, thence pass forward with a sigmoid curve to the anterior margin of the cephalon.

Thorax composed of ten segments; axis convex, about the same width as the pleuræ; pleuræ flattened for one-third to one-half their width from the dorsal furrows, then bent downward and backward, tapering to a point; each pleural segment is ornamented with a prominent tubercle situated near the point where the pleuræ curve downward; an angular furrow originates on the anterior margin of each pleural segment at the dorsal furrow and crosses it obliquely, reaching the posterior margin behind the tubercle; dorsal furrows distinct, nearly parallel from the first to the eighth thoracic segment, then converging posteriorly.

Pygidium short, much narrower than the posterior segment of the thorax, consisting of three segments; the anterior segment bears a pair of stout spines, which extend posteriorly with the points somewhat converging; axis undefined.

Surface of the cephalon, within the marginal borders, covered with irregularly placed tubercles; on the cheeks the tubercles are somewhat farther apart and the interspaces are pitted; the marginal borders and genal spines are finely granulose; two or more conical tubercles are situated on the posterior borders of the cheeks; the entire thorax is finely granulose, as is also the pygidium, but the granulations are more conspicuous on the caudal spines.

Measurements of the type are as follows:

Length on median line	28.7 mm.
Length including caudal spines	35.4 mm.
Width at genal angles	21.6 mm.
Width at points of genal spines	23.6 mm.
Length of cephalon including genal spines	11.5 mm.
Length of glabella	8.0 mm.
Width of posterior lobes of glabella	6.0 mm.
Width of anterior lobe of glabella	7.5 mm.
Width of pygidium	7.4 mm.
Length of pygidium	2.7 mm.

The above description is based on the type specimen from Cincinnati, Ohio, No. 6062 of the paleontological collection of the University of Chicago. The species is known to the writer from Fayette county by twelve more or less complete cephalons and two pygidia. These agree with the type except that in the type the genal spines are somewhat shorter, the tubercles on the posterior border are less conspicuous and the longitudinal curve of the glabella is somewhat more abrupt in front, making its anterior lobe appear shorter in dorsal view. This last feature may be due to distortion.

C. milleranus is distinguished from *C. pleurexanthemus* by its proportionally shorter cephalon, its less flaring genal spines, and by its eyes being globular and situated about equidistant from the dorsal furrows and from the posterior margin of the cephalon. The eyes of *C. pleurexanthemus* are conical and nearer the dorsal furrows. Further, the spines of the pygidium in *C. milleranus* converge at their points instead of diverging as in *C. pleurexanthemus*.

Locality and horizon.—Lower Maquoketa shales of Clermont and Elgin." After Slocom 1916.

Extended collecting by the author in Fayette county localities resulted in the finding of a few incomplete cephala, Nos. 9198 and 9204, and other fragments which undoubtedly belong to this species. They contribute nothing new. No trace of this species was encountered outside of the areas reported by Slocom except at Dover Mills and McGregor. In the last mentioned locality the species is found in the Platteville limestone.

Ceraurus elginensis Slocom

Plate XIX, fig. 10.

1913. *Ceraurus elginensis* Slocom, Field Mus. Nat. Hist., Geol. Ser., vol. 4, p. 73, pl. XVII, figs. 4, 5.
1916. *Ceraurus elginensis* Slocom, Iowa Geol. Survey, vol. XXV, Ann. Rep. 1914, p. 224, pl. XVIII, figs. 4, 5.

"Type specimens Nos. P. 16630A, 16630B, 17030 Field Museum.

Cephalon sublunate, width more than three times the length, anterior lateral margins arcuate, posterior margin transverse in the median portion, gently bent backward near the genal angles. Glabella convex, clavate; less than half the width of the cheeks at its posterior margin but gradually widening anteriorly until its width nearly equals its length; anterior lobe constituting about one-fourth the entire length of the glabella; three pairs of lateral furrows rather short, well defined, defining three pairs of convex lateral lobes, diminishing in size posteriorly; the two anterior pairs of furrows are transverse, the posterior pair are transverse for part of their length, then bent backward until they join the occipital furrow, isolating the posterior lobes; occipital segment elevated at the posterior margin, sloping into the occipital furrow; occipital furrow shallow, concave in the median portion, narrower, deeper and bent backward behind the glabella lobes; dorsal furrows deep, angular, forming deep angular pits where they merge into the marginal furrows; cheeks large, convex, posterior angles produced into long, stout spines, flattened anteriorly and pointing almost directly backward; palpebral lobes elongated, large for the genus, placed well forward, about midway between the dorsal furrows and the lateral margins but nearer the posterior margins than the dorsal furrows. Near the base of each lobe on the side toward the dorsal furrow is situated a decided pit; an indistinct furrow extends from this pit to the crest of the lobes; the ocular ridges extend from the anterior angle of the palpebral lobes to the pit in the dorsal furrows; the facial sutures originate on the lateral margins about in line with the posterior marginal furrow, curve forward and inward to the palpebral lobes, which they traverse, then forward to the anterior margin, which they reach in front of the glabella; marginal borders prominent, defined by shallow furrows; the posterior furrows curve into the lateral furrows just within the genal angles; free cheeks small, less than one-third the size of the fixed cheeks. The surface of the glabella, with the exception of the occipital segment and the cheeks, is covered with more or less regularly distributed rounded tubercles; a larger, more conical tubercle is situated on each fixed cheek, just in front of the posterior furrow, at about one-third the distance from the dorsal furrow to the genal angle. A row of spinelike tubercles traverses the posterior marginal borders of the cheeks, and similar tubercles are distributed over the flattened portions of the genal spines, gradually diminishing in size posteriorly until they become obsolete.

Thorax not known.

Pygidium transversely subelliptical in outline, aside from the spines length less than half the width; composed of three segments, the extremities of the anterior segment produced into long, stout, flattened spines, which curve outward and backward; second and third segments much smaller; axis not well defined. The surface of the caudal spines is covered with sharp conical tubercles similar to those on the genal spines. The pygidium above described was not associated with the cephalons but came from the same horizon at Bloomfield. Its size and the form and ornamentation of the spines are such as might accompany these cephalons and no other cephalons have been observed to which this pygidium could well be referred.

Measurements	P 16630A	P 16630B
Length of cephalon on median line	13.7 mm.	12.3 mm.
Width of cephalon at genal angles	38.5 mm.	36.3 mm.
Width of cephalon including genal spines (estimated)	40.0 mm.	38.0 mm.
Length of glabella	13.0 mm.	11.0 mm.
Width of anterior lobe of glabella	11.5 mm.	9.6 mm.
Width of posterior lobes of glabella	8.8 mm.	6.7 mm.
	P 17030	
Width of pygidium	10.7 mm.	
Length of pygidium	5.5 mm.	
Length of caudal spines (estimated)	20.0 mm.	

C. elginensis differs from all other species known to the writer in having extremely long genal spines with spinelike tubercles on their flattened portion. It is also distinguished from *C. milleranus* and *C. pleurexanthemus* by having the eyes farther apart. It is most nearly related to *C. dentatus* Raymond and Barton, but the ocular ridges are not present in that species and the eyes are not so far forward.

Locality and horizon.—The species is known to the writer from two cephalons from the top of the Lower Maquoketa beds at Elgin, and a pygidium, which is referred with some doubt, from the same horizon at Bloomfield. Fragments of genal spines and other parts of the test which, from their size and ornamentation, appear to belong to this species, have been observed on slabs from the Upper Maquoketa beds at Pattersons Springs." After Slocom 1916.

Ceraurus savagei, n.s.

Plate XXV, fig. 1.

Description.—Cephalon very broad, moderately convex, narrowly elongate-oval to subelliptical; the length is to the width as 3 is to 8. The genal angles are rounded and without spines. The glabella is prominent, broadly convex, expanding forward at the rate of 1 mm. for every 3.8 mm.; the anterior end is broadly rounded, slightly emarginate medially, and bordered by a narrow marginal rim. There are three pairs of short lateral glabellar lobes; the first and second pairs are nearly equal in size and are delimited by short lateral grooves which are very deep at the dorsal furrows but are obsolete a short distance on the glabella; the third or basal glabellar lobes are isolated and quadrangular in outline. They are separated from the median glabellar lobes by short transverse furrows which terminate in a pitlike depression and connect with short longitudinal furrows which in turn are continuous with the occipital groove. The distance between the basal glabellar lobes is equal to a little more than two and one-half times the width of one basal lobe. The occipital segment is strongly arched but incompletely preserved, the center having been worn away. The occipital furrow is distinct but very shallow at the base of the glabella, more sharply defined at the basal lobes and somewhat larger laterally upon the fixed cheeks; a short distance within the rounded genal angles it turns abruptly forward. The fixed cheeks are large, most convex at the eyes but not attaining to the height of the glabella. The eyes of this specimen are missing but the ocular sinuses extend much closer to the posterior margin of the cephalon than to the dorsal furrows. The posterior margin of the fixed cheeks describes an irregular curve which has a general forward trend toward the genal angles where it curves more sharply forward.

The surface of the glabella is covered with numerous small tubercles. Between the eyes and the dorsal furrows the fixed cheeks bear numerous pits and tubercles but distally near the genal angles the tubercles become coarser and the pits are wanting. The posterior margin of each fixed cheek bears two pairs of tubercles of unequal size; the smaller pair is located near the genal angles, the larger pair near the dorsal furrows and the area between them is smooth.

Dimensions.—Specimen No. 9183 is 15 mm. long and 38 mm. wide; the length of the glabella is 11.4 mm. and the greatest width anteriorly is 11.4 mm.; the width across the basal glabellar lobes is 9 mm.

Free cheeks, eyes, thorax and pygidium unknown.

Position and locality.—Number 9183, Elgin member of the Maquoketa, Dover Mills. Collected by the writer.

Remarks.—The cranidium above described represents all the material of this species in the University collection. The absence of genal spines differentiates it from all existing species of *Ceraurus* except *C. misneri* Foerste, which shares this same character. The latter differs, however, from ours in having a much more abruptly expanding glabella and in having the eyes approximately equidistant from the dorsal furrows and from the posterior margin of the cephalon whereas in *C. savagei* they are decidedly closer to the posterior margin of the cephalon than they are to the dorsal furrows. The position of the eyes is similar to that of *C. dentatus* Raymond and Barton, from which it differs in the absence of genal spines as well as in its much smaller size.

The absence of spines is a striking character but not unique since they are absent also in *C. misneri* mentioned above. As a rule the distal ends of the fixed cheeks of ceraurids tend to thicken for the support of the genal spines but in the holotype this margin is very thin and that of the two extremities has a similar contour, indicating that if genal spines ever were present it is scarcely possible that they could have broken away without leaving a trace on one or the other of the genal angles.

When it was collected the left fixed cheek was covered by a thick but soft matrix. This was removed with considerable care and no trace of a spine was observed although it was confidently expected. Therefore the writer feels fully convinced that this is another rare species without genal spines.

In the "Key to American Species of Ceraurus",[14] *C. savagei* would belong in group B, division c, but with glabella expanding less abruptly forward.

The species is dedicated to Dr. Thomas E. Savage of the University of Illinois, formerly Assistant State Geologist of Iowa and author of "The Geology of Fayette County."

Ceraurus herrmanni n.s.

Plate XIX, figs. 11-15.

Description.—Thorax depressed convex and composed of eleven segments. The sides are broadly rounded, converging abruptly near the posterior end. The axis is moderately convex and bordered by shallow but well defined dorsal furrows. Each segment is arched slightly forward and separated from the adjacent segment by a broad transverse groove. Along the dorsal furrow

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14 Percy E. Raymond and Donald C. Barton, A Revision of the American Species of Ceraurus: Bull. Mus. Comp. Zool., Harvard College, vol. LIV, no. 20, p. 527.

each axial segment is somewhat thickened. The amount of thickening increases posteriorly, having the appearance of a discontinuous ridge. The axis is about four-fifths the width of the pleura. No tubercles are present on the axis.

The pleural lobes are depressed convex and divided into a free outer non-articulating portion and an inner nodose articulating portion. The articulating part of each segment is divided into two convex triangular elongate nodes by a narrow deep diagonal furrow which begins in front at the dorsal furrow and passes outward and backward, ending at the fulcral fold. In the center of each pleura, along a line dividing the free from the fixed portion, there is a less prominent circular node separated from the outer triangular node by a shallow depression directed inward from front to back. In front of each of these tubercles there is a well developed elongate nodelike fulcral process. The free outer portion of each segment is flattened, relatively smooth, bent downward and backward, ending in a point.

The pygidium is composed of four anchylosed segments. The axis is well defined, bearing four transverse annulations. The first is curved forward and constricted medially, bearing a depressed lobe in the constricted portion. The fourth segment is represented by a rectangular nodelike process. The first pleural segment gives rise to a pair of long flattened spines which diverge posteriorly for about one-half their length, thence converge slightly to the end. The second and third segments each give rise to a pair of short blunt spines, and the post-axial area gives rise to a short triangular median spine making in all five short terminal spines within the great spines. At the proximal end of the great spines, adjacent to the dorsal furrows there is a pair of nodes; the anterior of these is about as large as the inner node on the pleura of the last thoracic segment; the posterior node is smaller and more elongate. The second and third pleural annulations are directed obliquely backward so as to appear trapezoidal with the second and third axial segments.

Dimensions.—Length from groove between first and second thoracic segment to median pygidial spine 63 mm., greatest width 60 mm., median length of pygidium 13 mm., total length of same 45 mm.

Position and locality.—Platteville limestone near mouth of Catfish creek, Dubuque. Collected by Mr. Richard Herrmann.

Remarks.—This species is quite similar to *Ceraurus dentatus* Raymond and Barton. Unfortunately, however, the cephalon is unknown so that a complete comparison is impossible. Our specimen differs from *C. dentatus* in the following characters: 1, The great spines are decidedly flattened and not rounded as in *C. dentatus*. This flattening appears to have been the original condition rather than an accident of preservation, since nearby nodes on the pleuræ are not flattened. 2, The distal portions of the great spines curve inward and not outward. 3, The posterior margin of the pygidium is less rounded, a line joining the tips of the small spines being nearly straight whereas in *C. dentatus* it is noticeably curved. 4, The pygidium of *C. herrmanni* is proportionally longer exclusive of great spines. 5, The axis of the pygidium tapers more abruptly between the first and third annulations.

Should a cephalon be found identical with that of *C. dentatus* our species probably would need to be referred to it.

Ceraurus herrmanni is of special interest because of its unusually large size, which exceeds that of the type of *C. dentatus*. The bifurcation of the left great spine on the pygidium is probably an acquired abnormality peculiar to this specimen. Similar bifid spines have been recorded for two or three other specimens of trilobites.

A large hypostoma, found in the Platteville limestone about three and a half miles south of McGregor, is here referred to *C. herrmanni* with some doubt. And several ceraurid free cheeks and cranidia from the same position and horizon as the hypostoma are similarly referred to *C. hermanni* because of their large size. See Plate XIX, figs. 13, 14, 15.

The type specimen was kindly loaned for study by the finder, Mr. Richard Herrmann of Dubuque, in whose museum the specimen now is. The writer takes pleasure in naming this species in honor of Mr. Herrmann.

CERAURINUS ICARUS (Billings)

Plate XX, figs. 10-13.

1860. *Cheirurus icarus* Billings, Can. Nat. and Geol., vol. 5, p. 67, fig. 2.

1873. *Ceraurus icarus* Meek, Pal. Ohio, vol. I, p. 162, pl. 14, figs. 11a-c.
1889. *Ceraurus meekanus* S. A. Miller, N. Am. Geol. and Pal., p. 537.
1913. *Eccoptochile meekanus* Slocom, Field Mus. Nat. Hist., Geol. Ser., vol. 4, p. 75, pl. XVII, figs. 6-9.
1916. *Ceraurinus icarus* Slocom, Iowa Geol. Survey, vol. XXV, Ann. Rep. 1914, p. 227, pl. XVIII, figs. 6-9.

"Body subovate in outline, moderately convex, distinctly trilobed. Surface smooth to the naked eye but under a magnifier the cephalon appears finely granulose.

Cephalon subsemicircular, somewhat flattened anteriorly, genal angles produced into short spines, posterior margin nearly straight until it merges into the genal spines, where it is bent nearly at right angles. Glabella subquadrate, rounded in front, length in front of the occipital furrow about equal to the width, depressed convex. Anterior lobe of the glabella transversely oval, about twice as wide as long, lateral lobes nearly transverse and about equal in size. Glabella furrows distinct, length about one-third the width of the glabella, anterior pair bent backward; middle pair nearly at right angles to the axis of the glabella; posterior pair similar to the middle pair for most of the length but having the inner ends abruptly bent backward until they meet the occipital furrow, isolating the posterior glabella lobes; occipital segment arched upward somewhat higher than the rest of the glabella, wider in the median portion, tapering towards the dorsal furrows; occipital furrow deep and narrow, arched forward. Dorsal furrows deep and narrow, diverging slightly at the posterior margin of the cephalon, thence passing to the front of the glabella, which they surround, leaving a narrow anterior border. In each furrow just in front of the anterior glabella furrow is a distinct pit. Cheeks large, sloping anteriorly and laterally from the eyes; posterior cheek furrows narrow; near the genal angles they meet the lateral furrows, which are wider and extend forward parallel to the margins until they meet the dorsal furrows; marginal borders somewhat concave on account of shallow marginal furrows, which originate on the genal spines. Eyes of moderate size, situated opposite the second glabella furrows, visual surface sublunate, palpebral lobes moderately prominent, approaching in height that of the glabella. The facial sutures originate a short distance in front of the genal angles, curve obliquely forward, then abruptly inward to the posterior angles of the eyes, follow the inner margin of the eyes and again forward with a broad curve, cutting the anterior margin of the cephalon in front of the glabella.

Thorax somewhat longer than wide, consisting of eleven segments, distinctly trilobed. Axis narrower than the pleuræ, regularly arched upward. Pleural lobes flattened for about one-third their width, thence abruptly curved to their lateral margins; each segment marked by a deep groove across the axis; another smaller groove originates on the anterior margin of each pleura near the dorsal furrows and crosses the pleura obliquely; on the anterior margin of each pleura, near the point where the pleura is bent downward, a still smaller groove defines a low oblong node which points forward, not upward. The segments are nearly transverse across the axis and about half the length of the pleuræ; their distal portions curve gently backward to the falcate extremities.

Pygidium small, transversely subelliptical, width more than twice the length, posterior curve much flattened. Axis small with three well defined annulations. Two shallow pits occur just back of the termination of the axis. Pleural lobes large, composed of three segments which are produced posteriorly into flattened spines. The anterior pair is the largest; carinate on top, strongly curved backward and obtusely rounded at the extremities; the other two pairs decrease in size inward and are more pointed.

In my previous paper I referred these forms to *Eccoptochile? meekanus* S. A. Miller, with a footnote stating that Barton had a paper in press in which he created a new genus to which this species should be referred. My judgment in using Miller's species was based upon a rather incomplete description and figure of the Canadian species, which led me to believe that the two forms were distinct. Dr. Raymond has since informed me that, after comparing the Canadian specimens with those from the Mississippi Valley, he considers them to be identical, so that they are here referred to *C. icarus* Billings.

Locality and horizon.—The specimens here described are from the Lower Maquoketa beds, Clermont.'' After Slocom 1916.

Professor A. O. Thomas and the author found a number of cephala and a nearly complete specimen in the Lower Maquoketa in the vicinity of Clermont but the material is rare and usually fragmentary. Number 9243 is a cranidium from section 19, Clermont township. Numbers 9244, the left half of a specimen, and 9245, a nearly complete specimen, were collected by Professor Thomas on the Patrick Leehy farm near Clermont. A number of years ago Professor Calvin collected two nearly complete specimens, Nos. 9169 and 9170, at Clermont.

SPHAEROCORYPHE MAQUOKETENSIS Slocom

Plate XX, figs. 4-6.

1913. *Sphaerocoryphe maquoketensis* Slocom, Field Mus. Nat. Hist., Geol. Ser., vol. 4, p. 77, pl. XV, figs. 1-4.
1916. *Sphaerocoryphe maquoketensis* Slocom, Iowa Geol. Survey, vol. XXV, Ann. Rep. 1914, p. 229, pl. XVI, figs. 1-4.

"Type specimens Nos. P 11152A, 11152B, 16954 and 17051 Field Museum.

Cephalon sublunate in outline, convex, distinctly trilobed; anterior margin truncated; posterior margin nearly transverse. Glabella very prominent, anterior lobe globular, produced beyond the anterior margin, comprising fully three-fourths the bulk of the glabella; a single pair of shallow, transverse, lateral furrows meets just behind the lateral lobe of the glabella and separates it from a pair of indistinct lateral lobes; occipital segment arched slightly forward, its posterior margin abruptly elevated, surface sloping into the furrow; occipital furrow shallow, not well-defined except at its extremities. Dorsal furrows well defined, much wider and deeper at the junctures with the occipital and glabella furrows, diverging somewhat in passing forward from the posterior margin of the cephalon until near the anterior margin where they abruptly converge until they meet, forming the anterior marginal furrow; cheeks depressed convex, greatest elevation at the palpebral lobes, which are situated about midway between the posterior and anterior margins and one-third the distance from the dorsal furrows to the genal angles; antero-lateral margins of the cheeks forming an elongate sigmoid curve; free cheeks triangular, small, less than one-half the size of the fixed cheeks; eyes large, prominent, globular; the facial sutures originate on the lateral margins well in front of the genal angles, pass inward and slightly backward over the palpebral lobes. thence forward to the anterior margin; the genal angles merge into stout, recurved spines; the posterior marginal furrows are continuations of the occipital furrow but narrower and deeper; they terminate abruptly before the genal angles are reached; a deep elongate pit on each fixed cheek and a longer, shallower one on each free cheek represent the lateral marginal furrows.

Thorax not observed.

Pygidium small, subtrianglar in outline, aside from the spines;

not distinctly trilobed, composed of three segments; the first of these has its extremities produced into long, diverging, slightly recurved spines; margin entire, with its ventral surface forming a thick doublure.

Surface of the globular portion of the glabella pustulose; pustules rounded, larger near the transverse glabella furrow and gradually diminishing in size anteriorly; balance of cephalon smooth or finely granulose; surface of pygidium pustulose, pustules more prominent on the spines.

Measurements of cephalon	Holotype P 11152A	P 11152B
Length on median line from posterior to anterior margins	4.6 mm.	
Length from posterior margin to front of glabella	7.4 mm.	10.4 mm.
Length from front of glabella to points of spines	13.0 mm.	
Length of anterior lobe of glabella	5.0 mm.	7.7 mm.
Width of anterior lobe of glabella	4.7 mm.	7.5 mm.
Width of cephalon at genal angles	10.2 mm.	14.6 mm.
Width of cephalon at points of spines	15.8 mm.	
Length of occipital segment	2.3 mm.	3.3 mm.
Width of occipital segment	1.0 mm.	1.2 mm.
Measurements of pygidium	**P 16954**	**P 17051**
Width of anterior margin	3.4 mm.	6.7 mm.
Length on median line	1.5 mm.	3.2 mm.
Length including spines	4.2 mm.	10.3 mm.

This species is the most abundant trilobite in the shales of the Lower Maquoketa beds, but a great majority of the individuals are represented only by the globular portion of the glabella. They range in size from 2.5 mm. to 7.5 mm. in diameter. The writer was fortunate enough to obtain about twenty more or less complete cephalons and three pygidia. No thorax has been observed that can be referred to this species so that it is not certain that these pygidia belong to the cephalons, yet from their form and the conditions under which they were collected, there is little doubt that they belong to this species.

S. maquoketensis differs from all previously described species in possessing large pits in place of the lateral marginal furrows. It resembles *S. granulata* Angelin in the form of the marginal outline, but in *S. maquoketensis* the cephalon is longer in proportion to the width and the pustules on the glabella are finer. *S. salteri* Billings is from a similar horizon, but in *S. salteri* the width of the glabella at its posterior margin is three-fourths of its greatest width, and it has tubercles at the juncture of the occipital and dorsal furrows; in *S. maquoketensis* the glabella is twice as wide anteriorly as posteriorly and the tubercles are wanting.

Localities and horizons.—Abundant in the top layers and somewhat less so in the middle layers of the Lower Maquoketa shales of Clermont, Elgin, and Bloomfield.'' After Slocom 1916.

As has been stated above by Slocom, fragments, principally parts of the head of this species, are exceedingly common in the Lower Maquoketa shales of Fayette county. But a complete specimen has not been found. Number 9246, a lot of two dozen heads, was collected from the gutters along the roadside between the north end of sections 23 and 24, Springfield township, Winneshiek county. Numbers 9247 and 9249 are from the Patrick Leehy farm near Clermont. Number 9248 was collected by Doctor Thomas in ''Ectenaspis Hollow'' near Clermont. Number 9208 is the metatype collected by A. W. Slocom at Clermont.

Family **PHACOPIDAE**

PTERYGOMETOPUS FREDRICKI Slocom

Plate XX, figs. 1-3.

1913. *Pterygometopus fredricki* Slocom, Field Mus. Nat. Hist., Geol. Ser., vol. 4, p. 79, pl. XVIII, figs. 1-5.
1916. *Pterygometopus fredricki* Slocom, Iowa Geol. Survey, vol. XXV, Ann. Rep. 1914, p. 232, pl. XIX, figs. 1-5.

''Type specimen No. P 17024 Field Museum.

Test elongate-ovate in outline, trilobation distinct. Cephalon sublunate in outline, convex, anterior border rather thick and rounded, posterior margin concave, genal angles rounded. Glabella large, convex, greatest elevation and greatest width near the anterior margin, well defined by the dorsal furrows; anterior lobe large, transversely elliptical, rising abruptly from the anterior border; it comprises more than half of the glabella; anterior pair of lateral furrows originating at the anterior angles of the eyes, passing obliquely backward but not crossing the glabella; second pair of lateral furrows smaller than the first and directed obliquely forward forming a pair of triangular lateral lobes; the third pair of lateral furrows bifurcate, the anterior forks extending forward parallel to the second lateral furrows defining the quadrangular second lateral lobes; the posterior forks extend backward until they join the occipital furrow isolating the small, posterior, glabella lobes; occipital segment elevated at its posterior margin, sloping to the occipital furrow; occipital furrow narrow, distinct. Dorsal furrows narrow and deep, nearly parallel from the posterior margin of the cephalon to the third, lateral glabella furrows, thence diverging to the antero-lateral margins. Cheeks slope regularly to the lateral margins; marginal borders wide at the genal angles, narrowing in each direction, marginal furrows shallow on the lateral margins, deeper on the posterior margins; palpebral lobes large, prominent, but not equaling the glabella in height; marked by a distinct furrow just within and parallel to the borders of the eyes; eyes large, lunate, extending from the posterior cheek furrows to the anterior glabella furrows, eye facets arranged in vertical rows of five facets each; the facial sutures originate on the lateral margins in front of the genal angles, curve inward with a sigmoid curve to the posterior angles of the eyes, follow the inner margin of the eyes to their anterior angles and thence pass forward to the anterior margin of the cephalon.

Thorax distinctly trilobed, composed of eleven segments. Axis convex, occupying somewhat more than one-third the width of the thorax; the pleural segments extend outward from the dorsal furrows for a little more than one-third their length, from which point they bend backward and abruptly downward to the lateral margins; extremities rounded; a straight groove originates near the anterior edge of each of the pleural segments at the dorsal furrows, extends slightly backward and outward and becomes obsolete on the flattened surface of each segment. The dorsal furrows converge slightly to the ninth thoracic segment, then more abruptly to the pygidium.

Pygidium subsemicircular in outline, slightly produced posteriorly, strongly trilobed. Axis narrow, convex, margins slightly incurved, abruptly rounded posteriorly; there are ten sinuous annulations; dorsal furrows narrow and deep, entirely surrounding the axis; the pleural lobes, consisting of six to eight segments, each bearing a median groove, curve slightly upward in their anterior portion, then downward to the margins. The segments are defined by grooves which are distinct in the anterior portion of the pygidium but gradually become obsolete posteriorly. This feature is more noticeable in young specimens. Both segmentation and median grooves become obsolete a short distance from the margins, thus leaving a smooth, undefined, marginal border.

The surface of the thorax and pygidium appears smooth to the eye, but under a magnifier it appears finely punctate, without nodes or spines. The surface of the cephalon is pustulose, the pustules on the glabella being somewhat more prominent than those on the other parts.

The dimensions of the type specimen (Field Mus. No. P 17024) are as follows: Length 24.2 mm.; width at genal angles 11.5 mm.; length of cephalon on median line 6.7 mm.; length including genal angles 7.4 mm.; length of thorax 11.5 mm.; length of pygidium 6 mm.; greatest width of pygidium 8.7 mm. A detached pygidium (Field Mus. No. P 16923A) measures, length 11.0 mm.; greatest width 14.6 mm.; it has ten annulations in tbe axis and eight segments in each pleural lobe, the last two being visible only with a magnifier. This is the largest pygidium observed and appears to belong to an old individual.

A small coiled specimen in the collection of Mr. A. G. Becker, found associated with typical specimens, is doubtfully referred to this species. It differs from the type in having a smooth instead of a pustulose glabella and the pygidium appears to be shorter in proportion to its width. Considering these characters in connection with its small size, it is probable that they only indicate the immaturity of the specimen. Its dimensions are: Length of cephalon 5 mm.; length of thorax 10.4 mm.; length of pygidium 3.3 mm.; width at genal angles 6.8 mm.; width at anterior margin of pygidium 4.9 mm.

P. fredricki is distinguished from *P. larrabeei* by having five rows of eye facets instead of eight, by its more inflated anterior portion of the glabella, by its thicker and shorter anterior margin, by its shorter pygidium and fewer annulations on its axis, and by the anterior limbs of the facial suture being less divergent. So far as is known to the writer, the number of rows of eye facets has not previously been used as a specific character, but it seems to be a constant character in the thirty specimens of the two species which he has observed. Specimens of *P. callicephalus* from the Trenton of Ottawa, Canada, which appear to be typical, have eight rows of eye facets. *P. fredricki* appears to be related to *P. callicephalus,* but aside from the eye facets, the glabella is more inflated anteriorly and the anterior margin is smaller and less angular in *P. fredricki.*

The specific name is given in honor of Dr. Fredrick Becker, who was one of the first collectors of fossils in Fayette county and who gave the writer much valuable information as to localities.

Localities and horizon.—The type is from the top of the Lower Maquoketa beds at Bloomfield. The species has been observed in beds somewhat lower down at Clermont and at Postville Junction.'' After Slocom 1916.

The collecting trip to northeastern Iowa yielded no additional material of this species.

PTERYGOMETOPUS LARRABEEI Slocom

Plate XX, figs. 8, 9.

1913. *Pterygometopus larrabeei* Slocom, Field Mus. Nat. Hist., Geol. Ser., vol. 4, p. 81, pl. XVIII, figs. 6-8.
1916. *Pterygometopus larrabeei* Slocom, Iowa Geol. Survey, vol. XXV, Ann. Rep. 1914, p. 235, pl. XIX, figs. 6-8.

"Type specimen No. P 11256 Field Museum.

Cephalon sublunate in outline, anterior margin produced into a thin subangular lip, genal angles well back of the occipital ring, rounded. Glabella large, depressed, convex, about twice as wide in front as at the occipital ring, anterior lobe transversely elliptical, sloping gently towards the front, comprising fully half the glabella; anterior pair of glabella furrows originating at the anterior angles of the eyes and passing obliquely backward but not meeting at the median line of the glabella; second pair of glabella furrows shorter and shallower than the first, directed obliquely forward; third pair of glabella furrows directed towards the axis of the glabella for a short distance, then bifurcating, the posterior forks bending abruptly backward and joining the occipital furrow leaving the small posterior lobes entirely detached; the anterior and larger forks bending obliquely forward defining the third glabella lobes; occipital segment wide, slightly rounded, of about uniform width until near the dorsal furrows where it is abruptly constricted; occipital furrow shallow but distinct. Dorsal furrows narrow and deep, nearly parallel from the posterior margin of the cephalon to the posterior glabella furrows, thence diverging in a regular curve to the anterior angle of the eyes where they become obsolete. Palpebral lobes large, prominent, exceeding the glabella in height, marked with a distinct furrow just within and parallel to the border of the eye; eyes large, lunate, extending from the posterior cheek furrows to the anterior furrows of the glabella; eye facets arranged in vertical rows of eight facets each; the cheeks curve regularly to the lateral margins, marginal borders rather wide on their lateral margins, narrow on their posterior margins, marginal furrows shallow on their lateral margins, narrower and deeper on the posterior margins. The facial sutures originate on the lateral margins well in front of the genal angles, curve inward and backward to the posterior angles of the eyes, follow the inner margin of the eyes to their anterior angles and thence curve outward to the margin of the cephalon, almost in line with the anterior furrows of the glabella. Surface of the glabella distinctly pustulose; that of the palpebral lobes, cheeks, occipital ring and anterior projection finely granulose.

Thorax not known.

Pygidium subtriangular, somewhat rounded posteriorly, distinctly trilobed. Axis narrow convex, margin slightly incurved, abruptly rounded posteriorly; there are thirteen sinuous annulations; the dorsal furrows entirely surround the axis; the pleural lobes, marked by seven or eight segments each bearing a median groove for part of its length, curve regularly to the lateral margins; both segmentation and grooves become obsolete a short distance from the margin, leaving a plain, undefined marginal border. The entire surface of the pygidium is finely punctate.

Measurements.—Type specimen (Field Mus. No. P 11256). Length of cephalon on median line 9.5 mm., length including genal angles 10 mm., width of cephalon 14.5 mm.; length of pygidium 9.2 mm., width 10.6 mm., width of axis on anterior margin of pygidium 3 mm., length of axis 7 mm. Another complete cephalon gave the following: Length on median line 11 mm., length including genal angles 12.5 mm., width 17.5 mm.

Remarks.—The above description is based on the type specimen (Field Mus. No. P 11256) consisting of a complete cephalon and a nearly complete pygidium. In general form this species resembles *P. callicephalus* but differs from it in the following characters: In *P. larrabeei* the cephalon is longer in proportion to the width; the cheeks do not curve so abruptly to the lateral margins; the glabella is less inflated anteriorly; the pygidium is longer and has more annulations and segments; the pustulose surface occurs only on the glabella; the surfaces of the palpebral lobes, occipital ring and cheeks are punctate. The pygidium of *P. larrabeei* appears to be midway between *P. callicephalus* and *P. intermedius* in form. The specific name is given in memory of the late Ex-Governor William Larrabee on whose property some of the specimens were collected.

Locality and horizon.—More or less complete cephalons and pygidia are comparatively abundant in the Lower Maquoketa beds at Clermont, Elgin and Bloomfield. The type specimen came from Clermont.'' After Slocom 1916.

Moderately well preserved dismembered parts of *P. larrabeei* are commonly found in the localities given by Slocom. Numbers 9201, a cephalon, 9203, a pygidium, and 9254, a lot of five cephala and one pygidium, are all from the Patrick Leehy farm near Clermont. Number 9255, a cephalon, comes from the Elgin member of the Maquoketa at Dover Mills.

TRILOBITES OF THE SILURIAN

Order **OPISTHOPARIA**

Family **ILLAENIDAE**

Illaenus ioxus Hall

Plate XXII, fig. 1.

1843. *Bumastus barriensis* Hall (non Murchison), Geol. New York, pt. 4, p. 102, fig. 4, p. 101; tab. org. rem., 10, fig. 4, and 19, fig. 2.
1867. *Illaenus ioxus* Hall, 20th Rept. New York State Cab. Nat. Hist., p. 378, pl. 22, figs. 4-11, pl. 23, fig. 1.
1907. *Illaenus ioxus* Weller. Chicago Acad. Sci., Nat. Hist. Surv., Bull. IV, pt. 2, p. 222, pl. 18, figs. 1-3.

Description.—Cranidium large, subquadrate, moderately convex, broadly rounded and subtruncate in front, sides constricted opposite the center. Glabella continuous with the cranidium in front of the eyes, defined posteriorly by broad, shallow dorsal furrows which converge in a gentle curve from the posterior margin of the cephalon to a point opposite the anterior angle of the eyes, whence they become obsolete. Palpebral lobes large, gently rounded but not rising to the height of the glabella, ending about midlength of the cranidium. The facial suture describes a narrow sigmoid curve in front of the eyes, cutting the antero-lateral margin of the cranidium in a straight line in front of the outer margin of the palpebral lobes. The width of the cranidium is slightly greater than the length.

Position and locality.—Specimen 9231, Niagaran, LeClaire beds, in the lower lime quarry at the Palisades, southeast of Bertram, Iowa (Ben H. Wilson).

This species occurs in the dolomitic LeClaire limestone and, though widely distributed in adjoining states and in the east, appears to be very limited in its horizontal and vertical distribution in Iowa. The only locality in this state from which it has been reported is the Palisades, where it is fairly common but incompletely preserved. Professor Norton (Iowa Geol. Survey, IV, p. 130) reports that "at the lower lime quarry, now abandoned, there are numerous nests of the saucer-like cephalic and tail shields of *Illaenus ioxus.*" The subtruncate anterior margin, the moderate convexity, the large size, and the shallow short dorsal furrows distinguish it from other species of this genus.

One incomplete cranidium was found by the writer in loose material in a quarry of the Maquoketa formation near Ossian, Iowa. This specimen, No. 9172, was evidently drifted in or let down from an erosion remnant of the Niagaran beds.

ILLAENUS IMPERATOR Hall

Plate XXI, figs. 1-3.

1861. *Illaenus imperator* Hall, Rept. Prog. Geol. Surv. Wisconsin for 1860, p. 49. Niagaran, Racine, Wis.
1870. *Illaenus imperator* Hall, 20th Rept. New York State Cab. Nat. Hist. (rev. ed.), p. 420, pl. 22, figs. 15-17; pl. 23, figs. 2-3. Niagaran, Wis.
1907. *Illaenus imperator* Weller, Chicago Acad. Sci.; Nat. Hist. Surv. Bull. IV, pt. 2, p. 225, pl. 16, figs. 13-16. Niagaran, Joliet, Ill.

Description.—Cranidium subquadrate, strongly convex, wider than long, anterior margin broadly rounded, posterior margin curved backward across the glabella. Dorsal furrows short but deep, straight and converging slightly from the posterior margin forward. Glabella broad, occupying one-half the width of the cranidium, and confluent with the general surface near the mid-length of the shield. Palpebral lobes small, situated close to the posterior margin of the head, rising at first abruptly from the dorsal furrows thence continuing laterally in a nearly horizontal plane. Eyes narrow, lunate, resting on a well-defined orbital ridge (see specimen 9218). Free cheek narrowly depressed and sulcate about the base of the orbital ridge, thence sloping abruptly to the margin.

The length of a small cranidium, No. 9221, is 28.5 mm., and the width 35.5 mm. across the palpebral lobes.

Position and locality.—Niagaran, Hopkinton dolomite, southeast of Monticello; Niagaran, Farley, Hopkinton, and Maquoketa.

Remarks.—Most of the specimens which have formerly been referred to *I. imperator* in Iowa are now referred to *I. slocomi.* The latter species has some points of resemblance as already pointed out in the remarks under that species. The University museum has four cranidia and one incomplete free cheek which undoubtedly belong to this species. All are of small size. To date no pygidium of *I. imperator* has been found in this state.

ILLAENUS SLOCOMI n. s.

Plate XXI, figs. 4-6.

Description.—Cranidium subhemispherical in shape, strongly and evenly convex, sides diverging slightly in front of the palpebral lobes, thence curving uniformly with the anterior margin. Posterior margin nearly straight. The length is nearly equal to the width. Glabella broadly convex, occupying nearly one-half of the width of the cranidium, sides curved gently inward. Dorsal furrows well defined and bearing a distinct elliptical impression near their anterior extremity. Eye lobes small and short, situated close to the posterior margin of the cranidium. Posterior limbs of the fixed cheeks short and deflected abruptly downward. The anterior margin of the cranidium bears a few indistinct and widely separated lamellose lines.

Pygidium transversely subelliptical; inner and anterior half depressed convex, the outer portion sloping in a broad curve to the margin. Trilobation distinct anteriorly. Antero-lateral angles obliquely truncate. Axis low and depressed, curving gently forward on the anterior margin, sides subparallel, ill-defined posteriorly and confluent with the general convexity of the surface. The greatest width of the pygidium is considerably less than twice the length.

Dimensions.—The type cranidium, No. 9215, is 62 mm. long and 63 mm. wide. Pygidium No. 9220 is 48 mm. long and 82 mm. wide.

Position and locality.—Niagaran, Maquoketa and Hopkinton (Dr. Samuel Calvin).

Remarks.—In many respects this species compares favorably with *Illaenus imperator* and has commonly been so identified in the various county reports. However, a careful examination reveals a number of differences which are practically constant for seven cranidia and three pygidia at hand. The position of the eyes, the size of the glabella and the general convexity of the pygidium agree closely with *I. imperator* but the cranidium is much more convex, considerably longer in proportion to its width, the anterior margin is more evenly rounded and the palpebral lobes are less prominent; the pygidium differs also in being proportionately longer.

There is a good deal of difference in size. The cranidia range in length from 49 to 84 mm. and the pygidia from 48 to 74 mm.

The species is named in honor of Mr. Arthur W. Slocom, who first recognized (in communication with Doctor Thomas) some of the differences between this species and *I. imperator*.

ILLAENUS TRIANGULARIS n. s.

Plate XXII, figs. 2-4.

Description.—Pygidium subtriangular in outline, surface depressed convex over the median area, sloping in a broad curve to the sides and in an increasingly stronger and shorter curve toward the posterior margin, which is parabolic in outline with the antero-lateral angles. Anterior margin nearly straight, axis curved gently forward, antero-lateral angles obtusely rounded. Length is to width as three is to four. Axis depressed, scarcely rising above the pleural lobes, well defined along the anterior margin, thence very obscurely until it becomes confluent with the general surface along the posterior third of the pygidium. The width is one-third the width of the shield. The type specimen, No. 9226, is 59 mm. long and 80 mm. wide.

Position and locality.—Niagaran, Hopkinton. Collected by Professor Calvin.

This species is readily distinguished from other species of *Illaenus* by the depressed dorsal surface, the depressed axis and the distinct triangular outline. No cephalon has been found that might be referred to this species.

ILLAENUS LOBATUS n. s.

Plate XXI, figs. 7, 8.

Description.—Pygidium subsemiovate in outline, anterior margin straight between the axis and the geniculation, curved across the axis, obliquely truncate at the antero-lateral angles. Length is to width as three is to four. Dorsal surface depressed convex, the sides and posterior fifth curving abruptly downward and under at the margin. This marginal incurvature is greatest posteriorly, decreasing gradually toward the antero-lateral angles. Axis occupying about one-third the entire width along the anterior margin, gently rounded, and rising slightly above the pleural lobes, becoming confluent with the general surface of the pygidium at its midlength. Dorsal furrows broad, very short and shallow. The outer margin is marked by several strong lamellose lines.

Length of specimen 9230, 37 mm., width 50 mm.

Position and locality.—Niagaran, two and one-half miles west of Manchester. Collected by Professor Thomas.

Remarks.—In general outline and the character of the dorsal surface this species agrees more closely with the original description of the pygidium of *I. daytoni* Hall and Whitfield than with any other Silurian species of this genus. Foerste[15] subsequently figured a profile view of a pygidium of *I. daytoni* which was taken from the type locality. This shows the posterior marginal curvature, parallel to the median longitudinal axis, to be quite different from that of our specimen. In the former the posterior margin has a backward slope whereas in the latter there is a distinct forward curvature ventrally. This difference is so striking that, in spite of the similarity of descriptions, *I. lobatus* can not be identified with *I. daytoni*.

Only the type specimen is known at the present time.

Family **GOLDIIDAE**

GOLDIUS LAPHAMI (Whitfield)

Plate XXII, figs. 5, 6, 7.

1878. *Bronteus laphami* Whitfield, Ann. Rep. Wisconsin Geol. Surv. for 1877, p. 88. Niagaran, Kewaunee, Wisconsin.

15 Foerste, Geol. Surv. Ohio, vol. VII, pl. 26, fig. 4b.

1882. *Bronteus laphami* Whitfield, Geol. Wisconsin, vol. IV, p. 310, pl. 22, figs. 1-4. Niagaran, Kewaunee, Wisconsin.
1915. *Goldius laphami* Bassler, Bibliographic Index of American Ordovician and Silurian Fossils, vol. I, p. 559.

Description.—"Glabella short and broad, very depressed convex, the division of parts somewhat obscure. Anterior lobe very broad in front, and rapidly decreasing in width from its junction with the marginal rim to behind the middle of its length, where it is not more than two-thirds as wide as in front; dorsal furrow obscure; posterior glabellar furrow well marked; occipital furrow distinct and the occipital ring rather large. Fixed cheeks narrow and rounded, indistinctly separated from the anterior lobe of the glabella in the middle, but not definitely so at the sides, its surface rather strongly striated." (Whitf. op. cit., 1882.)

Pygidium paraboloid in outline, nearly straight in front, broadly rounded behind, sides converging slightly, antero-lateral angles rounded, margin smooth. The axis is very short, moderately convex, well defined by deep dorsal furrows, elevated above the pleural lobes and marked by a submarginal annulation at the anterior end. Its length is about one-fourth the length of the pygidium. Pleural lobes broad, gently convex, sloping at first gently away from the axis thence more abruptly to the slightly recurved marginal zone. Each lobe bears seven well-defined segments which are broad, gently rounded to flattened, increasingly elongate and oblique from front to back and end at the margin. Extending back from the axis there is a long central segment which is narrower away from the axis for one-third of its length, whence it gradually increases in width to the margin, bifurcating approximately at its midlength, but in some specimens much nearer the axis, causing the posterior half of the segment to be double. The intersegmental grooves are deep, comparatively narrow, and well defined from the dorsal furrow outwards, obsolete at the margin.

The surface markings seem to depend more or less directly on the nature of the preservation. In one specimen (No. 9049) which preserves a part of the dorsal crust the segments are covered by numerous fine tubercles, but where the crust has been removed there are numerous subparallel, reëntrantly curved grooves and ridges concentrically arranged between the intersegmental grooves. In other specimens all the segments bear squamose transverse marks, also concentrically arranged, but obsolete in the intersegmental grooves. Still other specimens are entirely smooth.

The size of the pygidia varies considerably. Our smallest specimen has a length of 23 mm. and the largest specimen, if complete, would measure 100 mm.

Position and localities.—Numbers 9049, 9050, 9051 are from the Niagaran dolomite at Clinton. Collected by Dr. Farnsworth.

Number 9052 is from the Niagaran non-dolomitic beds of Hopkinton, south half of section 20, Coffins Grove township, Delaware county. Collected by Professor Thomas.

Number 9053 is from the Hopkinton dolomite of the Niagaran, Scotch Grove. Collected by Professor Thomas. Number 9048, from the Niagaran, Coralline beds, one-fourth mile east of Central City, was collected by Doctor Calvin. Number 9054, from the Niagaran dolomite at Maquoketa, was collected by Doctor Calvin. Number 9055, from the Niagaran dolomite at Monmouth, was collected by L. W. Stuart.

Remarks.—Entire specimens of *G. laphami* are unknown at the present time, nor have complete heads been recorded from any localities either within the state or elsewhere. The description of the glabella by Whitfield is included above for the sake of completeness but the writer seriously doubts that either this description or figure 1, Plate 22 of Whitfield, representing this description, is of a true glabella. Judging from the figure alone this specimen appears to be a hypostoma very likely belonging to this species since it is found associated with the pygidia. Our description of the pygidium is based on seven more or less fragmentary pygidia all of which have been collected in Iowa, which is thus far only the second state from which this beautiful species has been recorded.

Family **LICHADIDAE**

ARCTINURUS (METOPOLICHAS) OBVIUS (Hall)

Plate XXIII, fig. 3.

1870. *Lichas obvius* Hall, 20th Rep. New York State Cab. Nat. Hist. rev. ed., p. 424, pl. 25, fig. 19. Niagaran, Lyons, Iowa.

1885. *Lichas (Oncholichas) obvia* Schmidt, Mem. l'Acad. Imp. St. Petersburg, 7th. ser., 33, p. 31. Niagaran, Lyons, Iowa.
1893. *Lichas obvius* Vogdes, Bibliography Paleozoic Crustacea, p. 320. Niagaran, Lyons, Iowa.
1907. *Arctinurus obvius* Weller, Chicago Acad. Sci. Bull. IV, pt. II, p. 186. Niagaran, Lyons, Iowa.
1915. *Arctinurus obvius* Bassler, Bibliographic Index of North Am. Ordovician and Silurian Fossils, p. 66.

Description.—The following is a copy of the original description by Hall.

"Glabella gibbous, broad in front, length equal to the width between the eyes; occipital and dorsal furrows sharply defined; lateral lobes simple, of nearly equal width throughout, suddenly contracting near the base; surface finely pustulose."

Formation and locality.—In the limestone of the Niagara group, at Lyons, Iowa. From Dr. Farnsworth.

Remarks.—The type specimen upon which this species was erected is now in the possession of the American Museum of Natural History at New York City. The museum number of this specimen is 2154. No additional specimens of this species have been encountered.

This species is here referred to the genus *Arctinurus* with *Metopolichas* as a subgenus,—see remarks under the next species. In the absence of pygidia the true generic reference is somewhat problematical and it is possible that this species may again be referred to the genus *Lichas* if pygidia should be found which have a notched rather than a broadly rounded posterior margin.

METOPOLICHAS IOWENSIS n. s.

Plate XXIII, figs. 1, 2.

Description.—Glabella markedly convex, broadly rounded in front, obscurely rounded behind, sides sloping moderately, front sloping abruptly to the margin, which is bordered by a thickened, narrow and closely appressed rim adjacent to a shallow and narrow groove. The median lobe is subclavate in outline, widening abruptly toward the anterior end and forming on either side at the greatest width a winglike lateral subangular extension which ends marginally in front of the lateral lobe. The greatest constriction is two-fifths the length of the median lobe from the occipital groove. Posterior to this constriction there is a short but abrupt expansion followed by subparallel sides to the base. The width at the base is slightly less than one-half the greatest width across the anterior margin. The large side lobes are tricomposite, being formed by the coalescence of the first, second and third lateral lobes. They are separated from the median lobe by a narrow but sharp and well defined groove; in shape they are subreniform, being broadly curved along the inner margin, more sharply curved along the outer margin and of nearly uniform width throughout except for a constriction of the posterior portion. Antero-laterally the lobes are sharply rounded to wedge-shaped, ending submarginally between the lateral extension of the median lobe and the anterior end of the fixed cheeks; posteriorly they are restricted and truncated and end at the occipital furrow. A faint lateral furrow extends diagonally forward across each of the side lobes, indistinctly subdividing them near their midlength.

The occipital lobes are small, subtriangular and located directly back of the large side lobes. The anterior margin of each occipital lobe is transverse in direct line with the occipital groove; the posterior margin is curved and encroaches upon the occipital segment, from which it is delimited by a narrow sharp groove. The occipital segment is broad, gently arched, of uniform width back of the median glabellar lobe but constricted in the region of the occipital lobes.

The fixed cheek is small, posterior in position, depressed convex, narrow and continued toward the posterior end of the occipital segment.

The entire surface of the cephalon is covered by tubercles of varying sizes. A few of the coarser ones are scattered irregularly over the median glabellar lobe, being especially prominent over the median inflated portion.

Free cheeks, thorax, and pygidium unknown.

Position and locality.—The holotype, No. 9043, was collected by Mr. Fred. Orelup from the Niagaran dolomite at Clarence, Cedar county.

Remarks.—Dr. Aug. F. Foerste[16] suggests that the holotype "is generically a *Metopolichas* acording to American usage of that term." That it does not belong to the genus *Arctinurus* is evident from the fact that *Arctinurus* has no occipital lobes, whereas our specimen has very distinct occipital lobes.

M. iowensis bears a close resemblance to *Arctinurus* (*Metopolichas*) *obvius* (Hall) but is distinguished from the latter primarily in the configuration of the posterior portion of the median glabellar lobe. In *M. obvius* the sides diverge, forming an acute angle with the occipital groove; in *M. iowensis* the sides are subparallel, meeting the occipital groove almost at a right angle. This makes the width along the occipital groove proportionally narrower for *M. iowensis* than for *M. obvius*. The surface of the former is covered by numerous tubercles while the surface of the latter is covered with small pustules.

ARCTINURUS ANAMOSA n. s.

Plate XXIII, Figs. 4-9.

Description.—Cephalon subsemicircular in outline, convex transversely and longitudinally, length approximately equal to three-fifths the greatest width across the eye lines. Glabella subquadrate to subpentagonal in outline, wider in front than behind, bounded laterally by deep, wide dorsal furrows and anteriorly by a well-defined groove within a narrow thickened margin. Median lobe capstan-shaped with a narrow base, widest in front where it occupies nearly four-fifths of the width of the glabella and antero-lateral winglike extensions which end in front of the lateral lobes; the sides converge abruptly at first thence more gently along a curved line within a short distance of the base where there is an abrupt expansion to the occipital furrow; the width of the narrowest part, just in front of the posterior expansion, is one-fifth the greatest width; anterior margin broadly rounded, posterior margin straight. Lateral lobes compound, large, convex, oval-elongate, extending from the antero-lateral part of the glabella to the occipital furrow; sides of lobes subparallel; anterior end narrowly rounded; the outer margin sigmoid, postero-lateral

16 Personal communication, May 2, 1921.

angle truncated at occipital border. Each lobe bears at its midlength along the inner margin a slight constriction which represents the last faint trace of the second glabellar furrow. The fixed cheek is narrow in front of the eye, widening abruptly between the palpebral lobe and the dorsal furrow and is then produced laterally back of the eye almost to the outer margin. Along the posterior margin it bears the lateral continuation of the occipital groove. The facial suture is faintly discernible on the right side of specimen No. 9044. From the postero-lateral angle of the cephalon it is directed obliquely forward, thence inward along a curved line to the posterior margin of the eye, in front of which it is continued along a gentle convex curve to the anterior margin, cutting the latter at an acute angle. The eyes are lost from the specimens at hand but the size and shape of the eye-base and the reniform palpebral lobe are preserved. There is an impressed groove beneath the eye on the free cheek. The free cheek is small, triangular, rising abruptly from the outer margin to the base of the eye, where it is depressed, bearing a definite suboccular ridge limited to the free cheeks. The free cheek terminates at each extremity in a short sharp spine. The posterior spine rests against the distal border of the posterior limb of the fixed cheek. Occipital segment broad, of nearly uniform width and arched transversely. Occipital furrow broad, deep and well-defined throughout and continuous laterally with the posterior furrows of the fixed cheek.

Surface covered with numerous irregularly scattered, coarse and fine tubercles.

Thorax and pygidium unknown.

Dimensions.—No. 9044.

Length along median line	21.5 mm.
Width across eye line	34. mm.
Greatest width of median glabellar lobe	16.5 mm.
Greatest width of same at occipital furrow	7. mm.

Position and localities.—Numbers 9044 and 9045, two cranidia from the Niagaran dolomite in the vicinity of Anamosa. Collected by A. E. Wyant.

The foregoing description of this species is based on two heads, both of which came from the same locality. One of these, No. 9044, is nearly complete; the fixed cheek and eye is missing from the right side but on the left side only the eye is missing. The surface of this specimen has been considerably worn so that only a few tubercles remain on the antero-lateral region of the median glabellar lobe. In specimen No. 9045 both the eyes and fixed cheeks are missing.

In general form this species resembles *Arctinurus chicagoensis* Weller, from the Silurian of Hawthorne, Illinois, but differs from the latter in the configuration of the median glabellar lobe.

In *A. anamosa* the greatest constriction of the median glabellar lobe is proportionally farther back than in *A. chicagoensis* and the occipital lobe is well defined throughout in the former, while in the latter it is ill-defined and shallow back of the median glabellar lobe. *Arctinurus chicagoensis* is said to have a shallow and ill-defined occipital furrow back of the median glabellar lobe while in *A. anamosa* it is strong and well defined.

Order **PROPARIA** Beecher

Family **ENCRINURIDAE** Angelin

ENCRINURUS ORNATUS Hall and Whitfield

Plate XXIII, figs. 11-15.

1852. *Cybelė punctata* Hall, Pal. New York, vol. 2, p. 297, pl. 66A, figs. 1a-1.
1866. *Encrinurus punctatus* Billings, Cat. Sil. Foss. Anticosti, Geol. Surv. Canada, p. 61.
1875. *Encrinurus ornatus* Hall and Whitfield, Pal. Ohio, vol. 2. p. 154, pl. 6, fig. 16.
1896. *Encrinurus* cf. *E. punctatus* and *ornatus* Norton, Proc. Iowa Acad. Sci., vol. 3, p. 79.
1907. *Encrinurus ornatus* Vogdes, Trans. San Diego Soc. Nat. Hist., vol. 1, no. 2, p. 67.

Description.—General form ovate-elongate, broadly rounded in front, narrowly rounded behind, sides tapering gently from the genal angles to the anterior margin of the pygidium, thence more abruptly to the end. Surface convex and distinctly trilobate throughout. Length is to width as 12 to 5.

Cephalon sublunate to subtriangular in outline, produced into spines at the genal angles; posterior margin straight across the center, curved backward at the sides. Glabella prominent, convex, clavate, extending to the anterior margin, bounded by very deep dorsal furrows. Two pairs of short lateral furrows are present; the first pair is located opposite the eyes, the second pair nearly midway between the first pair and the occipital groove. Occipital segment prominent, smooth and strongly arched, bearing an indistinct node on each side. Occipital groove broad and deep medially, directed obliquely backward across the dorsal furrows and out over the fixed cheeks toward the genal angles. Fixed cheeks triangular in outline, strongly convex and tumid proximally, produced into spines at the genal angles. The facial sutures originate on the lateral margin of the cephalon a short distance in front of the genal angles and are directed obliquely to the eyes, in front of which they pass down the short anterior slope of the cheeks toward the margin. The eyes are pedunculate, rising obliquely outward and forward well above the height of the glabella.

Thorax subrectangular, sides gently rounded and converging toward the pygidium, composed of eleven segments. Length is to width as 3 to 5. Axis convex and sharply defined by narrow, deep dorsal furrows; sides nearly straight. The segments curve gently forward across the axial line and are slightly constricted at the sides so as to give rise to a small node adjacent to the dorsal furrow. The pleural lobes are flattened for about one-half their width, thence curve abruptly downward to the margin. The segments are narrow and rounded and of about the same width as the intersegmental grooves.

Pygidium subtriangular in outline, convex, wider than long, antero-lateral angle oblique, sides converging abruptly to an obtusely rounded, and in some specimens gently produced posterior extremity. A distinct caudal spine not observed. Axis well defined by the dorsal furrows, depressed convex, tapering uniformly to an acute termination just within the posterior margin; it is marked by sixteen to twenty-nine segments, of which only the anterior two to five cross the median region. Professor Norton (op. cit.) has observed as many as thirty-one segments. The number depends largely upon the size and state of preservation of the specimens. Some specimens are worn so that no segments are visible between the last two median axial nodes. The average number occurring on twenty casts and two impressions was found to be twenty segments. From five to eight median nodes are present on the otherwise smooth area; these are separated at intervals of one to five segments. The pleural lobes rise abruptly from the margin, approaching the axis on a gentle slope. Each lobe is marked by nine or ten ribs which are smaller and increasingly oblique from front to back, the last two being nearly in line with the axis and faintly defined in many specimens.

Surface markings.—All parts of the cephalon, except the grooves and posterior margin, bear well defined tubercles. The glabella bears a distinct row of eight tubercles around the anterior margin. The seventh and tenth segments of the axis of the thorax each bears a strong median tubercle. The pygidium bears, in addition to the axial tubercles previously mentioned, a tubercle on each pleural segment near the axis and a smaller one farther out. This character is shown only in unusually well preserved specimens.

Dimensions.—Specimen 9210, total length of body 38 mm., width at the genal angles 20 mm., length of thorax 15 mm., length of pygidium 12 mm., width of same 15 mm.

Position and locality.—Near the top of the Anamosa beds of the Niagaran, Platner and Kirby's quarry, Mount Vernon (Prof. William H. Norton and Prof. A. Collins).

Remarks.—This species was first mentioned in this state by Professor Norton (op. cit.) who made a careful and accurate analysis of the position of the nodes on the pygidial axes of forty-three specimens, and arrived at the significant conclusion that the position of these nodes on the axial segments can not be made the basis for specific rank. The analysis shows that the nodes do occur on any one of the segments up to twenty-three. These data are especially valuable and enlightening because all the specimens were taken from a single locality of very limited horizontal and vertical range. Vogdes (op. cit. p. 69) likewise discredits the value of the distribution of the nodes for specific distinction.

The preceding description is based on an internal mold of a complete specimen, one complete cast and twenty pygidia. The cast and pygidia were kindly loaned to the writer for study. They represent a part of the original forty-three specimens used by Norton as indicated above. All conform to the type of *E. ornatus* rather than to the European *E. punctatus*, which is characterized by a long caudal spine and a tuberculate posterior margin of the cephalon. This fine lot is in the Norton collection, Cornell College.

Family **CALYMENIDAE**

Calymene niagarensis Hall

Plate XXIV, figs. 1-5.

1843. *Calymene niagarensis* Hall, Geol. New York, pt. 4, p. 102, fig. 3, p. 101, tab. org. rem. 10, fig. 3. Niagaran, Lockport and Rochester, New York.
1865. *Calymene niagarensis* Hall, Adv. Sheets, 18th Rep., New York State Cab. Nat. Hist., p. 30. Niagaran, Wisconsin.
1867. *Calymene niagarensis* Hall, 20th Rep. New York State Cab. Nat. Hist., p. 30. Niagaran, Racine, Wisconsin.
1879. *Calymene niagarensis* Hall, 28th Rep. New York State Mus. Nat. Hist. (mus. ed.), p. 187, pl. 32, figs. 8-15. Niagaran, Waldron, Indiana.
1907. *Calymene niagarensis* Weller, Trilobites of the Chicago Area, p. 261, pl. XXIII, figs. 9-10. Niagaran, Bridgeport, Hawthorne, Joliet, near Lemont, etc., etc., Ill.

Note—For a more complete bibliography see Vogdes, "Bibliography of Paleozoic Crustacea," 1893, Weller, op. cit. 1907, or Bassler, "Bibliographic Index of American Ordovician and Silurian Fossils," 1915.

Description.—Body suboval-elongate in outline, anterior and posterior ends bent strongly downward, thorax "sway-backed", sides nearly straight and tapering uniformly from the occipital segment to the anterior border of the pygidium, thence more abruptly to the posterior end. Trilobation distinct throughout, the axis tapering gradually and uniformly from front to back.

Cephalon subsemicircular in outline, about twice as wide as long, anterior margin describing a broad curve with the free cheeks, posterior nearly straight or curving slightly forward.

Glabella very prominent, rising distinctly above the surface of the cheeks, rounded transversely, arched longitudinally and bordered anteriorly by a broad shallow concave groove within the recurved margin. Sides straight, diverging from front to back. Frontal lobe subquadrate, truncated in front and occupying a little less than one-third of the glabella. Lateral lobes three, increasing in size from front to back. On the postero-lateral angles of the frontal lobe of well preserved adult specimens there is a faint ridge which simulates a very small lateral lobe. Situated immediately back of this ridge is the first pair of small nodelike lateral lobes. The second pair of lateral lobes is considerably larger, appressed against the sides of the glabella and sharply defined by the short second lateral furrows in front and the much larger third lateral furrows behind. The third lateral furrow bifurcates indistinctly on the dorso-lateral side of the glabella, the shorter branch extending forward to the upper posterior border of the second lateral lobe and the larger branch curving back toward the occipital segment. The third lateral lobes are very large, oval in shape and almost pinched off from the glabella. Each of these lobes occupies nearly one-third the posterior width of the glabella. The occipital segment is strongly arched and forms the highest part of the body. The occipital groove is shallow and curved forward above, but is very deep back of the third lateral lobes. Near the anterior end of each dorsal furrow there is a conspicuous antennal pit. The fixed cheek is large, narrow in front of the eye, broad back of the eye and extended to the genal angle where it ends in a point. The eyes are small, nodelike, surrounded by a broad shallow groove and situated on the proximal angle of the free cheeks opposite the second glabellar furrows or about midlength of the head. The free cheeks are triangular, highly convex, outer margin evenly rounded, slightly recurved and bearing a wide shallow concave submarginal groove.

The thorax is composed of thirteen segments, highly convex transversely, sides nearly straight, tapering gradually toward the pygidium. Axis prominent, elevated above the pleural lobes and separated from them by well defined dorsal furrows; width a little greater than one-third the total width of thorax. Segments strongly rounded and arching slightly forward, separated by broad shallow grooves above, which are deeper and narrower at the sides. Each segment bears a large node on either side adjacent to the dorsal furrow. Pleural lobes gently rounded near the axis thence sloping almost vertically to the margin. The height from the free outer margin to the shoulder is nearly two times as great as the distance from the shoulder to the dorsal furrow. Each segment bears proximally a broad shallow median groove which is narrower on the lateral slope where it curves near the front margin and ends somewhat below the midlength of the side. Distally the segments are flattened and rounded.

The pygidium is small, transversely suboval in outline, the posterior margin forming an obtuse angle. Trilobation distinct. Axis prominent, evenly rounded, strongly elevated above the pleural lobes, tapering to a rounded termination well within the margin; segments six to seven, extending to the dorsal furrows and separated by broad grooves. The pleural lobes slope abruptly from the dorsal furrows to the margin. Each lobe is bounded distally by a broad smooth marginal zone which is narrower toward the end of the axis. Segments three to four, well rounded, smooth and extending from the dorsal furrow to the smooth zone. Intersegmental grooves well defined anteriorly, indistinct posteriorly. Pygidium directed downward at nearly a right angle to the axis of the body.

Dimensions.—Number 9057, greatest length of the body not including the dorsal curvature 61 mm.; greatest width across genal angles 44 mm.; median length of head 18.5 mm.; length of thorax 47 mm. This is an unusually large specimen, with pygidium missing. If complete it probably would have a length of 68 mm. The average length of twenty ordinary size specimens is 35 mm.

Position and localities.—Number 9057, Niagaran, near Farley. Collected by W J McGee. Number 9058, Niagaran, Anamosa. Collected by Samuel Calvin. The species is reported also from the McGlade quarry in South Fork township, Delaware county, as well as from other localities.

Remarks.—In the foregoing description the material from

Niagaran limestone of Grafton, Illinois, has been freely used. The Iowa material is somewhat limited and much of it is fragmentary but there is no doubt as to its identity with the Illinois material. All the specimens of this species are unusual in that they are all "sway-backed" when seen in lateral profile and the pygidium, instead of being extended posteriorly is usually directed downward and appressed against the pleural lobes of the thorax. All the Iowa specimens are preserved in either dolomite or chert.

Family **CHEIRURIDAE**

CHEIRURUS NIAGARENSIS (Hall)

Plate XXIV, fig. 6.

1852. *Ceraurus insignis* Hall, Pal. New York, vol. 2, p. 300, 306, pl. A 66, fig. 4; pl. 67, figs. 9, 10.
1867. *Ceraurus niagarensis* Hall, 20th Rept. New York State Cab. Nat. Hist., p. 376, pl. 21, figs. 10, 11.
1907. *Ceraurus niagarensis* Weller, Bull. Chicago Acad. Sci., Nat. Hist. Surv., vol. 4, pt. 2, p. 263, pl. 24, figs. 20, 21.
1913. *Cheirurus niagarensis* Raymond and Barton, Bull. Mus. Comp. Zool., vol. 54, p. 542 (gen. ref.).

This species appears to be quite rare in Iowa as it is represented by only one incomplete cranidium, specimen 9212. The glabella is smooth, moderately convex, gently arched longitudinally, subrectangular in outline with sides diverging slightly toward the front, anterior margin rounded, bounded laterally by well-defined dorsal furrows. There are three pairs of strong glabellar furrows: the first pair is directed inward and gently backward, extending approximately half way to the center of the glabella; the second pair is shorter and runs subparallel to the first: the third pair is stronger and continuous with the occipital groove across the axial region, thus delimiting a pair of prominent isolated triangular basal lobes with the occipital groove. The occipital groove is of the same size as the glabellar furrows. The occipital ring is arched slightly above the surface of the glabella, broad medially and narrow at the sides. A part of the right fixed cheek is preserved, showing a pitted surface. Total length 21 mm., width across the occipital ring 10 mm. The specimen is preserved in vesicular dolomite.

Position and locality.—Niagaran, Anamosa substage?—Clarence, Cedar county (Fred Orelup).

Family **PHACOPIDAE**

DALMANITES PLATYCAUDATUS Weller

Plate XXIII, fig. 10.

1907. *Dalmanites platycaudatus* Weller, Bull. Chi. Acad. Sci., Nat. Hist. Surv., 4, pt. 2, p. 272, pl. 25, figs. 3-5.

Description.—Cephalon, not including genal spines, subsemicircular in outline, surface moderately convex, anterior margin produced medially into a short, flattened, tongue-like extension; posterior margin within the genal angles nearly straight. Length is to width as 1 to 2. Glabella depressed convex, broadly rounded and widest in front, transverse behind, sides nearly straight and well defined by shallow dorsal furrows converging uniformly to the occipital groove. Anterior lobe large, gently and evenly convex, suboval in outline transversely, its median length equal to one-half the total length of the glabella. The first pair of lateral lobes is wedge-shaped, located opposite the inner anterior margin of the eyes and extending about three-eighths the distance across the glabella; the second pair is subquadrate and equal in width to the inner extremity of the first pair, located opposite the palpebral lobes; the third pair is similar to the second but narrower, and shorter on the posterior margin. The first pair of lateral furrows is large, extending obliquely outward and forward, increasing in width from a pitlike depression near the inner end; the second pair is much shorter, inclined gently forward and inward, and shallow near the dorsal furrows; the third pair appears somewhat longer because it extends undiminished in size to the dorsal furrows. None of the furrows crosses the axial region. The occipital groove is similar on the sides to the last pair of lateral furrows, but opens directly into the dorsal furrows and is very shallow medially. The occipital ring is broad, arched transversely, the center rising above the surface of the lateral lobes. Palpebral lobes well defined, rising at first gently, thence more abruptly to the facial sutures around the inner concave margin of the eyes. Eyes large, constricted around the base, rising considerably above the surface of the cephalon, outer surface sloping in front, nearly vertical in back, situated about three-eighths their length in front of the posterior margin of the cephalon. Cheeks large, depressed about the eyes, thence sloping uniformly to the margin. The posterior cheek furrow is wider and shallower outward. Length of cephalon (No. 9059) along median line 28.5 mm., estimated width across genal angles 56 mm.

Position and localities.—Niagaran dolomite, Anamosa (Mr. Green); two miles north of Mechanicsville (Professor Norton).

Only two incomplete cephalons represent this species in Iowa at the present time. These agree, however, so well with Weller's description that there can be little doubt about their specific identity even though the genal spines have not been preserved. The only difference observed is the absence of a broad flattened marginal border. Specimen 9059 has a slightly flattened border but specimen 9213 has a distinct sloping border except at the anterior end. This difference may be the result of preservation rather than a specific character.

TRILOBITES OF THE DEVONIAN

Order **OPISTHOPARIA**

Family **GOLDIIDAE**

GOLDIUS THOMASI n. s.

Plate XXV, figs. 2-4.

Description.—Cranidium subquadrate in outline; width across anterior end equal to length including the occipital spine. Anterior margin broadly rounded and bearing a narrow deep marginal sulcus in front of the glabella. This sulcus is deeper and wider laterally. Between the occipital furrow and the third lateral glabellar furrows the dorsal furrows are very deep and subparallel; in the region of the second glabellar lobes they rise abruptly, diverge, and continue as shallow grooves to the marginal sulcus.

The glabella is prominent, clavate in outline, strongly convex in all directions, rising considerably above the cheeks; the greatest height is in the region of the first lateral furrows; the width across the anterior end is nearly three times that of the posterior end. The frontal lobe is large and quadrangular. The first pair of glabellar furrows are clearly defined as short, straight and smooth depressions. The second lateral furrows are but faint depressions on the surface and do not open into the dorsal furrows. The third or basal furrows appear as constrictions on the sides of the glabella. The occipital furrow is broad and very shallow. The occipital segment is trigonal in outline, gently arched, decreasing in size laterally; the posterior margin is continued into a well defined short flattened spine. The fixed cheeks are large, broadly convex opposite the second and third glabellar lobes, thence sloping gently outward and forward to the broad marginal sulcus in front. The lateral and dorsal furrows are smooth but the remaining surface is covered with numerous pustules of varying size.

Eyes, free cheeks and thorax unknown.

Pygidium small, subsemicircular to parabolic in outline; outer margin entire and spineless, broadly concave and slightly reflexed at the edge; anterior margin nearly straight. The width is to the length as 3 to 2. The surface is gently convex near the axis and depressed distally.. The axis is short, triangular, raised above the pleuræ, about one-fourth the length of the pygidium and twice as wide as it is long. The fulcral fold across the anterior end is not preserved. No annulations present.

There are fifteen gently rounded to flattened pleural segments radiating from the axis, increasing in width distally and becoming obsolete at the margin. The second and third segments are sharply pointed proximally. The fourth to the seventh segments are curved gently forward near the axis. The proximal fifth of the postaxial or median segment decreases in width distally, thence the segment gradually widens until it becomes obsolete near the margin. The intersegmental grooves are shallow but well defined. The surface, except along the margin and within the grooves, is covered with pustules of varying size which are similar to those found on the cranidium.

Dimensions.—Specimen 9085, length of cephalon including the occipital spine 5.5 mm., width across the anterior end 5.5 mm. Specimen 9087, length of pygidium 8 mm., width of same 12 mm.

Horizon and locality.—Owen beds; northwest quarter of the southwest quarter of section 31, Portland township, Cerro Gordo county. Collected by Professor Thomas.

Remarks.—The foregoing description is based on a single cranidium and one pygidium. Both specimens were found in the Owen beds, a few feet above the contact with the fossiliferous marly zone, in a thin bed of hard, crystalline, dark gray, compact limestone which is crowded with the remains of two or three species of brachiopods.

The presence of the occipital spine distinguishes this cranidium from other American species of this genus. *Bronteus haidingeri* Barrande, from the Silurian of Bohemia, bears a similar occipital spine but differs in many other respects. The pygidium is almost identical with that of *Thysanopeltis* (*Bronteus*) *tullius* (Hall) from the Tully limestone of Onondaga county, New York, but it differs from the latter in having a pustulose axis, a constriction of the postaxial segment and a smooth margin. *Thysanopeltis tullius* bears spinules on the margin.

The cranidium and pygidium are here referred to the same species because of their association stratigraphically and because no other trilobite has ever been found in these beds.

In the University collection there is also another much larger pygidium which is very similar in proportions to *G. thomasi.* It is fairly well preserved and shows pustules on the axis and pleural segments though not quite as many as in the type. It was found by Professor Calvin along Turkey creek, near Iowa City, associated with two specimens of *Phacops rana* on the same slab of limestone. The exact horizon is unknown, but judging from the locality given, it occurs either a few feet above or below the Wapsipinicon-Cedar Valley formation contact. This pygidium is tentatively referred to *G. thomasi* until more material is found to establish it definitely.

This species is of peculiar interest because stratigraphically it comes from the uppermost and latest Devonian beds in the state of Iowa, beds which are roughly equivalent to the Portage beds of New York. The writer takes great pleasure in naming this species in honor of Doctor Thomas, who collected the specimens and placed them at the writer's disposal for study.

Family **PROETIDAE**

Proetus prouti Shumard

Plate XXV, figs. 5-8.

1863. *Proetus prouti* Shumard, Trans. St. Louis Acad. Sci., vol. II, no. 1, p. 110. Devonian, a short distance north of Davenport, Iowa.

1878. *Proetus davenportensis* Barris, Proc. Davenport Acad. Nat. Sci., vol. II, p. 287, pl. XI, fig. 8. Corniferous formation at Davenport. This is the Upper Davenport formation.

1888. *Proetus prouti* Hall and Clarke, Pal. New York, vol. VII, p. 126, pl. XXIII, figs. 16 to 18. Cooks Quarry, top of Upper Davenport formation, Davenport.

Description.—Body subelliptical to suboval in outline, surface moderately convex transversely, trilobation distinct, length to width across the center of the thorax as 2 to 1. In a well preserved specimen the ratio is probably as 3 to 2 but in the specimen at hand the pleuræ on the right side are compressed.

Cephalon subsemicircular, moderately convex, slightly produced and sharply rounded in front. Posterior margin arched, transverse, genal angles produced posteriorly into medially grooved spines which spread slightly and reach a point opposite the seventh segment. Border wide, flattened, bearing an outer and an inner groove separated by a low but distinct ridge. The outer groove is larger anteriorly and is bounded by a slightly recurved edge in front of the glabella. The inner groove is wide along the cheeks but narrow in front of the glabella. The length is to the width as 7 to 12.

The facial sutures spread abruptly in front of the eyes to the outer marginal furrow thence curve inward and forward to the front margin.

Glabella longer than wide, subconate, elevated, gently depressed convex, widest opposite the eyes, somewhat contracted in front, and ending narrowly rounded at the inner marginal groove. There are three pairs of lateral glabellar furrows visible on the translucent calcite. The first and second pair are short, subparallel and directed obliquely inward and backward. The posterior pair is much larger and bifurcates so that one arm of each is directed across the glabella and the other back toward the occipital groove. Occipital lobes prominent, transversely elongate-oval. Occipital segment strongly arched; furrow narrow medially, bifucating around the occipital lobes, wider on the free cheeks and continuing into the genal spines.

The eyes are not well preserved in the specimens at hand. According to Hall (p. 127, 1888) "the eyes are moderately large, lunate; orbital ridge depressed and strongly sulcate at its base. Palpebral lobe large and closely appressed against the glabella; palpebral sulcus narrow and elevated."

The free cheeks are large, elevated, depressed around the base of the eyes, sloping moderately to the broad, shallow inner marginal sulcus.

Thorax distinctly trilobate, composed of ten segments, subquadrate, sides gently rounded and tapering gradually toward the pygidium. Axis raised, strongly rounded to semi-cylindrical, decreasing uniformly in size toward the pygidium. Width of axis slightly less than one-third that of thorax. Pleuræ flattened near the axis, thence sloping in a curve to the margin. Each segment is flattened and conspicuously grooved medially, giving rise to a wide fulcral fold which becomes obsolete on the sloping side. In places where the test has been removed each segment shows a low, sharp diagonal ridge at the fulcrum.

The pygidium is subsemicircular in outline, wider than long. The margin is gently thickened, inclined, and bears a very narrow outer sulcus near the edge and a broader shallow sulcus proximally. The axis is semiconate, narrow, tapering abruptly to an obtuse termination well within the margin. It is composed of ten annulations which are directed forward along the sides but cross the median area in a gentle posterior curve, Segments one to six bear conspicuous median nodes which decrease in size posteriorly. The pleuræ are gently convex, bearing from seven to eight annulations, which end at the border. Each annulation is marked by a fine median groove, which increases in size proximally and distally from the center.

Surface markings.—The entire surface, except the sulci, is covered with fine pustules or granules, which are readily visible upon the glabella. A small median node or tubercle is present on the occipital segment and according to Hall "the last four or five segments of the thorax each bears a strong tubercle in the axial line". This last feature is not shown in our specimen because it is partly exfoliated.

Measurements of specimen number 9089.—Length of body 42 mm., width of same 24 mm., length of cephalon 14 mm., length of pygidium 13 mm.

Positions and localities.—Specimen 9089 is from the Upper Davenport beds at Davenport (Prof. William H. Norton). The species occurs also in the Cedar Valley formation; in the *Acervularia profunda* zone, Brandon (M. A. Stainbrook); in the Cedar Valley formation, Iowa City, and at Packard's quarry, Johnson county.

Remarks.—The above specimens agree in all respects with those described by the above cited authors except that the axial tubercles were not mentioned by them. The specimen described by Shumard was somewhat abraded so that the tubercles were not preserved and such may also have been the fate of the specimens described by Barris and later by Hall. Similar tubercles are mentioned by Hall as occurring on the pygidium of *Proetus rowi* up to the third segment. Since this latter species has a pygidium which is so similar in many respects to *P. prouti* only careful discrimination will separate the two species. A number of pygidia from this vicinity, as well as the one from Davenport, which is in conjunction with the rest of the body, show at least six axial tubercles on the pygidium as opposed to three on *P. rowi*.

Associated with *P. prouti* is a very interesting history. The original specimen, which was described but not figured by Shumard, was destroyed during the great fire at St. Louis. In 1878

Barris described and figured *Proetus davenportensis* from a complete specimen found in the Upper Davenport beds at Davenport. This specimen, according to Barris, was presented to the Davenport Academy of Sciences. Subsequently Barris loaned it and one other specimen to Hall who identified them with *P. prouti* and redescribed them under that name as cited above.

In the vicinity of Iowa City detached parts of this species are commonly found in association with *Proetus searighti, Conocardium altum* and *Cranaena iowensis.*

Proetus nortoni n. s.

Plate XXV, figs. 9-11.

Description.—General form ovate-elongate to subelliptical. Surface equally and distinctly trilobate. Length is to width as 3 to 2.

The cephalon is semielliptical in outline, strongly produced in front of the glabella; width is to length as 5 to 3. The border is broad, thickened, recurved, rounded at the edge and produced at the genal angles into stout spines which extend to the seventh thoracic segment. Within the thickened margin there is a prominent groove which is widest anteriorly and shallower toward the genal angles. The surface is depressed convex. The glabella is elongate subconate, very little longer than wide, gently arched transversely, the anterior half curved downward toward the submarginal groove but not extending fully to it. The glabella tapers abruptly to the narrowly rounded anterior extremity from a constriction opposite the anterior margin of the eyes. Three pairs of glabellar furrows are distinctly shown. They are subparallel to each other and directed obliquely backwards. The first pair is shortest, the second somewhat longer and the posterior pair is continued to the occipital groove so as to divide the posterior margin into three equal parts. The occipital lobes are moderately strong, having the form of an equilateral triangle with one of its bases paralleling the occipital groove. The occipital segment is broad, strongly arched transversely and gently rounded longitudinally, bearing a low but distinct tubercle in the axial line. The occipital groove is moderately deep and narrow throughout, scarcely widening on the cheeks. The dorsal furrow is represented in front and on the sides of the glabella by a narrow impressed groove.

The facial sutures are normal. They begin at the posterior margin one-third the distance from the outer edge and are directed diagonally across the thickened posterior margin of the cheeks toward the dorsal furrows back of the eyes. In front of the eyes they diverge abruptly and approximate again on the frontal margin. The palpebral lobes are prominent and gently arched transversely. The eyes are lunate, narrow-elongate, rising almost vertically from a low orbital ridge nearly to the level of the glabella. The free cheeks are gently depressed along a narrow zone about the base of the orbital ridge and thence curve abruptly downward over a narrow lateral area to the submarginal groove. The outer thickened rim and the nearly equally thick posterior margin are continued at the genal angles into the long, stout, rounded spine.

The thorax is composed of ten segments and is subrectangular and nearly twice as wide as it is long. The sides taper gently. The axis is strongly arched transversely; width at the anterior end is equal to one-third the width of the thorax. It tapers gradually but more abruptly than does the thorax. The segments are flattened, transverse and separated by narrow shallow grooves. The pleural lobes are flattened for two-thirds their width away from the axis, whence they bend abruptly downward to the margin. The segments are gently rounded to flattened throughout, there being no appreciable flattening distally but rather a transverse thickening at the outer margin; each bears a groove, in front of which there is a fulcral fold which becomes obsolete in a short distance on the sides.

The pygidium is semielliptical in outline and slightly emarginate behind. The width is to the length as 5 to 3. The surface is moderately convex. The border is conspicuously thickened and bounded proximally by a shallow groove. The axis is raised above the pleural lobes, well defined by shallow dorsal furrows, gently arched longitudinally, less than one-third the total width at the anterior end, tapering gradually to an obtuse termination at the submarginal groove. Segments fourteen, flattened to gently rounded transversely. The intersegmental grooves are narrow. Pleural lobes moderately convex, sloping for some distance gently away from the axis, thence abruptly downward to the border. Segments ten, all but the last distinctly defined. They are flattened and extend to the submarginal groove, except the first three, which become obsolete on the border. Segments one to four bear an indistinct sulcus proximally and a short submedian groove distally. This latter groove is not well shown on the fourth segment.

Surface markings.—The surface of the glabella, except along the furrows, is covered with numerous low rounded pustules which differ in size but in general are smaller toward the margin. Similar but smaller pustules are borne on the occipital lobes and the occipital segment. Faint or nearly obsolete pustules are present on the cheeks. Each of the axial segments of the pygidium bears a row of indistinct pustules. The thickened marginal rim of the cephalon bears impressed grooves.

Dimensions.—Length of body 32 mm., width across genal angles 20 mm., length of head 12 mm., length of glabella 7.5 mm., length of pygidium 10 mm., width of same 15 mm.

Position and localities.—The type specimen, No. 9095, is from the Upper Wapsipinicon beds, at Linn Junction, along the abandoned Chicago, Milwaukee and St. Paul Railway cut. It was collected by Dr. William H. Norton. A nearly perfect cranidium, No. 9098, preserving well the surface markings, was collected at this same locality by Mr. John E. Adams. This specimen is a paratype of this species. A nearly complete specimen, No. 9094, was collected close to the top of the Upper Wapsipinicon beds at Janesville, Iowa, by Professor Norton. It occurs also at Cedar Rapids and Solon.

Remarks.—The striking surface markings of the glabella, the continuation of the posterior lateral glabellar furrows to the occipital furrow, the long stout genal spines and the distinct segmentation of the pygidium distinguish this species from any other Iowa *Proetus*. In general outline of body and form of glabella it bears some resemblance to *P. haldemani* and it has been referred to that species in the county reports, but the genal spines and the surface markings readily distinguish the two species. *Proetus nortoni* is named in honor of Professor Norton, who collected the type specimen.

Specimen No. 9094 shows well the surface markings on the cheeks. A separate pygidium, No. 9101, collected by Professor Norton at Janesville, is here referred to this species because of its close similarity to the type, from which it differs in but one respect, that of having sixteen instead of fourteen axial segments and twelve instead of ten pleural segments. This difference may be due to its larger size. The axial segments of this specimen show the surface markings unusually well. The entire specimen, No. 9102, shows eighteen axial segments and twelve pleural segments in the pygidium.

PROETUS CLARUS Hall

Plate XXV, figs. 12-13.

1861. *Proetus clarus* Hall, Description New species of Fossils, p. 71. Upper Helderberg, N. Y.
1862. *Proetus clarus* Hall, Fifteenth Rept. New York State Cab. Nat. Hist., p. 99.
1876. *Proetus clarus* Hall, Illustrations of Devonian Fossil Crustacea, pl. XX, figs. 12-14.
1888. *Proetus clarus* Hall, Pal. New York, vol. VII, p. 104, pl. XX, figs. 12-14; pl. XXII, figs. 28-30.

Description.—Cephalon subelliptical to semicircular in outline, rounded in front, the even contour being somewhat broken by a slight protrusion of the cranidium; border continued posteriorly on each side into a short genal spine which extends approximately to the fourth thoracic segment. Posterior margin strongly arched and describing a gentle curve forward. The surface is highly convex. Length is to width as 1 to 1.5.

Glabella conate, gently rounded transversely, arched longitudinally, widest opposite the palpebral lobes, constricted at the anterior angles of the eyes, thence narrowing anteriorly, and ending in an evenly rounded frontal extremity. Length equal to width. Three pairs of glabellar furrows can be faintly distinguished upon the surface by a darker coloration of the calcite and the complete absence of pustules or granules on them. The first pair is short, rising opposite the anterior angles of the eyes, directed inward for two-thirds its length, thence obliquely backward. The second pair is longer, rises at the constriction of the glabella, and is directed obliquely backward. The third pair has its origin opposite the center of the palpebral lobes, is directed inward and thence abruptly backward, thus delimiting subrectangular basal glabellar lobes. The occipital lobes are well defined by deep grooves. The occipital segment is moderately broad. The occipital furrow is deep and narrow, increasing in depth on the cheeks. The surface of the glabella and the occipital lobes is marked by minute pustules which are larger posteriorly.

The eyes are large, semilunar, strongly elevated above the cheeks and closely appressed against the glabella. The palpebral lobes are small.

The cheeks are prominent, raised proximally and approaching the suborbital ridge along a gentle slope; abruptly descending laterally to the well-defined marginal groove within the prominent flattened border.

Since neither thorax nor pygidium has been preserved in our specimen Hall's description (1888, p. 105) of those parts is copied here. "Thorax subrectangular, lateral margins slowly approximating posteriorly. Length to width as 2 to 1.

Axis broad and strongly arched, width upon the anterior margin more than one-third the width of the thorax. Sides evenly approximating to the pygidium. The segments are flattened, transverse, or with a slight forward curve toward the axial line.

Pleuræ flattened near the axis, and at about one-third their width deflected in a more or less abrupt curve to the margins. Pleural annulations grooved, the anterior limb of each becoming rapidly obsolete beyond the fulcrum.

Pygidium.—Posterior outline the arc of a circle whose center is the middle point of the body; when slightly compressed it is distinctly emarginate at the posterior extremity; border broad, moderately thickened. Length about one-half the width.

Axis convex and slightly arched longitudinally, tapering to a broad, blunt termination just within the margin. Width equal to one-third the width of the shield. The sides are appressed just above the axial furrows, by a series of oblique impressions, one upon each annulation. From seven to eleven annulations may be counted upon the axis, the first five having an anterior inclination near the margins, and a posterior curve over the median region; the posterior annulations are transverse.

The pleuræ are depressed and curve evenly in all directions to the margins. They bear four annulations and traces of a fifth, and these are marked by fine impressed lines. All the annulations become obsolete upon the border, the articulating ring, however, encroaching upon it.'' Description modified after Hall 1888.

Dimensions of specimen 9090.—Length of cephalon 11 mm., width of same 17 mm.

Position and locality.—Upper Davenport beds, Davenport (Dr. William H. Norton).

Remarks.—*Proetus clarus* is considered by Hall to be one of the most abundant species of the genus *Proetus* in the Upper Helderberg of the east but it is extremely rare in Iowa. However, considering the geographical distance as well as the large time-break between the Upper Helderberg and the base of the Upper Devonian it is rather surprising that it should be found in Iowa at all. It has many points of similarity with *P. rowi* but can be distinguished from the latter by having relatively larger eyes, a less broadly rounded glabella anteriorly, smaller and more sharply defined occipital lobes, and somewhat differently directed basal glabellar furrows.

This species was first recorded by Norton in the Geology of Scott County, Iowa Geological Survey, volume IX, page 450.

PROETUS ROWI (Green)

Plate XXV, figs. 14-15

1838. *Calymene rowi* Green, Amer. Journ. Sci. and Arts, vol. XXXIII, p. 406.
1861. *Proetus rowi* Hall, Descr. New Species of Fossils, p. 75.
1862. *Proetus rowi* Hall, Fifteenth Rept. New York State Cab. Nat. Hist., p. 103.
1876. *Proetus rowi* Hall, Illustrations of Devonian Fossils, pl. XXI, figs. 2-6.
1888. *Proetus rowi* Hall, Pal. New York, vol. VII, p. 119, pl. XXI, figs. 2-6, 24-26; pl. XXIII, figs. 20-29.

1911. *Proetus rowi,* Cleland, Wisconsin Geol. and Nat. Hist. Surv., Bull. No. XXI, p. 142, pl. XLIV, fig. 1.

Description.—Body ovate in outline. Surface strongly but subequally trilobate, anterior and posterior margins broadly rounded. Length is to width as 1.5 to 1.

Cephalon subsemicircular in outline; strongly convex and bearing a moderately wide, flat border. Glabella very large, convex, broadly conate, longitudinally arched, somewhat expanded opposite the palpebral lobes, slightly constricted opposite the anterior angles of the eyes, and broadly rounded in front. Posterior margin gently oblique at the angles and curved forward medially. Length greater than width. Lateral furrows represented by three pairs of smooth, inconspicuous linear impressions. The anterior pair is short and directed obliquely forward. The second pair is somewhat longer, situated opposite the anterior angles of the eyes, and directed gently backward. The third or posterior pair is largest, extending a short distance inward and thence bifurcating, one arm being directed across and the longer arm continuing toward the posterior margin of the glabella. The surface is marked by faint, nearly obsolete pustules. A number of larger pustules are closely aggregated centrally at the base of the glabella to form a low inconspicuous tubercle. A short distance on either side of this tubercle there are groups of three or four small pustules. The occipital lobes are prominent, transversely suboval to triangular, encroaching faintly upon the postero-lateral angles of the glabella. The occipital segment is broad, flattened and strongly arched. The occipital furrow is deeply impressed centrally, shallow around the occipital lobes and deeper again upon the cheeks. Palpebral lobes prominent, flattened, elongate.

Eyes large, lunate, closely appressed against the posterior half of the glabella, raised on a high orbital ridge but not attaining the height of the glabella. Visual surface strongly convex. Fixed cheeks narrow and extended into postero-lateral limbs which end approximately midlength of the posterior margin of the free cheeks.

Free cheek elevated proximally and bearing a broadly rounded suborbital groove; sides sloping abruptly to the margin. The border of the cheeks is not preserved in our specimen but according to Hall (1888, p. 120) "the border is unusually wide and carries two parallel grooves, the outer of which is marginal, producing a beveled edge; the inner broad and shallow, becoming flat in old individuals. On the posterior border the margin is also beveled, and the genal spines are strongly ridged by the meeting of these beveled edges." The median half of the suborbital groove is marked by a series of faint radiating grooves and ridges.

Thorax subrectangular with sides gently rounded; composed of ten segments. Length is to width as 2 to 3. Axis strongly rounded, elevated above the pleuræ, tapering gradually toward the pygidium. Width greater than one-third the total width of the thorax. Segments transverse, gently rounded to flattened and separated by well-defined grooves. The dorsal furrows are not impressed. Pleural lobes flattened above for about one-half their width, thence sloping abruptly to the margin. The proximal two-thirds of each segment is deeply sulcate, giving rise to a sharp, trigonal fulcral fold. The posterior margin of each segment is marked by a row of minute tubercles or granules.

The pygidium of our specimen is so poorly preserved that for the sake of accuracy and completeness Hall's description (1888, p. 121) is taken verbatim: "Pygidium subsemicircular or subsemielliptical in outline, faintly and broadly emarginate behind; length to width as 1 to 2; surface depressed convex.

Axis broad on the anterior margin; width equal to one-third the width of the shield; arched and sloping to a termination within the posterior border, a low ridge connecting the apex of the axis with the margin; composed of nine or ten low, flattened annulations, which have a forward inclination for about one-fourth their width from the axial margins and pass over the median area in a gentle posterior curve.

Pleuræ gently depressed, bearing six annulations with indications of a seventh, which are low, flat and faintly sulcate, becoming obsolete at or near the margin. The border is conspicuously thickened and moderately broad."

Concerning the surface markings of the axis Hall states that "there are usually indications of a row of faint axial tubercles beginning at the occipital ring, omitting the first six thoracic segments, thence recurring and extending to the second or third annulation of the pygidium.'' (Hall, 1888, p. 121.) This latter feature is not shown on our specimen because of abrasion of the axis.

Position and locality.—Upper Davenport beds, Davenport (Prof. William H. Norton). Specimen number 9129.

Remarks.—For the present *Proetus rowi* must be considered as one of the rare trilobites in this state. The only previous record of this species is in the Geology of Scott County (Iowa Geol. Survey, vol. IX, p. 451) where Norton has recorded it with the fauna of the Upper Davenport beds. The University collection contains only the somewhat mutilated specimen described above and it is hoped that more and better material will soon be found so that a complete record can be made which will link up this western form with that found in the Devonian of Wisconsin and in the Hamilton of the east. The much broader glabella, larger eyes, shorter genal spines, and the median tubercle at the base of the glabella distinguish this species from *P. prouti.*

PROETUS OCCIDENS Hall

Plate XXV, figs. 16-17.

1861. *Proetus occidens* Hall, Descriptions New Species of Fossils, p. 80. Hamilton Group, New Buffalo, Iowa.
1862. *Proetus occidens* Hall, Fifteenth Rept. New York State Cab. Nat. Hist., p. 108.
1876. *Proetus occidens* Hall, Illustrations of Devonian Fossils, pl. XXI, figs. 22, 23.
1888. *Proetus occidens* Hall and Clarke, Pal. New York, vol. VII, p. 130, pl. XXI, figs. 22, 23.

The following is a copy of the original description by Hall (1861).

''This species, so far as known, is represented by only two somewhat imperfectly preserved pygidia. Their outline is semi-elliptical; length to width as 3 to 4; surface depressed convex. The axis has a little less than one-third the width of the shield on the anterior margin, is moderately convex and tapers evenly to an obtuse apex which lies just within the conspicuous marginal border. It bears about twelve transverse annulations. The lateral slopes are gentle and bear nine or ten flattened annulations, each of which appears to be faintly sulcate. Surface minutely granulose. The larger of the two specimens measures 18 mm. in length and 23 mm. in width; the smaller 14 mm. in length and 18 mm. in width. This species has proportions similar to those of *Proetus macrocephalus,* but has fewer annulations and lacks the conspicuous ornamentation of that species.

Distribution. Hamilton group. New Buffalo, Iowa."

Remarks.—While collecting in the type locality at Buffalo, Scott county, Iowa, the writer found two pygidia, the general outline, proportions, number of annulations, and surface markings of which answer the above description. Associated with these pygidia there was also a cranidium which is, however, so fragmentary and incomplete that its specific characters have been lost. But because of its association and the great scarcity of other trilobite material in this horizon this specimen is tentatively referred to this species.

All three specimens were found in a thin layer of bluish green shale interbedded between layers of massive crystalline limestone. They are numbered 9125, 9126, 9127.

Position and locality.—Upper Davenport beds, Buffalo quarries, Buffalo (same as New Buffalo of Hall).

Proetus haldemani Hall

Plate XXV, figs. 18-19.

1861. *Proetus haldemani* Hall, Descr. New Species of Fossils, p. 74. Hamilton formation.
1862. *Proetus haldemani* Hall, Fifteenth Rept. New York State Cab. Nat. Hist., p. 102.
1876. *Proetus haldemani* Hall, Illustrations of Devonian Fossils, pl. XXI, fig. 7-9.
1880. *Dechenella haldemani* Kayser, Zeitschr. d. deutsch. geol. Gesellsch., Jahrg., p. 707, pl. XXVII, fig. 9.
1884. *Proetus haldemani* Walcott, Monog. U. S. Geol. Survey, vol. 8, Pal. Eureka Dist., p. 210.
1888. *Proetus haldemani* Hall, Pal. New York, vol. VII, p. 113, pl. XXI, figs. 7-9; pl. XXIII, figs. 13-15.

Description.—General form ovate-elongate. Surface distinctly and equally trilobate. Length is to width about as 3 to 2.

Cephalon semicircular in outline; border broad, flat and abruptly sloping at the edge, widest in front of the glabella, gradually narrowing toward the genal angles. Submarginal groove narrow in front, wider and shallower posteriorly. Glabella conate, widest across the base, thence tapering gradually to a narrow rounded anterior extremity except for a slight expansion opposite the palpebral lobes. Greatest width slightly greater than the length. Surface depressed convex; the anterior third abruptly curved downward as a rule though some specimens show but a slight curvature. There are three pairs of well defined lateral glabellar furrows, all of which curve obliquely backward. The first pair is rather short, the second pair somewhat longer and more obliquely inclined, the third pair is longest, passing obliquely inward and thence abruptly backward toward the posterior margin but opening into the occipital furrow. Occipital lobes small and inconspicuous, tapering inwardly. Occipital segment broad and flattened, narrowing toward the dorsal furrows; a minute tubercle is located medially on the posterior margin. Occipital furrow narrow and shallow throughout. Palpebral lobes prominent, extending horizontally outward from the shallow dorsal furrows.

Eyes of medium size, narrow, lunate, raised on a well defined orbital ridge to the height of the glabella.

Free cheeks depressed convex, rising gently from the shallow marginal furrow to the shallow depression at the base of the orbital ridge. Genal angles faintly produced but not forming spines.

Thorax subrectangular; composed of ten segments. Axis broadly rounded transversely, distinctly elevated above the pleuræ; tapering uniformly toward the pygidium. Segments flattened, smooth, transverse and separated by well-defined but narrow and shallow grooves. Pleuræ gently sloping to flattened for about one-half their width, thence sloping in a more abrupt curve to the margin. Segments flattened and bearing a short narrow sulcus across the fulcrum, thus delimiting a narrow trigonal fold.

Pygidium subelliptical in outline, gently convex over all. Border faintly thickened, moderately wide on the sides, increasing in width posteriorly and sloping in a plane with the convexity of the surface. Axis low but well defined throughout, gently rounded transversely and tapering to a narrow rounded extremity at the border; composed of twelve to fourteen flattened annulations which are transverse across the center but slightly oblique at the sides. The pleural lobes slope gently from the axis to the border and bear eight to ten smooth flattened annulations of which the first three are bifurcate distally and end on the border whereas the others end at the border. One specimen from which the crust has been removed shows a faint median sulcus to each pleural segment.

Surface markings.—The surface of the entire test and especially that of the glabella is covered with very minute punctæ.

Dimensions.—Specimen 9092, a rolled-up form. Length of body measured along curvature 27 mm., length of cephalon 8 mm., length of thorax 11 mm., length of pygidium 7.5 mm. Width across genal angles 13 mm. Specimen 9093, a cephalon, has a length of 12 mm. and a width of 25 mm.

Position and localities.—Upper Davenport beds, one-half mile north of Elmira, Johnson county (Leroy P. Elliot); Linn Junction.

Remarks.—This species is so distinctive that it is not likely to be mistaken for any other species of *Proetus.* The glabella bears a superficial resemblance to *Proetus nortoni* in general outline and arrangement of lateral furrows but the posterior furrows of the former do not open into the occipital furrow as they do in the latter and the surface of *P. haldemani* is smooth while that of *P. nortoni* is always strongly pustulose.

Proetus arietinus n. s.

Plate XXV, figs. 21-22.

Description.—Body ovate or subelliptical in outline, broadly rounded anteriorly, more sharply rounded posteriorly. Surface strongly but subequally trilobate. Length is to width as 1.6 is to 1.

Cephalon subsemicircular in outline, posterior margin arcuate; border very narrow, forming almost a linear ridge and bearing an equally narrow and shallow marginal sulcus. The cephalon is disposed nearly at right angles to the long axis of the body. The facial sutures appear to be normal and widely separated on the frontal margin. Glabella large, moderately and evenly convex, subquadrate to semiovoid in outline, narrowing somewhat anteriorly. Length slightly greater than width across the palpebral lobes. Evidence of any glabellar furrows is entirely wanting either on the normal or exfoliated specimens. Occipital lobes present as low moderately well defined nodes. Occipital segment broad medially, narrowing laterally. Occipital furrow and dorsal furrows narrow and shallow. Dorsal furrow is continued around the anterior end of the glabella as a distinct groove.

Fixed cheeks very narrow immediately anterior and posterior to the palpebral lobes. Palpebrum small, elongate and subcrescentic in outline. The surface of the glabella is marked by faint, transverse, lamellose lines.

Free cheeks depressed at the summit about the base of the orbital ridge, thence sloping abruptly to the margin. The poor state of preservation makes it impossible to determine the presence or absence of genal spines.

The eyes are of medium size, slightly elevated but not attaining the height of the glabella.

Thorax subquadrate; length is to width as 2 to 3; margins nearly parallel; surface subequally trilobate. Axis prominent, broad, elevated above pleural lobes, evenly rounded and tapering regularly backward. Width nearly one-half that of thorax. Segments flattened, transverse. Pleural lobes flattened for a little less than one-half their width, thence sloping moderately to the margin. Each segment is flattened and grooved for two-thirds its length, giving rise to a relatively broad fulcral fold.

Pygidium semielliptical in outline; length is to width as 3 to 4. Axis very prominent, evenly rounded transversely, arched longitudinally, elevated above the pleuræ and tapering regularly to a narrow termination near the margin. Width greater than one-third the width of the shield at the anterior margin. Pleural lobes narrow, sloping along a gentle curve from the axis to the margin. Owing to the poor state of preservation a more specific description is impossible at the present time and other pygidia which may belong to this species can not be positively referred to it until a well preserved pygidium is found in conjunction with the rest of the body.

Dimensions of specimen 9122.—Length of cephalon as measured along the median curvature 15 mm.; length of thorax 13 mm.; length of pygidium 12 mm.; greatest width across genal angles 19 mm.

Position and localities.—Cedar Valley formation, Iowa City and Brandon; Upper Wapsipinicon, Linn Junction.

Remarks.—*Proetus arietinus* is described from a poorly preserved complete specimen and from two well preserved cranidia. It differs markedly from other members of this genus in the peculiar disposition of the strong convexity of the head, almost at right angles to the axis of the body, and in having an exceptionally narrow border about the cephalon. Another distinguishing character is the wide and prominent axis of the thorax and the pygidium. It differs from *P. bumastoides* in having occipital lobes, a broader occipital segment and a more conate glabella anteriorly. From *Proetus searighti* it can be distinguished by the much narrower frontal border.

PROETUS SEARIGHTI n. s.

Plate XXVI, figs. 1-9.

Description.—Cephalon semicircular in outline, globose, highly convex both transversely and longitudinally, border moderately wide, concave and slightly recurved in front, wider and nearly horizontal near the genal angles. Length is to width as two is to three.

Glabella conate, strongly convex, longer than wide, sloping in all directions from the axial line; sides slightly constricted opposite the palpebral lobes, thence tapering in a gentle outward curve to a narrow rounded anterior extremity which encroaches upon the marginal sulcus. Three pairs of glabellar furrows are very faintly outlined in both entire and exfoliated specimens. The first and second pairs are short and subparallel and rise within a short distance of each other opposite the anterior angles of the eyes and are directed obliquely backward. The third pair begins opposite the center of the palpebral lobes posterior to the second pair at a distance equal to twice that between the first and second pair; they are directed along a zig-zag path toward the occipital groove but do not open into it. A short pair of accessory furrows (best seen in 9105) is present between the third pair of lateral furrows. The surface of the glabella is marked posteriorly by low rounded pustules which give place anteriorly to narrow elongate pustules and finally to interrupted ridges and dashes. All trend in the same direction across the glabella. The occipital segment is marked by a strongly transverse arch, which is broad medially, but narrower laterally and bears a median node and minute pustules on the posterior margin. The occipital lobes are of moderate size, transversely oval and covered with minute pustules. The occipital groove is narrow, raised and shallow.

The free cheeks are strongly raised proximally, broadly depressed about the prominent occular ridge, thence sloping very abruptly to the shallow marginal sulcus; outer edge thickened, vertical and appressed against the nearly horizontal border. The surface is marked by small pustules and the descending vertical edge by lamellose lines.

The eyes are small, rounded, prominent and raised on a conspicuous orbital ridge.

Thorax unknown.

The pygidium is semielliptical in outline, strongly convex and equally trilobate; border broad, thickened, abruptly sloping on the sides and nearly vertical posteriorly. Axis strongly rounded transversely, arched longitudinally and gently depressed along the dorso-median area; tapering to a somewhat raised obtusely rounded extremity a short distance from the border; composed of thirteen to fourteen annulations which are directed forward laterally and are transversely to posteriorly curved medially. The annulations are flattened and separated by shallow grooves. Pleural lobes strongly convex, depressed near the axis and sloping abruptly on the sides to the border. Annulations eight to nine, the last two being indistinct; all are low, gently rounded and end at the border. Specimens retaining the crust show a faint median sulcus occasioned by two rows of small pustules on each annulation. Length is to width as two is to three.

Dimensions.—Cephalon (No. 9106), length 16 mm., width 23 mm., height 8 mm. Pygidium (No. 9109), length 11 mm., width 15.5 mm. Pygidium (No. 9130), length 15 mm., width 20 mm.

Position and localities.—Cedar Valley formation, Iowa City (outcrops along Templin road and along Red Ball Route), Mid River, and Packard's quarry, Johnson county.

Remarks.—The preceding description is based on specimens Nos. 9105-9110, 9130 and 9131. Dismembered parts of this species are fairly common in the Cedar Valley formation in the vicinity of Iowa City and nearby points to the north. A complete specimen has not been found. *Proetus searighti* is distinguished from the other members of this genus by the characteristic surface markings of the glabella, the moderately wide upturned frontal border of the cephalon, the very small eyes, high cheeks and absence of genal spines. In general outline of cephalon it resembles *P. crassimarginatus* but the absence of genal spines on *P. searighti* will readily distinguish it from the latter.

Because of its common association with parts of the head the pygidium above described has been tentatively referred to this species. A final determination must, however, await the finding of a complete specimen. In general proportions and number of axial and pleural annulations it resembles the pygidium of *P. crassimarginatus* but no mention is made by Hall of granular surface markings and faint sulci on the annulations of the latter. This difference may serve to distinguish the two species.

The writer takes pleasure in naming this species in honor of W. V. Searight whose untiring efforts have been responsible for obtaining most of the material upon which the description is based.

Proetus bumastoides n. s.

Plate XXV, figs. 23-24.

Description.—The cranidium is comparatively short and wide and strongly arched longitudinally. The anterior outline is broadly rounded and slightly produced medially. The border is narrow and closely appressed against the glabella, forming a low but sharp ridge parallel to the narrow marginal sulcus and is thence deflected into a relatively broad flattened descending area which is marked by five or six subparallel linear ridges.

The glabella is subrectangular in outline, somewhat longer than wide, strongly arched longitudinally, gently rounded transversely. The anterior margin is broadly rounded, the posterior margin is transverse, the antero-lateral angles are obtusely rounded and the sides diverge gently toward the occipital groove. All lateral glabellar furrows are wanting. The surface markings consist of numerous minute, anastomosing, linear ridges having a general transverse trend approximately parallel to the anterior margin. These markings are more conspicuous on the anterior than on the posterior half. The posterior margin of the glabella descends abruptly to the occipital groove. Occipital lobes wanting. The occipital segment is strongly arched, narrow and rounded above and still narrower on the cheeks. The dorsal furrows are shallow and raised opposite the palpebral lobes. The palpebral lobes are small, narrow elongate, lunate, close to the glabella, and extend horizontally outward from the dorsal furrows.

Free cheeks, thorax and pygidium unknown.

Dimensions of cranidium (No. 9115).—Length 11.6 mm., length of glabella 9.8 mm., width of same at palpebral lobes 9.4 mm.

Position and locality.—Cedar Valley limestone, at base of second outcrop (abandoned quarry) north of the Park bridge, Iowa City.

Remarks.—This species is known only from a single cranidium which differs from the other members of this group in at least as many cranidial characters as those species differ from each other. The narrow descending frontal margin, the equally narrow marginal sulcus, the shallow dorsal furrows, small palpebral lobes, very broadly rounded anterior outline of the glabella as well as the bumastoid convexity and surface markings form a combination of characters which readily distinguish this from all other species of Proetidae.

PROETUS CRASSIMARGINATUS Hall

1843. *Calymene crassimarginatus* Hall, Geology of New York, Surv. of Fourth Geol. Dist., p. 172, fig. 5.

1888. *Proetus crassimarginatus* Hall, Pal. New York, vol. VII, p. 99; pl. XX, figs. 6-8, 20-31; pl. XXII, figs. 20-26; pl. XXV, fig. 8.

This species has been reported from the Upper Wapsipinicon beds and more particularly from the Upper Davenport stage at Davenport, by Norton in Iowa Geological Survey, volume IX, page 451, and again in the same publication, volume XXVII, page 541. The writer has failed to determine definitely this species for Iowa. Pygidia have been collected from the Upper Wapsipinicon and the Cedar Valley formations in different parts of the state which are similar to that described by Hall. All these have been referred temporarily to *P. searighti* because to date no cephalon has been found which answers the description of *P. crassimarginatus*. With only dismembered parts for study it seems best to hold in abeyance any positive assertion concerning either the presence or absence of this species. Sooner or later an entire specimen may be found which will definitely dispose of this problem.

PROETUS sp.

Plate XXV, fig. 20.

A fragmentary pygidium resembling *Proetus* (*Phaethonides*) *gemmaeus* Hall as represented by figure 33, Plate 24, Paleontology of New York, vol. 7, was found by the writer in the Upper Wapsipinicon beds at Linn Junction. The axis of this specimen has been completely destroyed and of the pleural lobes only a portion of the right one is perfectly preserved. The pygidium is semicircular in outline, having an entire outer margin. The pleuræ slope moderately from the axial region to the broad shallow concave border within a faintly upturned edge. The surface is marked by eight low, narrow but sharp ridges each of which is continued to the margin without any decrease in size and bears a row of low distantly spaced pustules on the crest. The ridges are separated by very broad shallow grooves. The area back of the axis is smooth.

The length of this specimen, No. 9104, is 6 mm. and the width 9 mm.

Remarks.—Until more complete material is found this specimen can not definitely be referred to any species.

CYPHASPIS RARIPUSTULOSUS n. s.

Plate XXVI, fig. 11.

This species is represented by a very small fragmentary cranidium having the following characters: The area in front of the glabella is produced into a broad evenly concave groove having a thin recurved or upturned margin which reaches nearly to the height of the glabella. The facial sutures spread abruptly in front of the palpebral lobes. The glabella is moderately convex, semiovoid in outline, broadly rounded in front, transverse behind, sides spreading gently from the antero-lateral angles to the occipital groove. The length is equal to the width at the base. Two pairs of lateral furrows are directed obliquely backward; the antero-lateral pair is well defined but short; the posterior pair is longer, more deeply impressed, extending nearly to the occipital groove, and delimiting a pair of large subtriangular basal lobes. The occipital segment is broad, gently convex, strongly arched transversely. The occipital and dorsal furrows are shallow. The palpebral lobes are prominent.

Surface markings.—The entire surface is covered with numerous minute to microscopic punctæ which are largest on the frontal area. A few small, widely separated pustules are present on the frontal area immediately adjacent to the antero- lateral angles of the glabella, on the fixed cheeks opposite the glabella and on the basal lobes.

Imbedded in the same slab of limestone a few millimeters from the cranidium is a fragmentary free cheek which is characterized by a broad concave marginal groove similar to that comprising the frontal area of the cranidium. The lateral portion of the cheek is narrow, rises abruptly to the shallow suborbital impression and is marked by pustules similar to those on the cephalon. The eye is comparatively large, raised on a high orbital ridge and distinctly faceted. At the genal angle the cheek is produced into a broad spine.

Dimensions.—Length of cephalon 5.5 mm., length of glabella 3.3 mm. Museum number 9113.

Position and locality.—Cedar Valley limestone, Mid River. Collected by M. A. Stainbrook.

Remarks.—This species bears some resemblance to *Phaethonides varicella* Hall[17] in size and in possessing a broad concave frontal area with upturned margin, but the basal lobes of our specimen are much larger, the occipital segment is broader and the surface bears fewer and less regularly distributed pustules.

CYPHASPIS BRANDONENSIS n. s.

Plate XXVI, fig. 12.

Description.—Cranidium moderately convex, anterior outline very gently rounded. Frontal area narrow, slightly elevated near the glabella, thence sloping abruptly for about one-half its width to the narrow, deep marginal groove beyond which it is continued into a thickened, rounded border. Glabella prominent, evenly convex, subpyriform, longer than wide, elevated above the cheeks, bounded anteriorly and on the sides by the sharply impressed dorsal furrows, which are somewhat shallower opposite the basal lobes. The length of the glabella is slightly less than two-thirds the length of the cephalon. The basal lobes are pyriform, small but prominent, and separated from the glabella by narrow, deep lateral furrows which are directed posteriorly along a gentle curve and open into the occipital groove. The occipital segment is broad, strongly arched transversely, somewhat recurved medially, decreasing in breadth laterally, and bearing a conspicuous tubercle on the posterior margin in the axial line.

The facial sutures cut the anterior margin of the cephalon directly in front of the eyes and do not diverge appreciably as they pass forward. The fixed cheeks are narrow and raised, forming a low rim around the glabella.

Surface markings.—The surface of the glabella, basal lobes and occipital segment is ornamented by numerous closely set,

17 Hall, Pal. New York, vol. VII, p. 135, pl. XXIV, fig. 29.

minute rounded pustules. The area adjacent to the dorsal furrows and the rounded frontal border are marked by fewer and smaller pustules.

The thorax and the pygidium are unknown but an incomplete thoracic segment occurs on the same slab of limestone near the cranidium. The axial portion of this segment is strongly arched transversely, occupying approximately one-third the total width. The pleura is very gently arched for two-thirds its width away from the axis and thence bends abruptly downward to the margin. The small size and general proportions of this segment as well as the close association with the cranidium constitute the basis for referring the specimen to this species.

Dimensions.—No. 9114, length of cephalon 3.3 mm., length of glabella 2 mm.

Position and locality.—Independence shale, Brandon (station 3). Collected by M. A. Stainbrook.

Remarks.—This species is of peculiar interest because it is the first trilobite ever recorded from the Independence shale of Iowa. In general outline and proportions it bears some resemblance to *C. bellula* Whiteaves, and also to *C. ornata* Hall. But it differs from the former in being much less convex and in having a narrower frontal area; and from the latter in having a narrow instead of a broad concave marginal groove. From both species it is readily distinguished in not having the single row of beadlike tubercles on the frontal border.

Family **PHACOPIDAE**

ASTEROPYGE BARRISI (Hall)

Plate XXVI, fig. 18.

1888. *Dalmanites* (*Cryphaeus*) *barrisi* Hall, Nat. Hist. New York, Paleontology, vol. VII, p. 48, pl. 16a, fig. 18.

The following is a copy of the original and only description of this species to date:

"Specimens of pygidia from the buff and drab Devonian limestones in the state of Iowa present certain peculiarities which will not permit their union with either of the foregoing species (*Dalmanites* (*Cryphaeus*) *boothi* Hall, and *Dalmanites* (*Cry-*

phaeus) *boothi* var. *calliteles* (Hall). The general aspect of these caudal shields is quite similar to that presented by very young individuals of *Dalmanites boothi* var. *calliteles,* with the exception that in the latter the axial spine is scarcely developed, while in the Iowa species it is conspicuous and broader than any of the lateral spines. The lateral spines are long, round, slender and terete, with a gentle backward curve; slightly thickened at the base, and not elevated along the middle as in the New York species. They are also relatively much larger than in any adult specimen of the variety *calliteles* observed.

The axis of the pygidium tapers rapidly, and bears from six to eight annulations, which have a strong forward inclination in the middle.

All the specimens representing this species are small, but are of about the same size, and have undoubtedly attained their mature growth. The best preserved of the specimens has a length of 8 mm. to the extremity of the axial spine, a width of 9 mm. along the anterior margin to the bases of the lateral spines; the length of the anterior spines is 5 mm.

Distribution.—Hamilton group. In the limestones usually referred to this horizon near New Buffalo, and at Searstown and Iowa City, Iowa."

Remarks.—The above description is copied verbatim because we have no material for comparison or study. The species is here referred to the genus *Asteropyge* as defined in Zittel, page 726.

ASTEROPYGE FITZPATRICKI n. s.

Plate XXVI, fig. 19-21.

Description.—Pygidium small, subsemicircular in outline, distinctly trilobate, bearing a row of eleven comparatively long, slightly backwardly curved spines on the outer margin, which is broadly rounded. The width is one and one-half times the length exclusive of the spines. The axis is depressed convex, distinct throughout, gently rounded transversely, not arched longitudinally nor raised above the pleural lobes, tapering abruptly to a narrow rounded extremity and terminating one-half its anterior width within the margin. Annulations nine, the anterior six well defined and curved forward medially, the posterior three indistinct. The width of the axis at the anterior end is about one-fourth the total width of the pygidium. Dorsal furrows narrow anteriorly, wider posteriorly and ending in a shallow rounded depression at the postero-lateral angle of the axis. Pleural lobes depressed, gently rounded medially, marked by five strong segments which are increasingly oblique from front to back, the fifth being straight or directed slightly inward rather than outward. Each segment is continued into a strong inwardly curved marginal spine which is rounded proximally, flattened dorso-ventrally and spatulate distally. The spine of the fifth segment is clavate, being constricted proximally. The first two or three pleural segments are broad, flattened, bearing a median linear groove which extends from the dorsal furrow to a depression within the outer margin. The posterior half of the segment ends at this depression, the anterior half continues to the margin where it becomes abruptly expanded and thickened to form the base of the marginal spine. The fourth and fifth segments are rounded transversely and not divided longitudinally. The intersegmental grooves are narrow and shallow. Back of the axis there is a broad smooth zone which is continued into a short median terminal spine of nearly uniform size throughout. The marginal spines appear to decrease regularly in length from front to back. The entire surface is smooth.

Dimensions.—Length including terminal spine 8 mm., width exclusive of marginal spines 12 mm., length of the anterior spine 3 mm.

Position and locality.—Cedar Valley limestone, Johnson county. Collected by Prof. T. J. Fitzpatrick, in whose honor the species is named.

Remarks.—The description is based on a single pygidium the characters of which are so different from any described species that it is here made the type of *A. fitzpatricki*. On comparing it with *A. barrisi*, a closely associated species, the following differences are observed. In *A. barrisi* all the segments of the pygidium, both axial and pleural, are subequally divided, the posterior part being narrow and smooth, the anterior part wide and bearing a median row of small tubercles; the terminal spine is V-shaped, having a broad base, and the submarginal depressions at the end of the first three pleural segments are wanting. In *A. fitzpatricki* the surface is smooth, the axial segments are not divided, the pleural segments bear a median groove, and the terminal spine is slender and of nearly uniform width throughout.

Both of these species possess characters which relate them to divisions I and III of the Dalmanitinae as defined by Reed[18]. Division I, primarily Ordovician, is characterized by a pygidium having a smooth rounded outline and rarely more than ten axial segments. Division III, primarily Devonian, is characterized by a pygidium having many marginal spines and from sixteen to twenty axial segments. Our species, though having but few axial segments in the pygidium, must be referred to the Devonian genus *Asteropyge* of division III because the spinose margin as well as the geological position must take precedence over the small number of segments. This would necessitate a revision of Reed's division III to include Dalmanitinae with as few as eight or nine axial segments in the pygidium.

The pygidium of the genus *Dalmanites* "is strongly mucronate, with 12-16 segments", therefore this name as used by Hall for his species *barrisi* should be dropped. The name *Cryphaeus*, which antedates *Dalmanites*, has been shown by Reed to be preoccupied.

During the spring of 1921 Miss Helen Nicholson collected a specimen of *Asteropyge* in the Wapsipinicon beds at Linn Junction. This specimen is incomplete, consisting of a fragmentary head and the last four thoracic segments in conjunction with an imperfect pygidium. The outline of the head is semicircular to lunate, with a broadly rounded outer margin and a re-entrantly curved posterior margin. The glabella is large and pentamerously segmented, the frontal lobe is transversely elliptical, its width greatly exceeding the length of the glabella. There are three pairs of well defined lateral lobes, which decrease abruptly in size from front to back. The anterior lateral glabellar furrows are longest and directed obliquely inward and backward; the second and third lateral furrows are nearly straight and all end equidistant from the median line of the glabella. The surface is dense-

18 Reed, The Classification of the Phacopidae: Geol. Mag., Dec. V, vol. 2, p. 224, 1905.

ly covered with short, stout tubercles. The dorsal furrows converge abruptly from the sides of the frontal lobe to the occipital segment. The palpebral lobes are located opposite the first and second lateral lobes and rise sharply from the dorsal furrow. The free cheek is large, strongly concave, rising sharply along an inward curve to the orbital ridge, and ending marginally in front of the eye. The eyes are large, reniform and raised above the cheeks and glabella. From the specimen it is impossible to tell whether cheek spines are present.

The thorax, represented by the last four segments only, is raised. The axis is prominent and elevated above the pleural lobes. Each segment is rounded, slightly swollen on either side, bearing a row of short, stout tubercles. The pleural lobes are convex, flattened above, and gently sloping at the sides. The anterior margin of each segment bears a narrow fulcral fold which extends from the dorsal furrow to the convexity. Minute tubercles are present on the surface.

The pygidium is incomplete, the terminal portion is entirely missing and of the marginal spines only the proximal part remains. In general appearance the preserved part is similar to *A. fitzpatricki,* but the number of axial segments is greater by three or four, the axis does not taper uniformly throughout its length, having nearly parallel sides from the sixth segment to the end, and all the segments are strongly pitted, each pit marking the base of a broken tubercle.

This specimen may very well prove to be a new species. But in the absence of entire marginal spines on the pygidium it is here tentatively included with *A. fitzpatricki* until more material will make possible an undoubted specific reference.

PHACOPS RANA Green

Plate XXVI, figs. 23-26.

1832. *Calymene bufo* var. *rana* Green, Mon. Tril. North America, p. 42, casts 11, 12.
1844. *Calymene bufo* Owen, Geol. Expl. Iowa, Wisconsin, Illinois, p. 74, pl. 12, fig. 1.
1861. *Phacops rana* Hall, Description New Species Fossils, p. 65.

1888. *Phacops rana* Hall, Pal. New York, vol. 7, p. 19, pl. 7, figs. 1-11; pl. 8, figs. 1-18; pl. 8a, figs. 21-33.
1888. *Phacops rana* Clarke, Jour. Morphology, vol. 2, p. 253, pl. 21.
For more complete bibliography see Vogdes, "Bibliography of Paleozoic Crustacea," 1893.

Description.—General outline elongate, subovate, anterior and posterior margins describing the arc of a large and small circle respectively. Sides of the thorax straight, subparallel, converging gently posteriorly. The length is to the greatest width across the genal angles as 2.2 to 1.

The cephalon is strongly arched, subsemicircular in outline, slightly produced at the glabella and genal extremities. Posterior margin nearly straight within the genal angles. The glabella is large, convex, subpentagonal in outline, well defined laterally by deep diagonal dorsal furrows; greatest width in front of the eyes; antero-dorsal portion barely projecting over the margin. Two or three pairs of lateral glabellar furrows are present, opposite the eyes, in some well preserved specimens. Where present they appear as gentle, forwardly curved, linear depressions in the tuberculate surface. The posterior pair of furrows traverses the glabella, thus delimiting a narrow annulation in front of the occipital segment. Adjacent to each dorsal furrow this annulation forms a low node. The occipital segment is prominent, rounded, strongly arched transversely, and as large as the first thoracic segment. The occipital groove is narrow and shallow, becoming obsolete upon the cheeks posterior to the eyes. The free cheeks slope abruptly from the suborbital groove to the margin in a plane with the surface of the eyes. They are wide and rounded at the genal angles and narrower in front of the eyes. Ventrally the cheeks are infolded to form a doublure which bears a groove just below the margin. This groove is wider on the epistoma beneath the glabella and toward the genal extremities it bears six crenulations. This latter character is seen only in favorably preserved specimens.

The eyes are large and very prominent, reaching nearly the height of the glabella. The visual surface is large, lunate and raised on a low occular ridge within a broad, shallow groove on the cheeks. The number of lenses differs according to the size and age of the individual. One small specimen has thirty-six lenses and a rather large specimen has ninety-three. The latter is a rather unusually large number for this species. The palpebrum is crescentic in outline and gently arched medially. The palpebral lobe is large and directed obliquely toward the dorsal furrow.

Facial sutures are not shown on any of the specimens at hand. Concerning these sutures Hall (Pal. New York, VII, p. 20) makes the following statement: "Facial sutures very rarely discernible. Occasional examples, in unusually perfect state of preservation and favorably weathered, or compressed in such manner as to slightly separate the cephalon along these lines, show that they take their origin on the lateral margins just in front of the genal angles, pass along the posterior edge of the visual area, thence forward along the margin of the palpebrum, following the frontal furrow of the glabella until they meet, thus taking the normal direction for the facial sutures in the Phacopidae. It is probable that the separate parts of the cephalon, in all stages of growth, are virtually anchylosed along these lines, as the cheeks are rarely, if ever, found detached."

The thorax is subquadrate, strongly trilobate and composed of eleven segments. The length is to the width as 11 to 9. The axis is evenly convex, less than one-third the total width, widest across the third segment, thence tapering gently toward the pygidium. Each segment is strongly rounded medially and somewhat flattened laterally. The intersegmental grooves are wide and moderately deep. The pleural lobes are flattened above and abruptly deflected at about two-thirds their width from the dorsal furrows. The proximal two-thirds of each segment is rounded, giving rise to a well-defined fulcral fold which becomes obsolete a short distance upon the sides. At the fulcrum each segment curves slightly backward.

The pygidium is smaller than the cephalon, strongly convex, distinctly but subequally trilobate, semiovate to semicircular in outline in older specimens and transversely lentiform in younger specimens, bounded by two curved lines meeting at the antero-lateral angles, of which the posterior line describes the more convex and uniform curve and is somewhat emarginate medially.

The axis is strongly curved and gently arched longitudinally. In mature specimens it tapers abruptly posteriorly and ends in an acute termination just within the margin. In very young specimens it tapers very gradually and is obsolete before reaching the margin. Width equal to a little more than one-fourth the width of the shield. Depending on the age of the specimen, from seven to nine annulations may be counted upon the axis. In young specimens the annulations are obsolete after the seventh although the outline of the axis is still well defined for some distance. All are transverse, strongly rounded and bear a row of short but distinct tubercles. The nonannulate posterior part of the axis of young specimens is covered with similar tubercles which lack, however, a definite arrangement. The pleural lobes are gently depressed near the axis, thence curve abruptly downward, approaching the narrow smooth linear border along a comparatively broad slope. The surface is marked by five to seven distinct annulations, which become obsolete near the margin. In some specimens annulations one to three are unequally subdivided by a faint sulcus on the posterior slope of each, giving rise to a linear ridge which is obsolete distally. All the segments and even the linear ridges are covered with numerous tubercles.

Surface markings.—Unworn specimens show small tubercles on the glabella, free cheeks, palpebrum, palpebral lobes, thoracic axial segments, descending portion of the thoracic pleural segments, and on all the annulations of the pygidium.

Dimensions.—Specimen number 9116; length of cephalon 22 mm., length of thorax 44 mm., length of pygidium 15 mm. Greatest width across genal angles 36 mm.

Position and localities.—Cedar Valley limestone or Upper Davenport formation, Iowa City, Solon, Brandon, Linn Junction, Elmira and Linwood. Professor Samuel Calvin also reports this species from Independence. A nearly complete specimen, No. 9289, from the Upper Davenport, Wapsipinicon shaly limestone, was collected by Dr. Thomas, at Linn Junction.

Remarks.—The cephalic characters of this species are so well defined and so adequately described by Hall (1888) that even the beginner will experience little difficulty in identifying *Phacops* *rana*. The pygidial characters, however, are subject to some variation and may cause mistakes unless a sufficiently large number is available showing both the young and adult characters. The outline of young specimens is transversely lentiform, the number of axial and pleural annulations is fewer, the axis is nearly parallel-sided, the tuberculation is more distinct and the first three pleural annulations are faintly subdivided. In more mature specimens the outline is semiovate and all the annulations are simple. The axis tapers much more rapidly and has a very characteristic acute termination which is not present in young specimens.

The description of *Phacops rana* is based on specimens numbered 9116-9121 inclusive.

CIRRIPEDES OF THE DEVONIAN

Superorder **Cirripedia** Burmeister

Order **THORACICA** Darwin

Family **LEPIDOCOLEIDAE** Clarke, J. M., 1896

Genus LEPIDOCOLEUS Faber 1887

Lepidocoleus iowensis Thomas

Bibliography of Lepidocoleus and some allied forms.

1888. Hall, J., and Clarke, J. M., Paleontology of New York, vol. VII, pp. 212-220. *Strobilepis spinigera* and five species of *Turrilepas* are described.

1896. Clarke, J. M., Notes on Certain Fossil Barnacles: Am. Geol. vol. XVII, pp. 137-143, pl. VII. The genera *Turrilepas* and *Lepidocoleus* are discussed, the generic characters of the latter are given and on the basis of multi- or biserial plates the family names Turrilepadidae and Lepidocoleidae respectively are proposed.

1913. Savage, T. E., New Species of Arthropods: Am. Jour. Sci., vol. 35, pp. 149-152. Contains the original description and figures of *Lepidocoleus illinoiensis*. From the Clear Creek (Upper Oriskany) chert, Illinois.

1914. Moberg, Johann Christian, Silurian Cirripedes of Sweden; Lunds Universitets Arsskrift, N. F. Afd. 2, Bd. 11, Nr. 1, Kongl. Fysiografiska Sallskapets Handlingar, N. F. Bd. 26, Nr. 1.

1914. Bather, F. A., Paleozoic Cirripedes From Sweden; Geol. Mag., Decade 6, pp. 558-560. In this article Doctor Bather reviews the work of Moberg and indicates that there are about six species of *Lepidocoleus* described. Three are American and three European.

1915. Whithers, T. H., Some Paleozoic Fossils Referred to the Cirripedia: Geol. Mag., Decade 6, pp. 120-123 with figures. The opinion is expressed that *Lepidocoleus, Plumulites,* and *Turrilepas* are classified with the Cirripedia for want of a better place to put them.

LEPIDOCOLEUS IOWENSIS Thomas

Plate XXVII, figs. 15-16.

This very interesting species is represented in the University collection by thirteen more or less incomplete but otherwise well preserved specimens. The ensuing description is by Doctor Thomas and the drawings are by O. T. Walter.

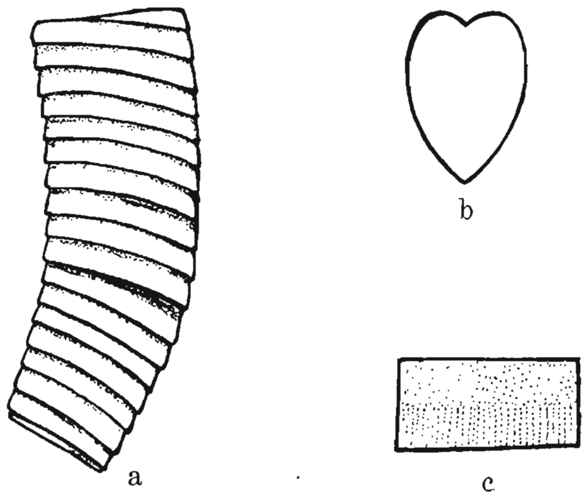

FIG. 27.—a, enlargement of Lepidocoleus iowensis, Mus. No. 9264; b, outline of cross section of same; c, a part of one segment to show the character and amount of imbrication.

The following characters are based on a study of the type specimen No. 9264, as well as a number of others.

The body is elongate, gently arched dorso-ventrally, having a gentle curve along the dorsal edge and a more conspicuous curvature on the ventral edge toward the posterior end. The curvature on the ventral side is brought about in part by the decrease in size of the body posteriorly. The body is higher than wide, made up of two series of imbricating plates arranged bilaterally with respect to a longitudinal dorso-ventral plane and directly apposed along both the dorsal and ventral edges. From the ventral carinate edge each plate rises upward along a gently curved line to the top, bends inward in an abrupt and short curve and is then directed downward into a dorso-median groove to meet the plate of the opposite side. Passing posteriorly each plate overlaps about one-half of the next succeeding plate and is thicker in the exposed part than in the covered part. The exposed part of each plate is covered by numerous microscopic straight or slightly sinous lines and ridges which run parallel to the ventral edge. In cross section the anterior end is cordate, grading posteriorly into an elongate oval section.

Horizon and locality.—Devonian, Lime Creek shale, *Devonocidaris* zone, Floyd county, Iowa. Collected by Dr. A. O. Thomas and Mr. C. H. Belanski.

Remarks.—This species is of special interest because it represents thus far the oldest phylogenetically and the last member chronologically of this genus. All the other Devonian species of *Lepidocoleus* have been recorded from lower horizons in both Europe and America.

TRILOBITES OF THE MISSISSIPPIAN

Order **OPISTHOPARIA**

Family **PROETIDAE**

Genus PROETIDES gen. nov.

Characters of the genus.—Cephalon paraboloid in outline; free cheeks produced into spines at the genal angles. Glabella subconical, bearing three pairs of lateral furrows, which cross the median region in a progressively sharper curve from front to back; entire surface strongly tuberculate. Anterior border broad, deeply concave, having the outer margin strongly reflected. Eyes prominent. Pygidium semielliptical; axis conical, having eleven or more strongly tuberculate segments; pleural lobes moderately convex and with fewer annulations.

This genus differs from all existing genera of Proetidae in that the three pairs of lateral furrows cross the median area. The short glabella and broad upturned border in front serve to distinguish it from *Proetus, Phillipsia* and *Griffithides;* the presence of facial sutures differentiates it from *Brachymetopus;* and the presence of more than one pair of glabellar lobes readily distinguishes it from *Cyphaspis.*

The six specimens (Nos. 2191, Univ. of Michigan) used by Winchell for the description of *Phillipsia insignis* are here made the basis for the new genus. The six specimens include two cranidia without free cheeks, one free cheek without a cranidium, and three pygidia. The association of these forms in the same formation is strongly suggestive, though not altogether conclusive, that they belong to one and the same species. In view of the association of the parts the cranidia are understood to constitute the genotype material.

PROETIDES INSIGNIS (Winchell)

Plate XXVI, figs. 13-17.

1863. *Phillipsia insignis* Winchell, Proc. Acad. Nat. Sci. Philadelphia, vol. 15, p. 24.

The original description follows:

"Head paraboloid; border wide, broadly and deeply furrowed, with the margin reflected upward, and the lateral angles continued posteriorly in acuminate prolongations, reaching twice the length of the glabella from the anterior end; the margin and reflected portion of the test marked by fine longitudinal striae. Glabella elongate paraboloid, tuberculated. In the middle of the posterior border of the glabella is a pair of tubercles, and in front of these a second and third pair, the last resting on the middle of the glabella—the whole so arranged as to form two longitudinal rows; opposite the first pair are two small complementary lobes, with four pustules on the summit of each; opposite the second pair, on each side, a transversely elongate tubercle with a trifid crest; opposite the first pair, a similar tubercle with a bifid crest; the ornaments on the posterior half of the glabella being consequently arranged in three transverse series, in the posterior of which are ten elevations, in the middle eight, and in the anterior six; the anterior half of the glabella is covered by pustules somewhat promiscuously arranged, and varying in different specimens. Eyes large, globoid, slightly excavated by the palpebral lobe of the fixed cheek, situated opposite the posterior third of the glabella. Occipital ring broad, with its posterior margin elevated nearly as high as the posterior extremity of the glabella, and ornamented with a row of small, raised points turned backwards. Pygidium very convex, semielliptic, the axis very prominent and forming about one-third the width at the anterior margin; consisting of twelve to fourteen rings, each bearing six small tubercles, the whole of which are arranged in six longitudinal rows; the tubercles often worn down on the exterior of the test, but always well defined in the cast; lateral lobes bent rather abruptly downwards, having ten ribs, which become indistinct and disappear toward the margin, and are entirely wanting over the narrow space behind the axis; the anterior ribs showing a faint median groove toward their vanishing extremities, and a few of the posterior ones bearing feeble tuberculations toward their axial extremities.

The pygidium of this species nearly resembles that of *P. truncatulus* Phillips sp. (Geol. Yorkshire ii. p. 240, Pl. XII, fig. 13) but the head is widely different.

From the base of the Burlington limestone.'' More particularly from the Yellow sandstone which is the equivalent of Bed 4 of the Kinderhook according to Keyes.

The specimens upon which the above description is based are now at the University of Michigan. They were collected largely by Dr. C. A. White and submitted to Winchell for study.

Through the courtesy of Dr. G. M. Ehlers these specimens were loaned to the University for further study and comparison.

PROETUS cf. P. MISSOURIENSIS Shumard

Plate XXVI, fig. 10.

1855. *Proetus missouriensis* Shumard, 1st and 2nd Geol. Rep. Missouri, p. 196, pl. B, figs. 13 a, b. Lithographic limestone, Hannibal, Louisiana and Chouteau Springs, Missouri.

1863. *Phillipsia meramecensis* ? Winchell, Proc. Acad. Nat. Sci. Philadelphia, pp. 24-25. Yellow sandstone, Burlington, Iowa.

The following is a very good description by A. Winchell of a fragmentary cranidium from the Yellow sandstone lying beneath the "Burlington Limestone" at Burlington, which is the equivalent of Weller's bed No. 6[19] of the Kinderhook at Burlington.

"Border of head of medium width, regularly convex, separated from the glabella by a narrow, distinct furrow. Glabella oblong, slightly quadrangular, a little broader behind than before, convex, highest in the middle; complementary lobes obliquely oval, protruding a little beyond the lateral boundaries of the glabella, from which they are separated by shallow depressions; a diminishing series of three feeble lobes in front of each complementary lobe; surface of the glabella smooth to the naked eye, but under a lens finely granulated. Eyes opposite the last quarter of the glabella.

The fragment above described is associated with the pygidium described by Dr. Shumard (Mo. Rep., Part ii, p. 199, Pl. B, fig. 9) simply in consequence of the granulated surface of the two, and the impossibility of proving them distinct. The original specimen, however, was obtained from the Archimedes limestone of St. Louis County, which, according to Prof. Hall, is the equivalent of the Keokuk Limestone."

Remarks.—The median length of this cranidium (Mus. Cat. No. 4908, Univ. of Michigan) from the anterior margin to the occipital groove is 7.4 mm. The length of the glabella is 6.1 mm. There exists a great deal of doubt concerning the specific reference of this cranidium. The only evidence upon which Winchell doubtfully based his identification is the granulated surface, which in itself is inadequate, and there is very little more conclusive evidence even now. The principal difference between our specimen and the type of *P. missouriensis* is one of size, the latter being a little more than twice as large as the former. Any other differences that may be present are only of minor importance. Dr. George H. Girty[20] has a number of specimens from the Kinderhook beds at Burlington which he considers as belonging to the same species as the cranidium described by Winchell, but which Girty identifies as *Proetus missouriensis*. This identification by Girty is here used as additional evidence for referring the cranidium in question to *Proetus missouriensis.*

19 Iowa Geol. Survey, vol. 10, p. 77, 1899.
20 Personal communication. August 17, 1922.

PHILLIPSIA TUBERCULATA Meek and Worthen

Plate XXVI, fig. 22.

1870. *Phillipsia tuberculata* Meek and Worthen, Proc. Acad. Nat. Sci. Philadelphia, p. 52. Burlington limestone, Kinderhook, Pike County, Illinois.

1887. *Phillipsia tuberculata* Vogdes, Ann. New York Acad. Sci., vol. 4, p. 92. Burlington Group, Kinderhook, Pike County, Illinois.

1894. *Phillipsia tuberculata* Keyes, Missouri Geol. Survey, vol. 4, p. 235, pl. 32, fig. 6. Burlington limestone, Sedalia, Missouri.

To date only a single pygidium of this species has been reported from Iowa. This was collected by T. Van Hyning, and is said to have come from the Burlington limestone in the vicinity of Fort Madison. This specimen is now in the State Historical Department museum at Des Moines (Mus. No. 4474).

As intimated elsewhere in this paper Mr. Ben H. Wilson has been very helpful in securing specimens for comparison and study. It was he who located the above specimen in the Museum at Des Moines and he obtained the permission of Curator Harlan to have it loaned to the author for study and illustration. Except that it is somewhat smaller, all of its characters are identical with the original description of Meek and Worthen which is included verbatim.

"Attaining a large size. Head and thorax unknown. Pygidium semielliptic, the length being nearly four-fifths the breadth, very convex; posterior margin obtusely rounded; lateral margins diverging rapidly forward, with convex outlines. Axial lobe well defined, obtuse, and rather prominent behind, and gradually widening forward, with nearly straight sides; rather distinctly more elevated than the lateral lobes, which it nearly equals in breadth at the anterior end, as seen in a direct view from above, but one-fourth narrower than the latter, measuring over the curve of each; showing sixteen or seventeen straight, well defined segments, each of which is provided with six small tubercles, arranged so as to form six rows. Lateral lobes with about fourteen segments each, the very short posterior ones being nearly on a line with the axial lobe, while the others grow gradually more transverse anteriorly, so as to show only a moderate obliquity toward the front; all extending down so as to leave only a very narrow, undefined, smooth, marginal space, and each ornamented by from two or three to twelve tubercles, the number increasing regularly with the length of the segments toward the anterior. Surface between the segments and tubercles smooth.

Length of pygidium, 0.95 inch; breadth, 1.45 inches; convexity, 0.40 inch.

Locality and position.—Kinderhook, Pike County, Illinois. Burlington division of the Lower Carboniferous." To this add Burlington limestone, Fort Madison, Iowa.

GRIFFITHIDES PORTLOCKI Meek and Worthen

Plate XXVII, figs. 17-19.

1865. *Phillipsia* (*Griffithides*) *portlockii* Meek and Worthen, Proc. Acad. Nat. Sci. Philadelphia, p. 268.
1873. *Phillipsia* (*Griffithides*) *portlockii* Meek and Worthen, Geol. Surv. Illinois, vol. 5, p. 525, pl. 19, figs. 6a, b, c.
1884. *Griffithides portlocki* Walcott, Pal. Eureka Dist., U. S. G. S., Monograph , 8, p. 266, pl. 24, figs. 4, 4b.
1887. *Griffithides portlocki* Vogdes, Ann. New York Acad. Sci., vol. 4, p. 93, pl. 3, fig. 9.
1894. *Phillipsia portlocki* Keyes, Missouri Geol. Survey, vol. 4, p. 236, pl. 32, fig. 7.

Description.—Cephalon subsemielliptical in outline, nearly twice as wide as it is long, produced into short pointed spines at the genal angles. Glabella large, ventricose, oval-elongate; surface curving abruptly downward in all directions from the greatest convexity in front of the eyes; anterior extremity rounded and forming the anterior margin of the cephalon; posterior extremity contracted to the occipital groove. A pair of short lateral furrows extends obliquely backward from the dorsal furrows opposite the anterior margin of the palpebral lobes. A second pair of stronger furrows originates at the dorsal furrows opposite the center of the palpebral lobes, curving obliquely backward to the occipital groove, dividing the posterior margin into three nearly equal parts and isolating, with the dorsal furrows, a pair of small, triangular, nodose basal lobes. Dorsal furrows deep and well-defined throughout. Occipital groove transverse, narrow and deep, somewhat wider as it continues along the posterior margin of the cheeks to the outer marginal groove at the genal angles.

Occipital segment prominent, strongly arched transversely and rising to about one-half the height of the glabella. Fixed cheeks narrow opposite the large median glabellar lobe, increasing in width posteriorly and continued laterally into the posterior limbs, which end approximately midway between the dorsal furrows and the genal angles. Palpebral lobes small, rising abruptly from the dorsal furrows to the level of the eyes, thence continuing a short distance laterally in a horizontal plane.

Eyes large, subglobular, rising strongly above the surface of the cheeks to about three-fourths the height of the glabella; situated a little more than one-half their length in front of the posterior margin of the cephalon and occupying the entire space between the palpebral lobes and the outer marginal groove.

The facial sutures originate on the posterior margin of the cephalon about midway between the dorsal furrows and the genal angles, extend obliquely forward and inward to the dorsal furrows back of the eyes. In front of the eyes they describe a gentle curve around the antero-lateral angles of the cranidium, cutting the anterior margin in line with the inner anterior margin of the eyes.

Free cheeks small, narrowly sulcate about the base of the eyes; anterior and posterior margins thickened and continued posteriorly into the genal spines, bounded proximally by a well-defined marginal groove which also continues into the genal spines.

Entire surface granulose, the granules at the base of the glabella being the largest.

Pygidium semielliptical in outline, approaching semicircular, broadly rounded posteriorly, wider than long, moderately convex; margin smooth and sharp-edged, narrow and decreasing in width anteriorly. The axis comprises about one-third the width of the pygidium, is well rounded transversely, slightly arched longitudinally and strongly elevated above the pleural lobes. Sides of the axis flattened appressed and sloping from a faint groove to the dorsal furrows. The tapering of the entire axis is more rapid than that of its median rounded part. There are fourteen well-defined segments separated from each other by narrow but deep groves which are shallower or nearly obsolete at the sides. The terminal axial segment is nodose and higher than those immediately in front of it. Situated along the crest of each segment there is a row of seven to eleven fine tubercles. The slope of each segment anterior to the crest is longer and more gentle than the posterior slope. Pleural lobes moderately convex, somewhat depressed along the axis, thence sloping strongly to the margin; marked by twelve ribs which extend nearly to the margin and are increasingly oblique toward the posterior end. The last two or three ribs are less distinct. No ribs present immediately back of the axis. The four anterior ribs are faintly but distinctly subdivided throughout four-fifths their entire length along the posterior margin. Each segment bears a row of fine tubercles similar to those on the axis. The areas between the rows of tubercles are smooth.

Dimensions.—Number 9242; median length of cranidium 10.3 mm., width across genal angles 17 mm. This specimen is somewhat distorted. Number 9032, length of pygidium 14 mm., width of same 17 mm., length of axis 11.5 mm., greatest width of axis 6.5 mm.

Position and localities.—Keokuk limestone, Keokuk, Galland station and Montrose, Lee county (Wilson and Walter); Fort Madison (Superintendent Cruikshank, Mount Pleasant); section 4, Jackson township, Henry county, along a small tributary of Skunk river.

Remarks.—Dismembered parts of this species occur rather commonly in the Keokuk limestone. It is the only trilobite found in this formation and is practically limited to bed number 6 of Savage's type section of the Keokuk in section 4, Jackson township, Henry county. Here also the specimens are more numerous than in any outcrop in Lee county.

In the latter county the specimens have a smaller vertical range, occurring in thin layers of gray shaly limestone as in Henry county. Keyes, 1894, reported *Griffithides portlocki* for the first time from Iowa as a *Phillipsia*. His figure 7, Plate 32, is that of a nearly complete but somewhat distorted specimen. Subsequently it was reported by Savage, 1902, in the faunal list of the Keokuk limestone of Henry county, as a *Phillipsia* resembling

Phillipsia portlocki. This species is a good index fossil of the Keokuk.

GRIFFITHIDES WILSONI n. s.

Plate XXVII, figs. 1-10.

1916. *Phillipsia* sp. Weller, Contributions Walker Museum, vol. 1, No. 10, p. 263, pl. 19, fig. 24. A pygidium is figured.

1918. *Phillipsia* (species undetermined) Thomas, Iowa Acad. Sci., vol. XXV, p. 615, pl. XII, fig. 25, pygidium.

Description.—The cephalic characters of this specimen are based on a nearly complete but greatly distorted head which is a part of an enrolled imperfect specimen, No. 9082, and a nearly perfect cranidium, No. 9100.

The cephalon is paraboloid in outline and apparently produced into spines at the genal angles. Each genal angle of specimen No. 9082 is broken. The outer margin slopes abrutly downward and is very narrow in front of the cranidium. The glabella is very prominent, oval oblong, rising considerably above the palpebral lobes and free cheeks. Sides subparallel, anterior margin and antero-lateral angles rounded. The surface is strongly convex transversely and moderately convex longitudinally. A shallow glabellar furrow originates opposite the center of each palpebral lobe and extends obliquely inward, thence abruptly backward, opening into the occipital groove, thus dividing the base of the glabella into three nearly equal parts and delimiting a pair of small subtriangular basal lobes. The dorsal furrow is very narrow and shallow. The occipital grooves rise abruptly from the dorsal furrows and continue nearly horizontally to the top of the eyes. The eyes are large, conspicuously raised above the surface of the free cheeks and appressed against the palpebral lobes in specimen No. 9082. The fixed cheeks are very narrow in front of the palpebral lobes but noticeably wider opposite the antero-lateral angles of the glabella. The free cheeks are large, depressed about the eyes, abruptly sloping at the margin and prolonged along the facial sutures in front of the cranidium. The outer margin of the cephalic shield is marked by delicate parallel impressed lines. The surface of the glabella is covered by numerous microscopic granules.

The thorax is too poorly preserved for accurate description. The right half is almost entirely wanting. The posterior two or three axial segments are strongly arched and well defined by intersegmental grooves. The dorsal furrows are broad and deep. Eight pleural segments are partly shown on the left side. The proximal two-thirds of each segment is subequally divided by a distinct shallow sulcus extending outward to the geniculation. The surface is finely granulose.

The pygidium is semi-elliptical in outline, somewhat wider than long, highly convex, marginal zone broad, smooth, of nearly uniform width throughout and bounded by a definite shallow submarginal furrow which is parallel to the free outer edge. The axis is prominent, strongly elevated, comprising approximately one-third the entire width of the pygidium anteriorly. It is strongly rounded transversely and moderately arched longitudinally. The sides are somewhat flattened near the dorsal furrow. The proportions of the axis diminish regularly from front to back. Segments fourteen in number, rounded and well defined anteriorly, fainter distally, separated by narrow but deep grooves which are continued almost to the dorsal furrows. The surface of each segment is marked by numerous minute granules. The pleural lobes rise strongly from the margin, thence arch over and flatten horizontally toward the dorsal furrows. Segments seven to eight, broad, rounded and well defined throughout, all ending at the submarginal furrow except the anterior two which extend beyond and approach the free outer edge. The surface is smooth to the unaided eye but under a lens a row of minute tubercles is seen on the posterior margin of each segment and similar tubercles are scattered over the remaining area.

Measurements.—Catalog No. 9082; median length of cephalon 8.2 mm., width across genal angles 10.2 mm. Length of pygidium 7.5 mm., width of same 8.3 mm., width of axis at anterior end 2.5 mm.

Position and localities.—Number 9082, Pella beds, Ottumwa, from the limestone taken out of Des Moines river near the Market Street bridge (Mr. G. A. Larson). Number 9100, Pella beds, southeast quarter of section 17, township 71 north, range 6 east, Henry county, on the north side of Big creek in the marl beds (Ben H. Wilson). Number 9024, five pygidia, Pella beds, three miles north of Fremont, Mahaska county (Ben H. Wilson). Number 9039, Pella beds, along north branch of Lizard creek, Webster county (Lees and Thomas). A pygidium of this species was collected by Dr. Max Littlefield in the Pella beds about one mile northwest of Ollie, Keokuk county.

Remarks.—This species is so different from any described species of *Griffithides* that a comparison is scarcely necessary. *Griffithides mucronatus* Girty, from the basal Fayetteville shale in the Fayetteville quadrangle, Arkansas, agrees in a general way with our form but the average number of axial and pleural segments on the pygidium is somewhat larger and the surface markings of the glabella are coarser. The pygidium of *G. wilsoni* also bears a general resemblance to that of *G. pustulosus* Snider[21] from the Mayes limestone of the Chester group of northeastern Oklahoma in the character of the margin and the surface markings but it differs from the latter in being considerably smaller and in having fewer segments. The number of segments is given as thirteen to fourteen for the axis and ten to eleven for the pleural lobes but Snider's figure 14 of Plate 7 shows only nine segments for the axis and eight for the pleural lobes. The configuration of the glabella also is somewhat different, that of *G. pustulosus* being proportionally wider across the anterior end.

Weller's specimen of *Phillipsia* species from the Ste. Genevieve limestone of Monroe county, Illinois, is here included under *G. wilsoni* because the specimen shown in his figure 14, referred to above, is almost identical in appearance with the pygidia of *G. wilsoni* from Iowa.

Through the courtesy of Dr. George H. Girty, the writer was enabled to make direct comparisons with specimens taken from the Ste. Genevieve limestone, at Ste. Genevieve, Missouri. These are quite similar to the specimen figured by Weller and also to the Iowa material so that there can be little doubt that the ma-

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21 Snider, L. C., Oklahoma Geological Survey, Bull. 24, pt. II, p. 120, pl. 7, figs. 14, 15, 16, July, 1915.

terial from the Missouri and Illinois localities is conspecific with that from Iowa. Included in the material loaned by Doctor Girty there is a very fine free cheek which is similar to that of the type specimen but has in addition a very long genal spine. The presence of this spine is more conclusive circumstantial evidence that the broken genal angles of the Iowa type, No. 9082, represent the bases of lost genal spines.

A pygidium, No. 9039, now referred to this species, collected in the Pella beds at Fort Dodge, was briefly described by Professor Thomas as cited above. This is the first description of any of the material here referred to *G. wilsoni*. His diagnosis covers the essential points in so far as the meager material permitted.

Associated with the pygidia representing the above species are several, for example Nos. 9056 and 9083 from Iowa, which have a smooth margin, a nearly obsolete marginal groove and much less distinctly defined axial and pleural segments. The faint definition of segments is such a striking and easily observed character that the varietal name *genevievensis* is offered for these pygidia. These differences may be due to wear and abrasion, they may be due to the age of the specimens, they may be due to sexual characters of the species, or they may represent perfectly good varietal or specific features. If further material should prove the last assumption to be correct then the varietal name will probably receive specific rank.

The writer takes great pleasure in naming this species in honor of Mr. Ben H. Wilson, who collected most of the material for study.

A DECAPOD FROM THE MISSISSIPPIAN

PALAEOPALAEMON IOWENSIS Walter

Plate XXVII, fig. 20.

1917. *Palaeopalaemon iowensis* Walter, Iowa Acad. Sci., vol. XXIV, p. 119, pl. Va. figs. 1-4.

The following is a copy of the original paper on this species:

"The specimen which is the subject of this paper is the same as the one noted by Professor Stuart Weller in his article on 'The Succession of Fossil Faunas in the Kinderhook Beds at Burlington, Iowa.'[1] The specimen was collected in an argillaceous shale —bed number 1 of the paper cited—and was among the material illustrating the fauna of that bed submitted to Doctor Weller by Professor Calvin and Professor Udden. In Weller's paper, page 69, the specimen is referred with some doubt to *Palaeopalaemon newberryi* Whitfield, with a note that it 'is probably the same crustacean that Whitfield identified from Cascade,' now a part of the city of Burlington. Weller further comments that 'it is by no means certain that the Burlington specimens are identical with the types of the species or even that they belong to the same genus.' Whitfield had obtained his Burlington specimen from Dr. A. S. Tiffany of Davenport, Iowa. According to his description it differs in perfection from the one here discussed in having abdominal segments and telson both well preserved, while the cephalo-thorax is much less perfect.[2] In spite of its imperfections Whitfield believed it to be identical with his type specimen *P. newberryi* described[3] some years before from the Erie shale at Leroy, Ohio, and re-described by Hall and Clarke.[4] The Erie shale is late Upper Devonian in age[5] and is thus somewhat older than the bed in which the Burlington specimens occur.

The cephalo-thoracic portion only is preserved in the specimen at hand but this part exhibits features not heretofore noted in this class of remains. The dorsal and lateral regions of the cephalo-thorax are quite perfect and admit of a certain degree of accuracy in description but the appendages are either wholly wanting or are represented by the proximal segments alone.

The sides of the shrimplike cephalo-thorax are so strongly compressed that the postero-lateral portions of the branchiostegite are subparallel; the sides are longer below than above. The postero-ventral angle of the right branchiostegite is perfect, that of the left is partly broken. Transversely the dorsum is highly arcuate as far forward as the rostrum, which ends in a short spine; longitudinally the dorsum is very gently arched. The surface of the specimen is smooth, glossy, or polished in appearance and marked by greater and lesser punctæ. The greater punctæ are not very numerous and can be seen with the naked eye; the lesser punctæ are very numerous and can be seen only with the aid of a microscope. The region of the ophthalmic segment or the

1 Iowa Geological Survey, vol. X, pp. 63-79; 1900.

2 Amer. Geologist, vol. IX, p. 237; 1892.

3 Amer. Jour. Sci., 3d Ser., vol. XIX, pp. 40-42, pl. (circulated) figs. 1-3, 1880; also Ann. N. Y. Acad. Sci., vol. V, p. 505, pl. XII, figs. 19-21, Dec., 1890; and Geol. Ohio, vol. VII, p. 461, pl. VIII, figs. 19-21; 1893.

4 Pal. New York, vol. VII, p. 203, pl. XXX, figs. 20-23; 1888.

5 Geol. Survey Ohio, 4th series, Bull. 15, p. 115; 1912.

rostral region is not arcuate but flattened and slopes gently to the dorso-lateral angle.

Extending from the posterior end of the cephalo-thorax to the transverse gastric sulcus there is a dorsal carina bearing a narrow mesial threadlike keel; anterior to the transverse gastric sulcus it is continued as a low lamellar crest and terminates in a short laterally compressed rostral spine. The hepatic sulcus (or sinus) begins at the base of the antenna, extends backwards along a slightly curved line for a distance of six millimeters, thence bends abruptly upward at a right angle to the dorsal carina, for a space of four millimeters whence it bends forward in a short curve, then back upon itself postero-dorsally at a sharp angle, and finally, after describing a short semicircle, it passes anteriorly along the side of the dorsal carina as the gastro-dorsal groove. There is but one spine on each side of the cephalo-thorax; each is located at the antero-lateral angle of the cephalic carapace and on a level with the base of the rostral spine. From this lateral spine a shallow but distinct groove extends backward to within a millimeter of the hepatic sulcus and its course is almost parallel to the ventral margin of the cephalic carapace,—the two being approximately 1.5 mm. apart. This groove bears a delicate threadlike ridge along its bottom. Beyond the hepatic sulcus and about 1 mm. dorsally a similar groove continues nearly to the end of the cephalo-thorax, its course being practically parallel to the dorsal carina. This may be called the cardiaco-branchial groove. It is situated along a broad angle and with its elevated edges gives superficially the appearance of a ridge. Anteriorly the groove has a low but well marked rim or edge on either side and these rims are gradually more prominent and the groove less so until at the posterior end the two rims blend into a ridge or carina and the median groove is obsolete. Extending from a point slightly anterior to the midlength of the dorsum and at right angles to it is a short shallow transverse gastric sulcus; it reaches half way to the cardiaco-branchial groove or ridge and is deepest in the middle and decreases in depth toward both ends. Beginning at the anterior end of the cardiaco-branchial carina a broad rounded ridge extends postero-dorsally past the ventral end of the transverse gastric sulcus to a dorso-median point immediately posterior to the midlength of the cephalo-thorax. This ridge or carina the writer will call the "cervical ridge" as opposed to the common cervical groove of modern decapods. The portion of the cervical ridge between the transverse gastric sulcus and the dorsal end bears a fine mesial sinus. Running one millimeter dorsally and parallel to the anterior portion of the cervical ridge from the hepatic sulcus to the transverse gastric sulcus there is a deep gastro-hepatic sulcus. Two millimeters from the ventral margin of the cephalo-thorax and beginning at the postero-ventral apex of the hepatic sulcus there is a strong marginal carina which tends to coalesce with the free margin toward the posterior end. The entire free margin of the cephalo-thorax is slightly thickened and the ventral part of it bears a small submarginal groove. The portion of the branchiostegite from the marginal carina downward is inwardly inclined.

The eye stalks are partly preserved. The one on the right side has a height of 5 mm.; the left, 1 mm. A part of a laterally compressed peduncle of the right antennule is visible. The antennæ are not shown but the proximal portions of well developed antennal scales are present, forming a continuous shelf beneath the antennules. The line of demarcation has been obliterated but this condition may have been brought about by the process of substitution and by the great pressure exerted upon the thin inner margins of the scales, which may have been partly imbricated at the time of entombment. Each scale has a prominent outer submarginal groove which probably represents the main axis of support. The dorsal surface of each scale bears a trace of a delicate diagonal pattern.

Extending forward from the antero-ventral side of the cephalic region are two long subcylindrical processes which are broken off anteriorly and somewhat swollen near their proximal ends. The part of the left member which is preserved has a length of 17 mm. and its greatest diameter (dorso-ventral) is 5 mm. Their surfaces are polished and punctate. Whether these appendages represent the first joints of the antennæ, segments of extremely large maxillipeds, or the first (or second) pair of proximal segments of the first pair of pereiopods the writer is unable to determine. From their comparatively large size it is probable that they are parts of the first pair of pereiopods. Compare, for example, the first pair of pereiopods of the modern form *Sabinea princeps* Smith.[6] The remaining thoracic appendages are represented by their proximal segments only and these are preserved so poorly and in such a way that the number can not be determined with accuracy. One of them has a length of 4 mm. and a diameter of 2 mm.; others are larger but less well defined. On the ventral surface near the posterior end there is exposed a fragment which may be a part of an abdominal pleura or a part of the telson that may have become impressed on the under side

6 For figure see Bull. Mus. Comp. Zool., vol. XXIV, No. XVII, p. 38, Pl. VIII, fig. 1, Cambridge, 1893.

of the thorax while in a flexed position. The hardness of the matrix makes it difficult to learn its exact character.

Measurements.—Total length of the specimen 5 cm.; dorsal length of the cephalo-thorax 32 mm.; greatest width 12 mm.; height of carapace 13 mm.; distance of antero-lateral spine from the rostral spine 7 mm.; greatest distance across the base of antennal scales 8 mm.

This specimen agrees with the genus *Palaeopalaemon* Whitfield, in that the cephalo-thorax is narrow and shrimplike as well as keeled on the back and sides but it differs from it in being rostrate. The appendages which Whitfield has called antennæ are here considered as parts of the first pair of pereiopods. The presence of a larger number of sulci and carinæ and of a right and left spine as well as the antennal scales further differentiate our specimen from *P. newberryi.* Indeed, the characters just pointed out are suggestive of the modern family Crangonidæ rather than of the family Palæmonidæ. The first pair of legs strikingly suggest those of *Sabinea princeps,* mentioned above, while the large antennal scales are also characteristic of the Crangonidæ. However, in the absence of more complete material and, too, for the lack of a more appropriate genus for its reception the writer prefers tentatively to refer the specimen to the old genus *Palaeopalaemon.* It is felt, moreover, that the characters pointed out are sufficiently different and important to deserve specific recognition and consequently the specific name *iowensis* is offered.

The specimen is in the paleontological collections of the State University of Iowa. It was preserved in an exceedingly hard nodule of pyritic shale, a part of which has been removed with sharp instruments and much patience. Museum number, 9277.

TRILOBITES OF THE PENNSYLVANIAN

Order **OPISTHOPARIA**

Family **PROETIDAE**

Griffithides scitulus Meek and Worthen

Plate XXVII, figs. 11-14.

1865. *Phillipsia* (*Griffithides*) *scitula* Meek and Worthen, Proc. Acad. Nat. Sci. Philadelphia, p. 270. Upper Coal Measures, Springfield, Illinois.

1872. *Phillipsia scitula* Meek, U. S. Geol. Surv. Nebraska, p. 238, pl. 6, fig. 9. Upper Coal Measures, Nebraska City, Nebraska; Springfield, Illinois. Lower Coal Measures, Illinois.

1873. *Phillipsia (Griffithides) scitula* Meek and Worthen, Geol. Surv. Illinois, vol. 5, p. 612, pl. 32, fig. 3. Upper Coal Measures, Springfield, Illinois.

1884. *Phillipsia (Griffithides?) scitula* White, 13th Rep. Geol. Surv. Indiana, p. 173, pl. 39, figs. 6-9. Coal Measures, Perrysville, Eugene, Lodi, Silverwood and Newport, Indiana.

1887. *Phillipsia scitula* Herrick, Bull. Denison Univ., vol. 2, p. 62.

1887. *Griffithides scitula* Vogdes, Ann. New York Acad. Sci., vol. 4, p. 97, pl. 3, figs. 11-13. Upper Coal Measures; Springfield, Illinois; Plattsmouth, Nebraska. Lower Coal Measures, Illinois.

1923. *Griffithides scitulus* Thomas. Proc. Iowa Acad. Sci., vol. XXX, p. 478, pl. ii, fig. 38. (Appeared, July, 1924).

Description.—The cephalon of this species, number 9035, is represented by a fragmentary cranidium of a nearly complete but greatly distorted specimen. The cranidium is so poorly preserved that an accurate description is impossible. The glabella is pyriform, elongate, broadly rounded in front and bounded by a distinctly thickened anterior (marginal) rim or border which bears minute impressed lines parallel to the free margin. It is bounded on the sides and in front by a distinct dorsal furrow. The posterior half is strongly granular as seen under a lens, the anterior half less so. A pair of isolated, well-defined, triangular basal lobes is present. Between these, at the base of the glabella, there is a prominent median node. The occipital segment is broad, gently rounded, bearing a small median tubercle. Occipital furrow wide and moderately deep. Fixed cheeks narrow. Antero-lateral angles of cranidium rounded. The facial sutures cut the anterior margin in line with the palpebral lobes. Palpebral lobes small, crescentic and situated immediately anterior to the basal glabellar lobes. Length of cranidium 5.4 mm.

Free cheek.—The only free cheek (number 9214) associated with the trilobite material is moderately large and continued at the genal angles into a prominent spine. The surface slopes gently away from a shallow suborbital groove to the thickened outer margin. The wide surface of this margin bears a number of parallel linear grooves which are continued into the genal spine. Maximum length of specimen is 8.2 mm.

The thorax of specimen 9035 is incomplete, showing but seven segments. Trilobation distinct. Unlike the axial segments of the pygidium the axial segments of the thorax are evenly rounded, being neither flattened dorsally or flattened and appressed laterally. Each bears a row of small tubercles. The pleural lobes are flattened near the axis and bent strongly downward about midway, being, however, less geniculate than the pleural lobes of the pygidium. Each segment bears 2 to 3 minute tubercles.

Pygidium (number 9035) small, semielliptical, highly convex, width greater than length, bordered by a comparatively broad, steeply sloping margin which decreases but slightly in width anteriorly. Axis highly elevated, subquadrate in transverse cross-section, arched longitudinally; sides flat, steeply sloping, upper surface flattened to depressed and of nearly uniform width throughout. Entire axis tapers moderately from front to back and terminates abruptly at the submarginal furrow. Segments eleven, narrow, scarcely curving forward, divided by broad, deep grooves all of which are shallow on the sides and are progressively weaker posteriorly, where they are obsolete. Each segment bears four to six tubercles on the dorsum. The tubercles on the dorso-lateral angles are larger than those medially situated. Pleural lobes less convex than axis, bearing six segments and an indistinct seventh which extends back to the region of the eighth axial segment. These segments rise sharply from the submarginal furrow, thence bend over and approach the narrow and shallow dorsal furrow along a nearly horizontal upward slope. Each bears a single large tubercle along the crest of the geniculation. Except for the tubercles already mentioned the entire surface is smooth.

Since the above was written a cranidium, No. 9291, and one pygidium, No. 9292, in excellent state of preservation, were collected in a black shaly limestone along Soldier creek, in section 9, Cooper township, Webster county, by Robert Rule and presented for examination and study by his teacher, Miss Katherine Mauthe of the Junior College faculty at Fort Dodge. The age of the beds along Soldier creek which furnished these specimens is Des Moines of the Pennsylvanian system. (See text figure 28.).

Dimensions.—Greatest length 6.8 mm.; greatest width 8. mm., length of axis 5.5 mm.; width of axis 3 mm.

Horizon and locality.—Cherokee shaly limestone, Des Moines. Collectors; Mr. Ben H. Wilson, Prof. A. O. Thomas.

Remarks.—The Iowa material of this species is usually fragmentary, poorly preserved and rather uncommon. The generic and specific characters are fully established by the imperfectly preserved cranidium. The pygidium, however, shows only minor differences from *Griffithides parvulus* and *Griffithides ornatus.* It is the opinion of the writer, an opinion also shared by Dr. George H. Girty,[21] that *G. parvulus* may prove to be a synonym of *G. scitulus.* The pygidium of *G. ornatus* described by Girty from the Morrow formation differs in having a moderately broad, horizontally extended and slightly upturned marginal rim, which is entirely wanting in *G. scitulus.* But the original *G. ornatus* of Vogdes and that of Smith are essentially similar to our *G. scitulus.* The similarities of the cephalic shield are relied upon for the specific identification.

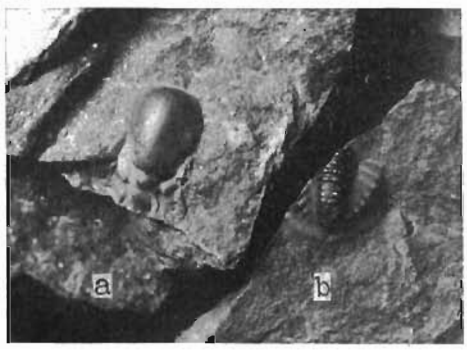

FIG. 28.—*Griffithides scitulus.* a, a well preserved cranidium x2/1. No. 9291. b, a nearly complete pygidium x2/1. No. 9292. From Pennsylvanian limestone, near Fort Dodge. Collected by Robert Rule.

The name and synonymy of this species has long been *G. scitula.* However, the writer prefers to follow Grabau (Index Fossils, vol. II, page 305), Girty (Strat. Penn. Series Missouri, vol. XIII, pp. 300, 306), and others in changing the spelling to *scitulus* to conform in gender with the generic name.

21 Personal communication, July 19, 1922.

PHILLIPSIA MAJOR Shumard

Plate XXVI, figs. 27-28.

1823. *Trilobus* Say, Long's Exped. to Rocky Mts., vol. 1, p. 148, (224) footnote 176, 17. On west shore of Missouri river, five miles below Council Bluffs.
1858. *Phillipsia major* Shumard, Trans. St. Louis Acad. Sci., vol 1, p. 226. Upper Coal Measures, Clinton county, Missouri; valley of the Verdigris, and twelve miles south of Lecompton on the Santa Fe road, Kansas.
1861. *Proetus longicaudus* Hall, Des. New Species Foss., p. 80. Hamilton. (Found northeast of Des Moines, Iowa.)
1862. *Proetus longicaudus* Hall, 15th Rep. New York State Cab. Nat. Hist., p. 168, pl. 10, figs. 7-9.
1872. *Phillipsia major* Meek, U. S. Geol. Surv. Nebr., p. 238, pl. 3, figs. 2a-c. Upper Coal Measures, Bellevue and Plattsmouth, Nebraska; Clinton county, Missouri; Vermilion river, twelve miles south of Lecompton, Kansas.
1876. *Proetus longicaudus* Hall, Illus. Dev. Foss. Crust., pl. 20, figs. 32-34.
1881. *Proetus longicaudus* Williams, Am. Journ. Sci., 3rd series, vol. 21, p. 156. Upper Carboniferous, Madison, Greenwood county, Kansas.
1887. *Phillipsia major* Herrick, Bull. Denison Univ., vol. 2, p. 60. Upper Coal Measures, Kansas.
1887. *Phillipsia major* Vogdes, Ann. New York Acad. Sci., vol. 4, p. 85, pl. 3, fig. 14. Upper Coal Measures, Clinton county, Missouri; valley of Verdigris river, twelve miles south of Lecompton on the Santa Fe road, Kansas; Kansas City, Missouri; Bellevue, Nebraska.
1888. *Proetus? longicaudus* Hall, Pal. New York, vol. 7, p. 131, pl. 20, figs. 32-34. Near Madison, Kansas; northeast of Des Moines, Iowa.
1891. *Phillipsia major* Hare, Kansas City Scientist, vol. 8, p. 33, pl. 1, figs. 5, 8a-c. Coal Measures, Kansas City, Missouri.
1894. *Phillipsia major* Keyes, Missouri Geol. Survey, vol. 4, p. 238, pl. 32, figs. 8a-e. Upper Coal Measures, Kansas City, Missouri.
1897. *Trilobus* Harris, Bull. Am. Pal., vol. 1, p. 382 (112).

Description.—General form ovate-elongate, more broadly rounded in front than behind. Cephalon semicircular, strongly convex, genal angles produced into strong spines, width through the eyes greater than length along the midline; anterior margin evenly rounded, posterior margin within genal angles transverse. Glabella subquadrate, longer than wide, sharply set off from the fixed cheeks, rising strongly from front to back, greatest height opposite the anterior end of the posterior glabellar furrows; sides subparallel, expanding slightly opposite the palpebral lobes, which are near the posterior end; posterior margin of glabella curved forward medially. First and second glabellar furrows short, subparallel, directed inward and backward. First furrow shortest and on a level with or slightly back of the anterior margin of the eye. Posterior glabellar furrows curve back to the occipital segment, delimiting a subtriangular basal lobe at each postero-lateral angle. The distance between the first and second furrows is less than that between the second and third furrows. The margin in front of the glabella is narrow and thick. Palpebral lobes large, crescentic, and situated opposite the glabellar furrows, separated from the latter by a deep dorsal furrow. Occipital segment highly arched, increasing in width toward the center, separated from the glabella by a broad, moderately deep occipital groove.

Eyes very prominent, reniform, rising abruptly from a crescent-shaped ridge on the posterior half of the free cheeks. The eye has the appearance of a band appressed against the cranidium between the palpebral lobes above and the free cheeks below. The facial sutures begin at the thickened posterior margin midway between the outer edge and the dorsal furrows; cutting diagonally across the thickened margin they are directed inward close to the dorsal furrows back of the eyes, thence forward around the palpebral lobes, spreading abruptly in front of the eyes and converging again to cut the anterior margin of the cephalon at an acute angle. Antennal pits present, one on each side of the glabella in the dorsal furrow in front of the eye.

The free cheeks are large, produced into strong spines posteriorly and short spinelike extensions anteriorly. The margin is thickened, rising abruptly at first, thence flattening out nearly horizontally and becoming somewhat depressed around the eyes. The posterior margin bears a strong furrow continuous with the occipital furrow. The fixed cheeks are narrow everywhere except opposite the antero-lateral portion of the glabella where they widen considerably.

Thorax composed of nine segments. Axis rounded transversely and strongly elevated above the pleural lobes, segments narrow and rounded with broad intersegmental grooves. Pleural lobes less convex than the axis, divided into an outer free abruptly sloping portion and an inner nearly horizontal articulating portion. Each segment is flattened and bears an elongate triangular lobe along the anterior margin in the region of the geniculation; this represents the fulcral process. The intersegmental grooves are narrow and shallow.

Pygidium convex, paraboloid, sides nearly straight, posterior margin narrowly rounded, length slightly greater than width, bordered by a smooth sloping margin which is very wide back of the axis and uniformly narrower toward the anterior end. Axis conical, upper part sharply rounded transversely, sides flattened and smooth, bearing a faint groove below the rounded portion. Width less than one-third the total width of the pygidium. The axis tapers uniformly, ending at the submarginal furrow. Segments eighteen to twenty, smooth and flattened. Intersegmental grooves narrow and shallow, obsolete on sides except near the anterior end. The pleural lobes are strongly convex, rising abruptly from the smooth margin and depressed near the axis. Segments nine to twelve, broad, moderately oblique, decreasing abruptly in length posteriorly and ending opposite the posterior end of the axis. All the segments extend to the proximal part of the smooth marginal zone except the first two or three, which may extend beyond nearly to the edge. Entire surface smooth.

Dimensions of No. 9040.—Length of entire specimen 54 mm., median length of cephalon 18.5 mm., greatest width of same 30 mm. Median length of pygidium 24 mm., greatest width of same 26 mm. Width of axis at anterior end 8.2 mm.

Positions and localities.—Number 9040; Decatur county, collected by Prof. T. J. Fitzpatrick. Numbers 9025 to 9028, one cephalon and three pygidia, Missouri limestone, Winterset, collected by Prof. Samuel Calvin. Number 9030, a large pygidium from the Tarkio limestone, two and one-half miles northeast of

Norwich, Page county, collected by Dr. Geo. L. Smith of Shenandoah.

This species is also reported by Dr. John L. Tilton from the Bethany Falls, Deer Creek, and Tarkio limestones of the Missouri series in southwestern Iowa and also from the Henrietta limestone, Des Moines series, north of Stuart.

Remarks.—The first record we have of this species dates back to the year 1823 as cited in the bibliography. Thomas Say found a cephalon and numerous pygidia in the sandstone five miles below Council Bluffs on the west bank of Missouri river. These he described in a footnote under the name *"Trilobus."* The description of the cephalon is as follows: "But a single specimen occurred, which we can, without any doubt, consider as the thorax of a *trilobus;* but whether or not it appertains to the same species with the above (pygidia), or to some other of which we have no other fragment, we are at a loss to determine. Like the above mentioned abdomen it is distinct from any we have figures of. It is of a narrow lunate form, highly convex, the disk destitute of sculpture, and the eyes prominent." From this description of the cephalon, the dimensions given of the pygidia and the locality it is reasonable to conclude that this could be none other than the subsequently described *Phillipsia major.* Not only is this the first record we have of a *Phillipsia* from the vicinity of Iowa but it is the first record of any trilobite whatsoever from this region.

The first entire specimen to be described and subsequently figured is that by Hall 1861 under the name *Proetus longicaudus.* This specimen was collected northeast of Des Moines and was referred to the Hamilton of the Devonian. In 1881 Williams recorded specimens, similar to those described by Hall as *Proetus longicaudus,* from the Upper Carboniferous, near Madison, Greenwood county, Kansas. In the year 1888 Hall questions both the generic reference as well as the age of this species as illustrated by his observations as follows:[22]

"There exists a great deal of doubt as to the generic status and the geological age of this species. The original and type specimen (*Proetus longicaudus* Hall) was presented many years ago by the Rev. Mr. Nash, of Des Moines, Iowa, together with specimens of *Phacops rana,* and was said to have been found in asso-

22 Hall, Pal. New York, vol. 7, 1888, p. 132.

ciation with the latter at some point to the northeast of that place. This was the only specimen of the species known until certain others were described by Mr. H. S. Williams from a blue limestone near Madison, Greenwood County, Kansas, and he has suggested that these may have been derived from rocks not older than the Carboniferous. Mr. Williams' specimens were obtained from Mr. Edwin Walters of Hickman, formerly of Madison, Kansas, who, in response to inquiries, writes that he has found this species in association with *Phacops bufo* (*rana*). Admitting its association with this well known and characteristic fossil, its geological age would appear to be that of the Hamilton group.

On the other hand the species, in many important structural features, is more closely related to the Carboniferous *Phillipsiae* than to the typical forms of *Proetus*. The possession of but nine thoracic segments, which appears to be a normal feature of the species at maturity, is known in but one other species of *Proetus*, viz., *P. sculptus* Barrande, from the étage G. For the genus *Phillipsia* this is the normal number. Moreover, the oval, slightly constricted glabella, the reniform eyes, the absence of occipital lobes, the great length of the pygidium and the number of its annulations are all Phillipsoid characters.

The species may ultimately prove to be a Carboniferous fossil, but any satisfactory determination of its age must await the acquisition of more complete material."

In view of the foregoing considerations of Hall and Williams and the identity of the descriptions and figures with *Phillipsia major*, Hall's *Proetus longicaudus* is here made a synonym.

The foregoing description of this species is based on characters observed in four separate pygidia, one nearly complete cephalon, one cranidium and a nearly perfect entire specimen.

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PLATES ILLUSTRATING IOWA TRILOBITES

All the figures represented by these plates are of natural size unless otherwise indicated.

PLATE X.

Figs. 1-9. *Dikelocephalus minnesotensis* Owen..........................192

1. A cranidium showing four glabellar furrows, the first and second pair being rather indistinct. This figure also shows a nearly complete thoracic segment. No. 9017.

2. The outline of a complete free cheek and a part of the anterior border of the cranidium. The outline is marked with ink. No. 9010.

3. A hypostoma, No. 9014; and 4, a smaller hypostoma, No. 9015.

5. An incomplete thoracic segment showing the diagonal pleural groove.

6. A ventral impression of a free cheek. No. 9018.

7. A pygidium of average size. No. 9013.

8. A very well preserved cranidium showing the normal convexity of the glabella and of the anterior border. This specimen was collected by Dr. M. M. Leighton at Baraboo, Wisconsin. No. 9005.

9. Longitudinal median profile of figure 8, showing the curvature of the glabella and the anterior border.

Agnostus parilis Hall..184

Fig. 10. A cephalon, No. 9240. Times 4.

Fig. 11. A pygidium, No. 9239. Times 4.

Saukia pyrene Walcott..196

Fig. 12. A small incomplete cranidium. No. 9004.

Fig. 13. An enlargement of the same.

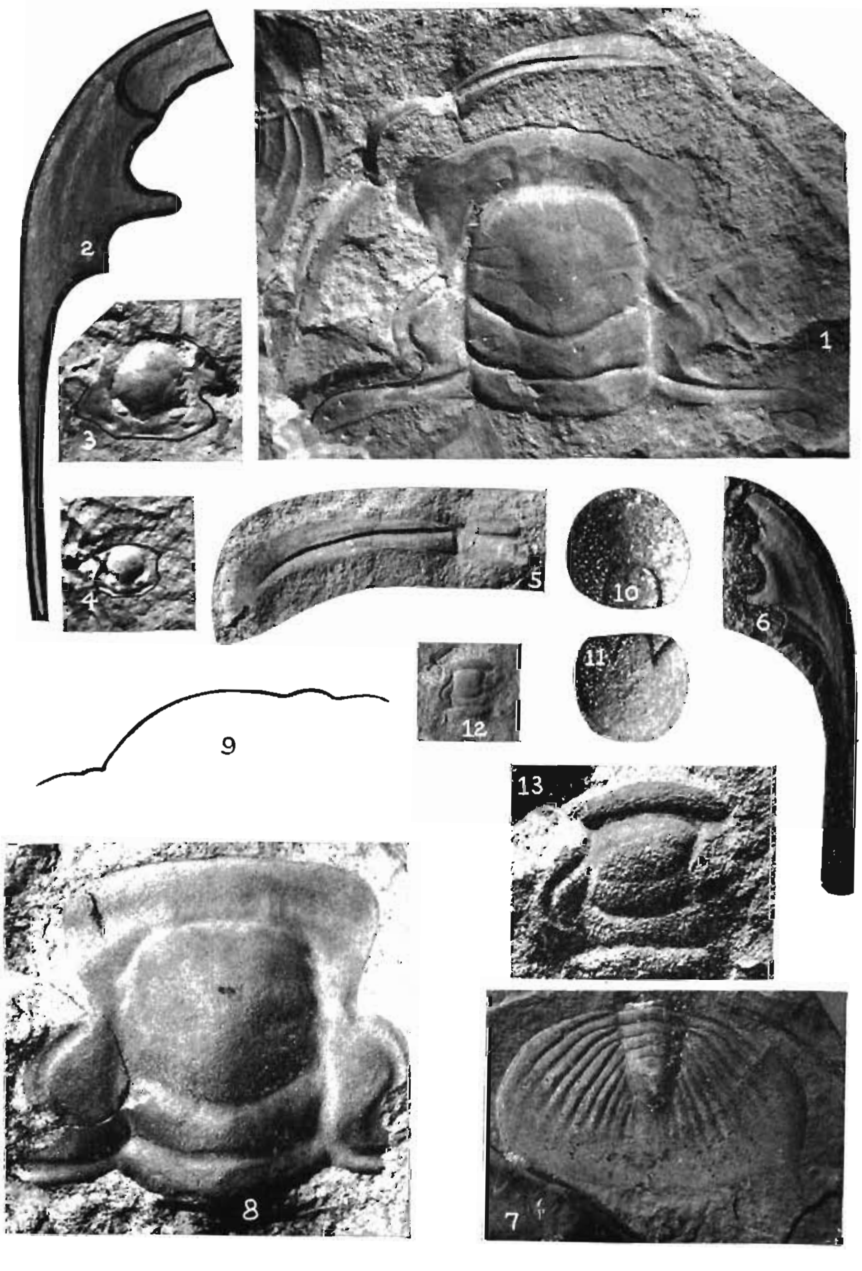
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PLATE XI.

Figs. 1-4. *Aglaspis thomasi* Walter..198

1. The holotype cranidium. No. 9009.
2. The same greatly enlarged.
3. A part of an abdominal segment showing the pitted surface. No. 9020.
4. The same specimen considerably enlarged.

Figs. 5,6. *Conaspis micros* Walter..185

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12. An incomplete free cheek, a part of the spine being lost. No. 9236.
13. A pygidium showing the longitudinal subdivisions of the pleural segments. No. 9279.
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17. View of a nearly complete specimen showing the location of the thorax and the pygidium. No. 9000.
18. Dorsal aspect of a pygidium showing indistinct lobation. No. 9280.
19. A free cheek. No. 9003.
20. A pygidium and free cheek. No. 9281.

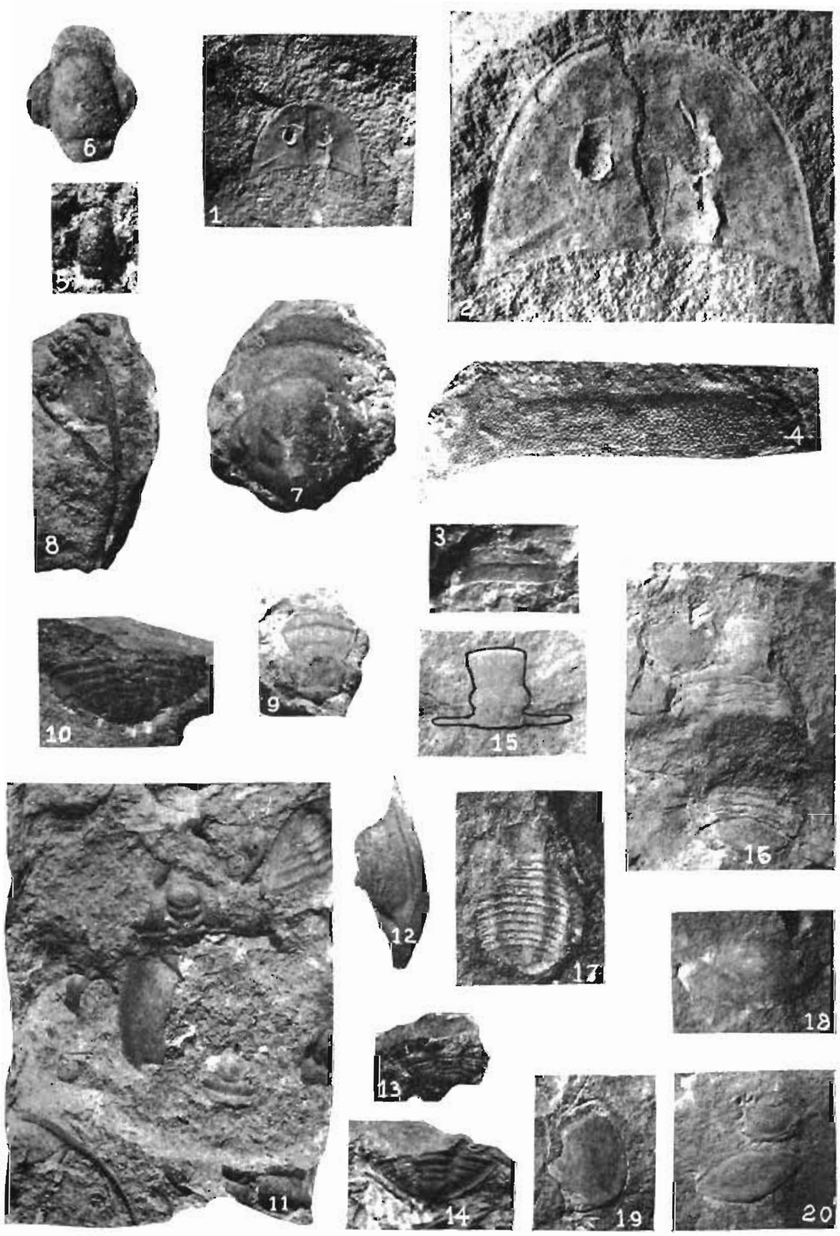
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PLATE XII.

This is a view of a slab enlarged two diameters to show the crowded association of trilobite remains as it occurs in the Eau Claire formation. No. 9239.

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Fig. 2. Cranidia of *Conaspis micros*. See also Plate XI.
Fig. 3. Pygidium of *Ptychaspis striata*. See also Plate XI.
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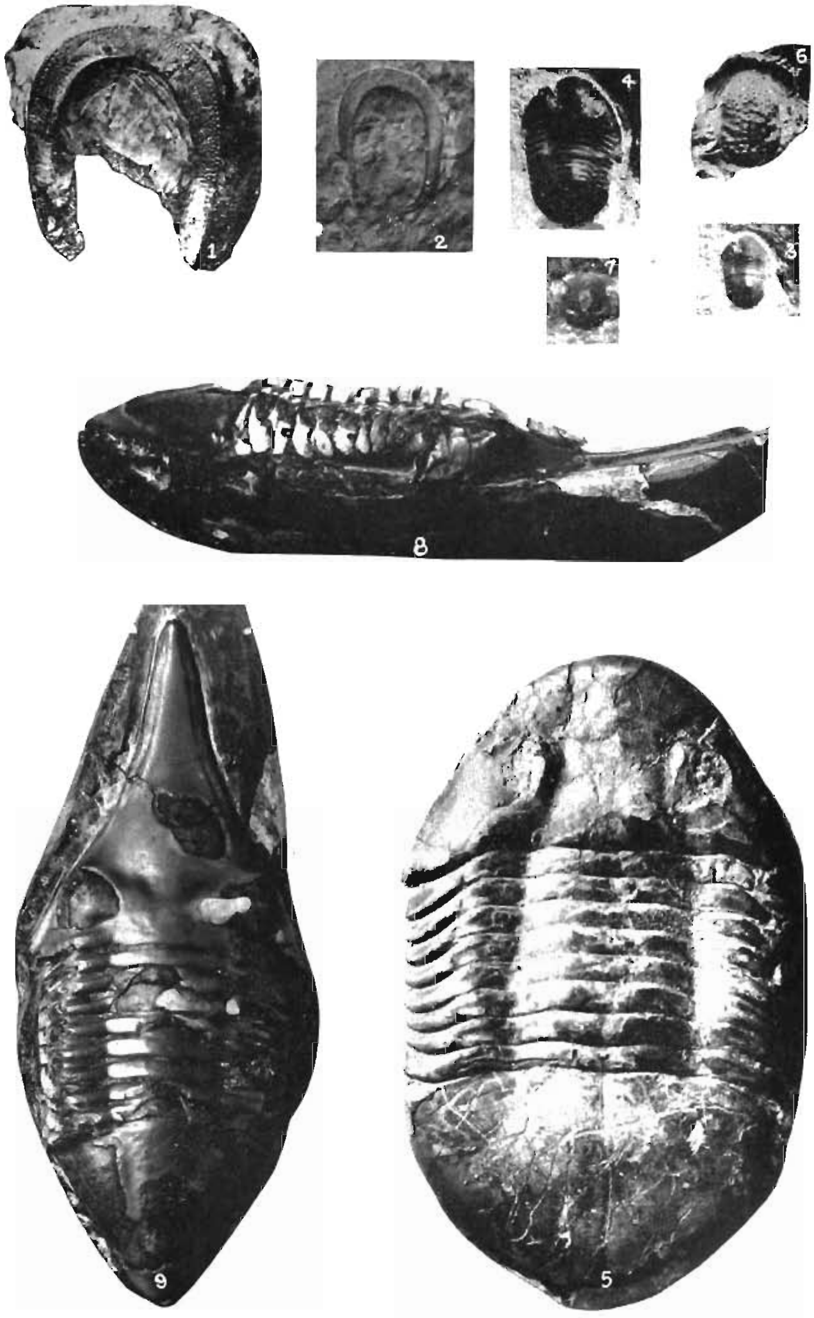
Fig. 9. Dorsal view of the same specimen, which was loaned to the University for study by the collector, Mr. A. G. Becker.



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7. Cephalic view of an enrolled specimen. No. 9168.

8. Pygidial view of the same specimen.

Figs. 9, 10. *Brachyaspis* species

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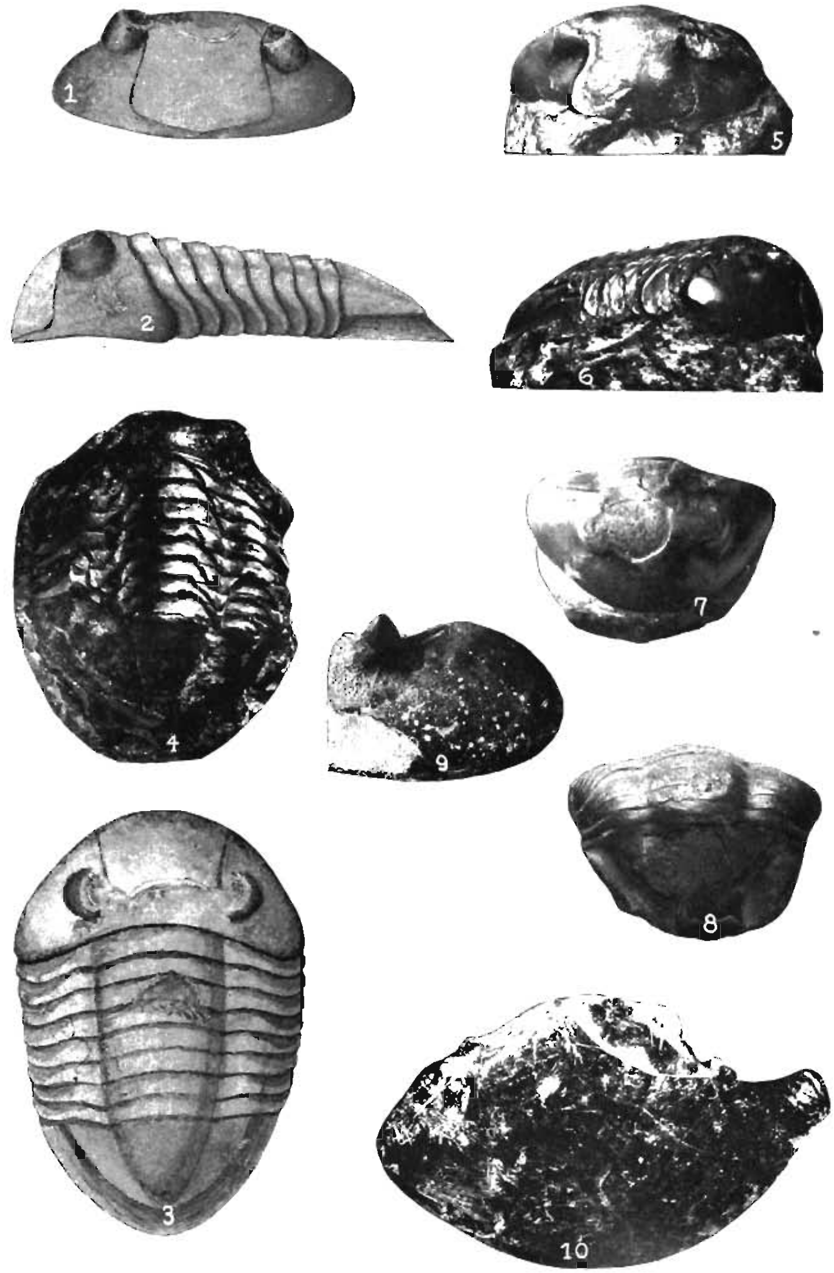
Fig. 10. A view of a large pygidium having a narrow axial lobe. This also is tentatively referred to a large *Brachyaspis* by Dr. Raymond and the writer. No. 9174.



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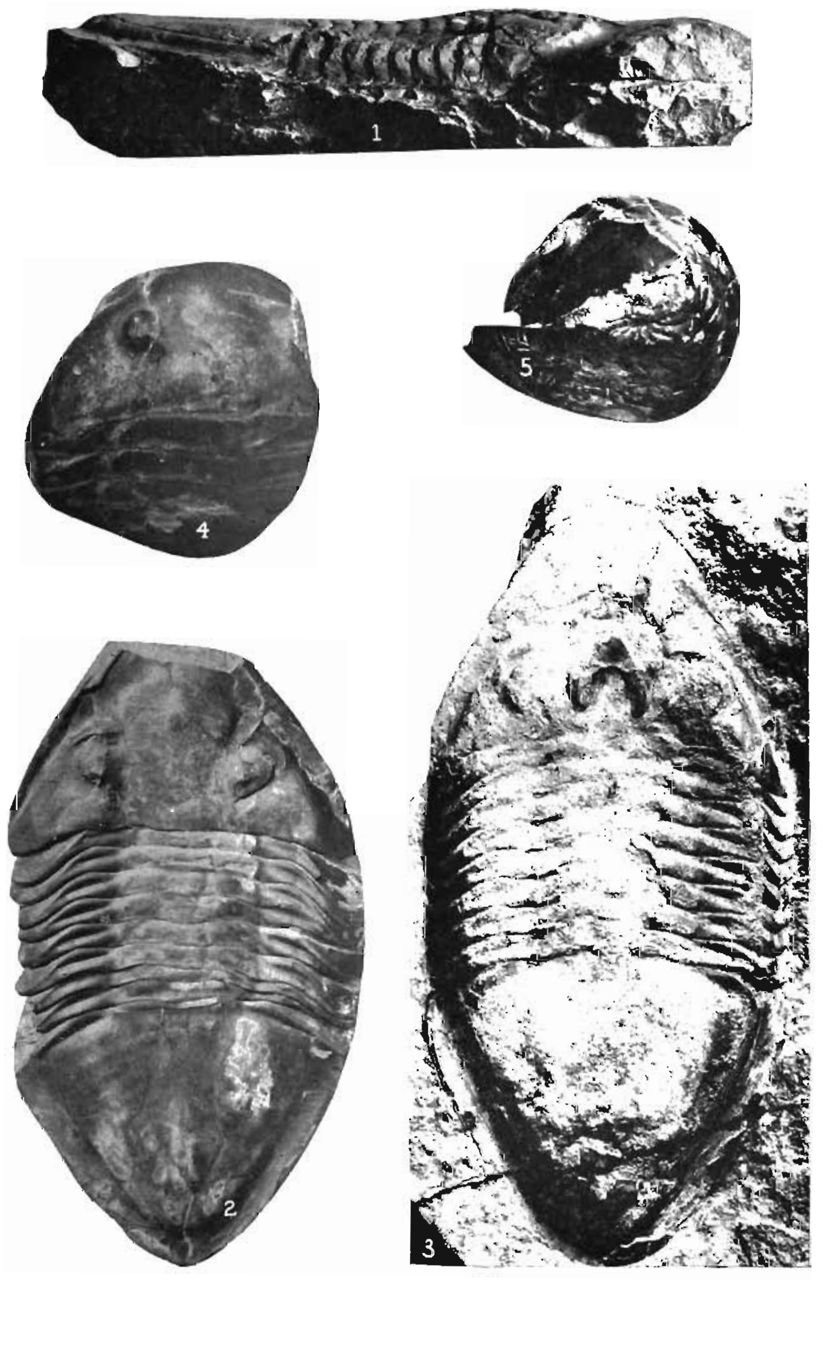

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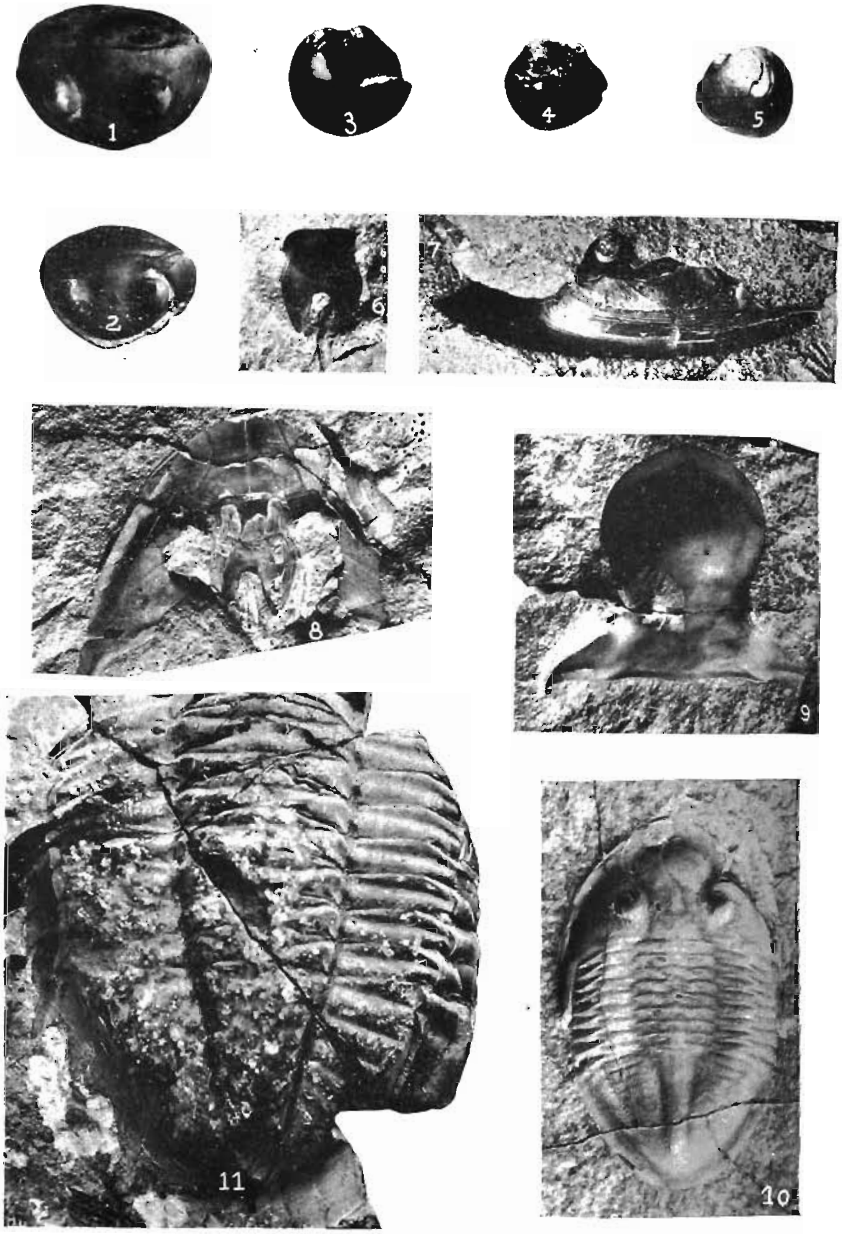
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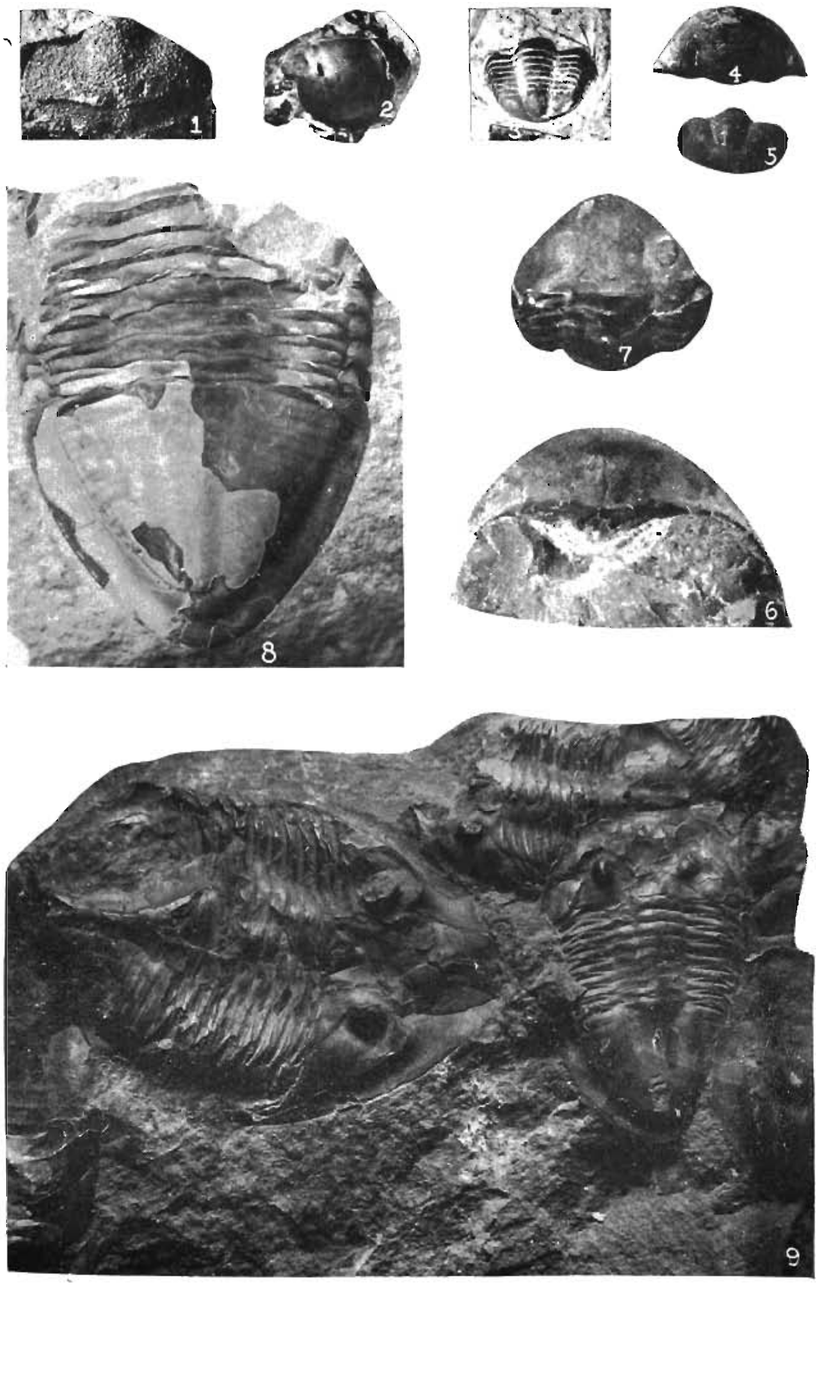

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* Figures obtained by courtesy of Field Museum of Natural History. They are after illustrations in their publication No. 171.

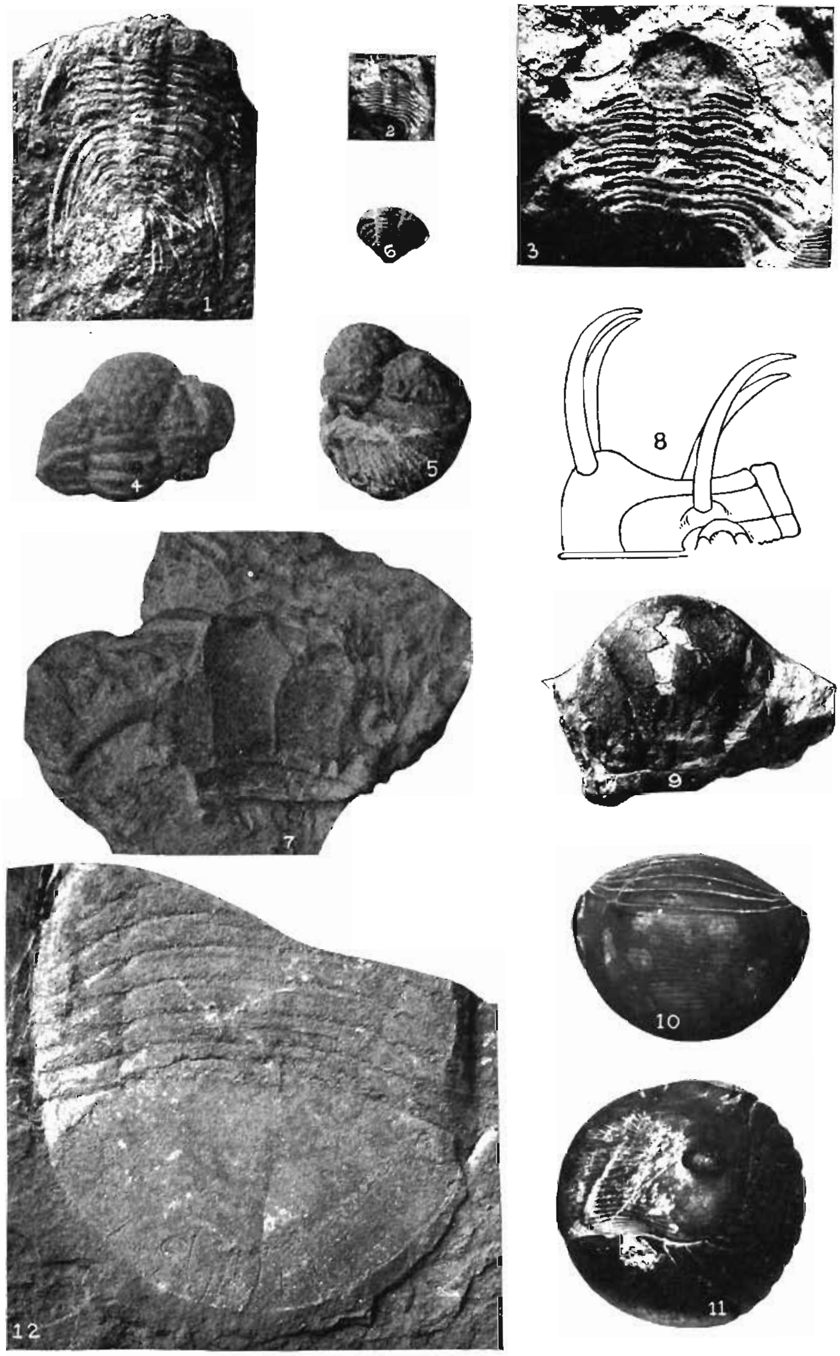
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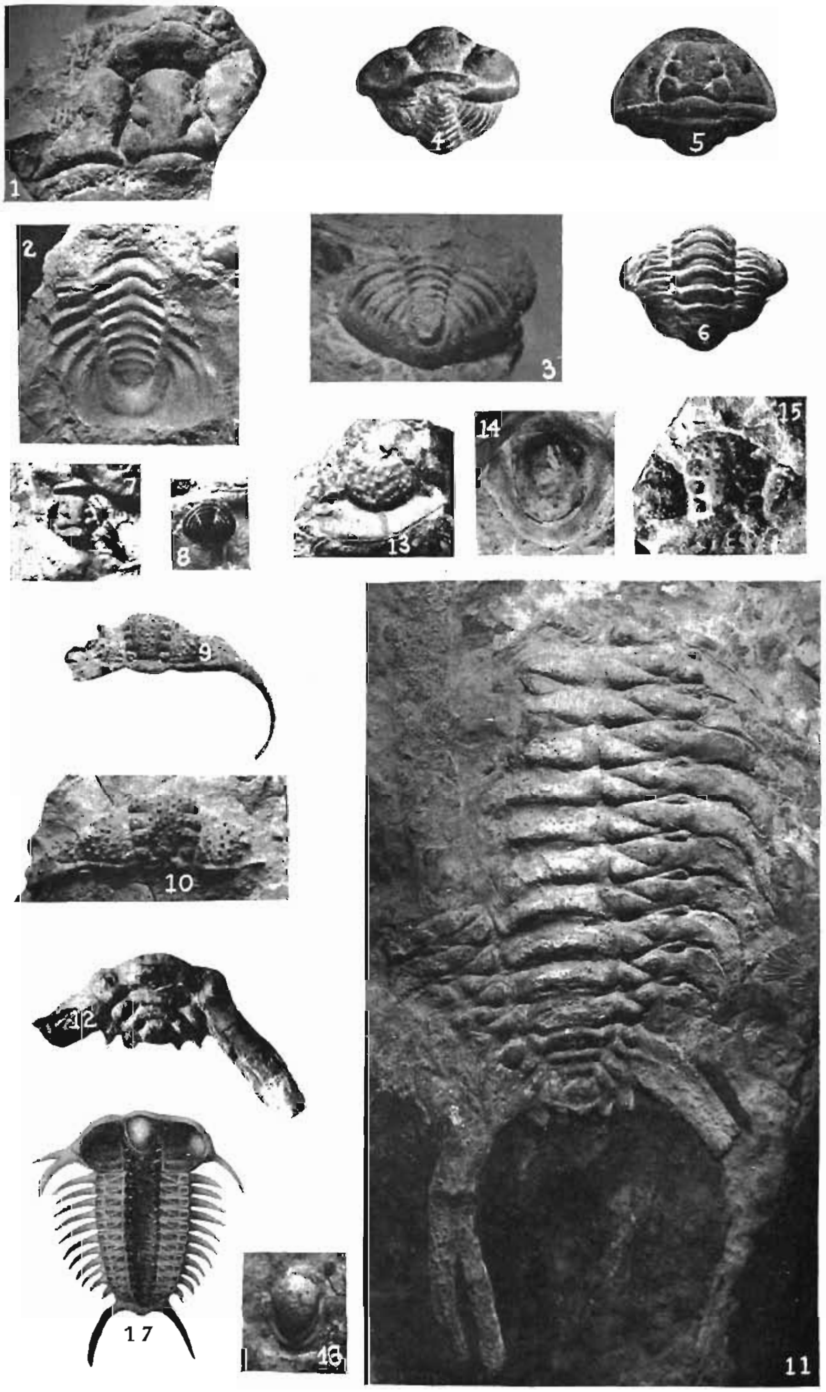
Fig. 12. A pygidium of this species collected from the Platteville limestone at Sny Magill. No. 9182.

Figs. 13, 14, 15, representing a free cheek, a hypostoma and a cranidium respectively, are associated with the py-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The illustrations on this plate are from negatives in the Field Museum of Natural History. They are photographs of the specimens described and figured by Slocom, 1916.

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Fig. 12. Ventral view of a complete pygidium. Field Museum No. P 11150.

Fig. 13. An imperfect cranidium showing the outline of the facial suture, x3/2. Field Museum No. P 11150.

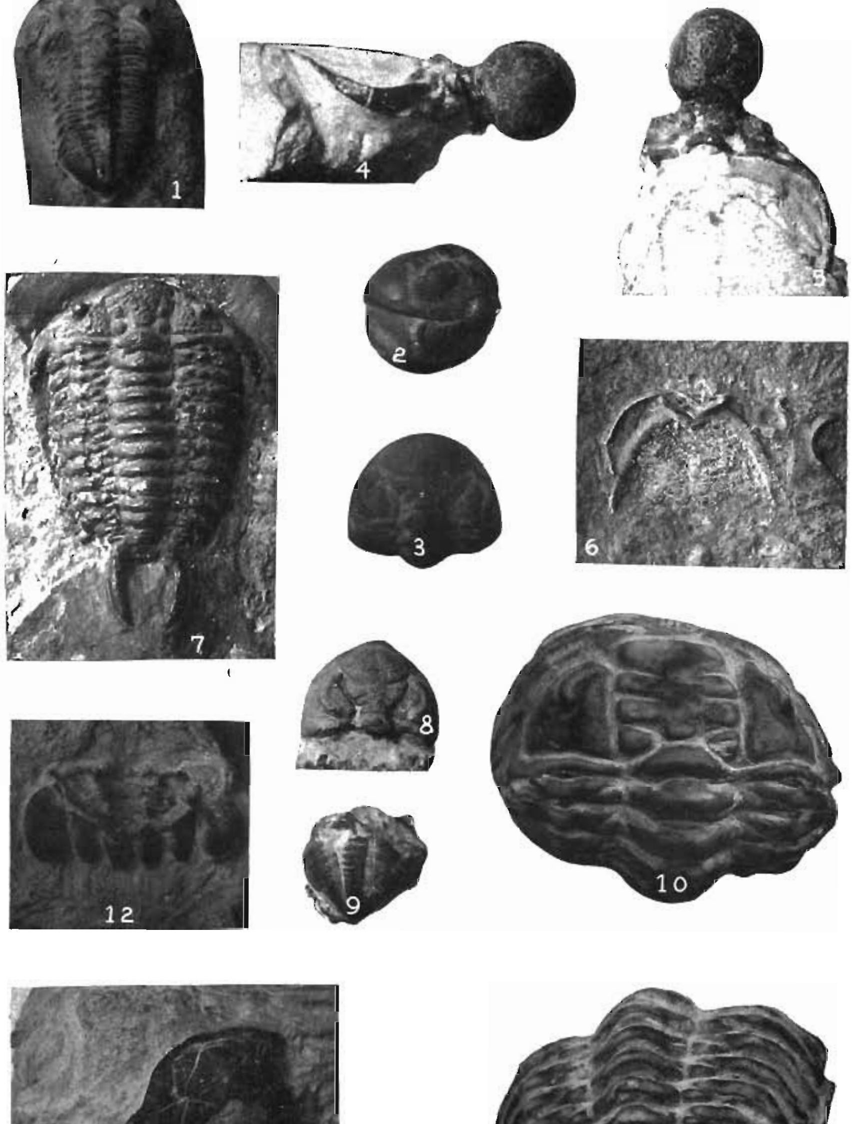
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PLATE XXI.

Illaenus imperator Hall.......................................262

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Fig. 7. A pygidium. No. 9052, from the nondolomitic beds of the Hopkinton stage, in the south half of section 20, Coffins Grove township, Delaware county. Collected by Professor Thomas.

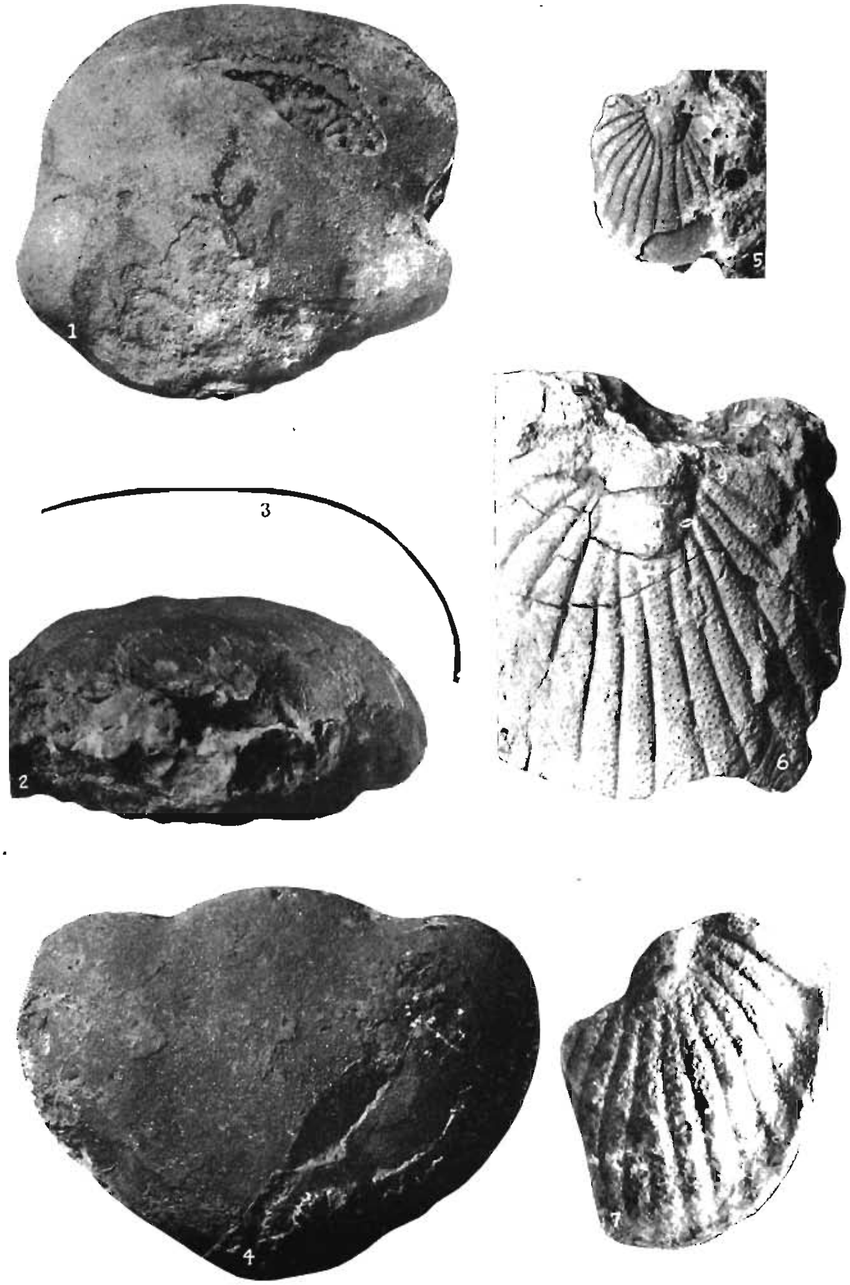
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PLATE XXIII.

Metopolichas iowensis Walter.....268

Fig. 1. Dorsal view of the holotype cephalon. The furrows have been marked in ink. No. 9043.

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6. A fragment of an even larger cephalon. No. 9046.

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8. A profile view of the same. The furrows are here outlined in ink.

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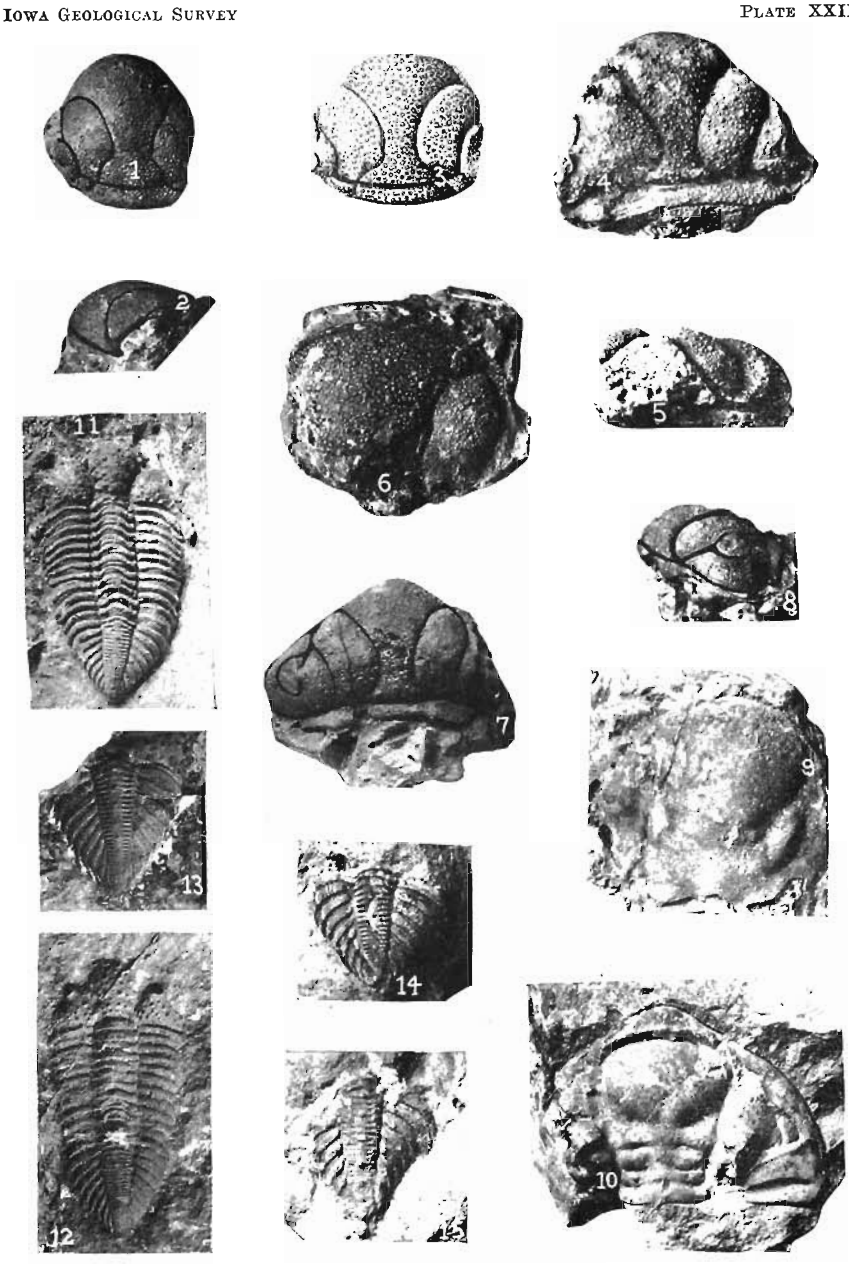
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PLATE XXIV.

Calymene niagarensis Hall 275

Fig. 1. Dorsal view of an average size specimen. No. 9085.

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Fig. 3. Lateral view of a giant form which also is characterized by the sway-back.

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Cheirurus niagarensis (Hall) 278

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Cybele species

Fig. 7. View of an incomplete pygidium. No. 9260.

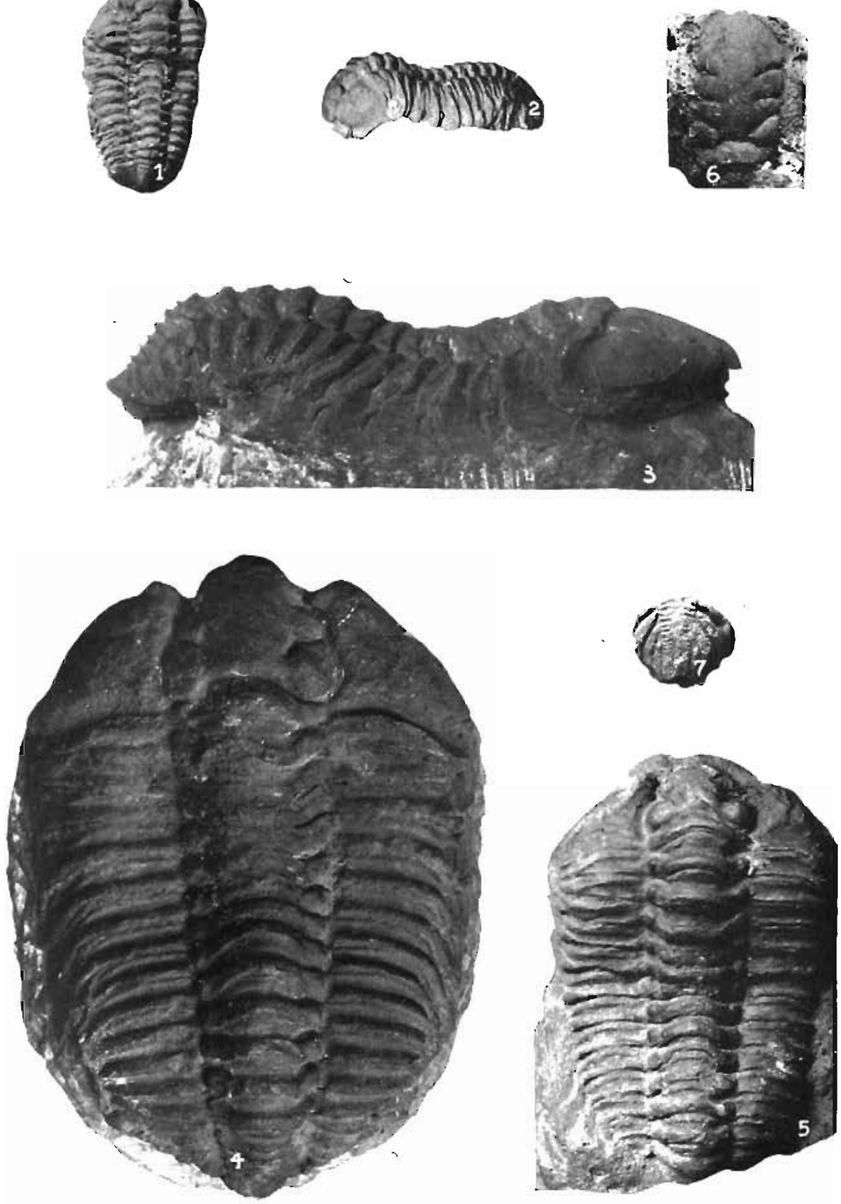
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PLATE XXV.

Ceraurus savagei Walter..247

Fig. 1. Cranidium imperfectly preserved. Note the absence of genal spines. No. 9183. The holotype.

Goldius thomasi Walter..280

Fig. 2. A view of the type cranidium showing the occipital spine and narrow frontal margin. No. 9085.

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Fig. 15. Profile view of the same specimen.

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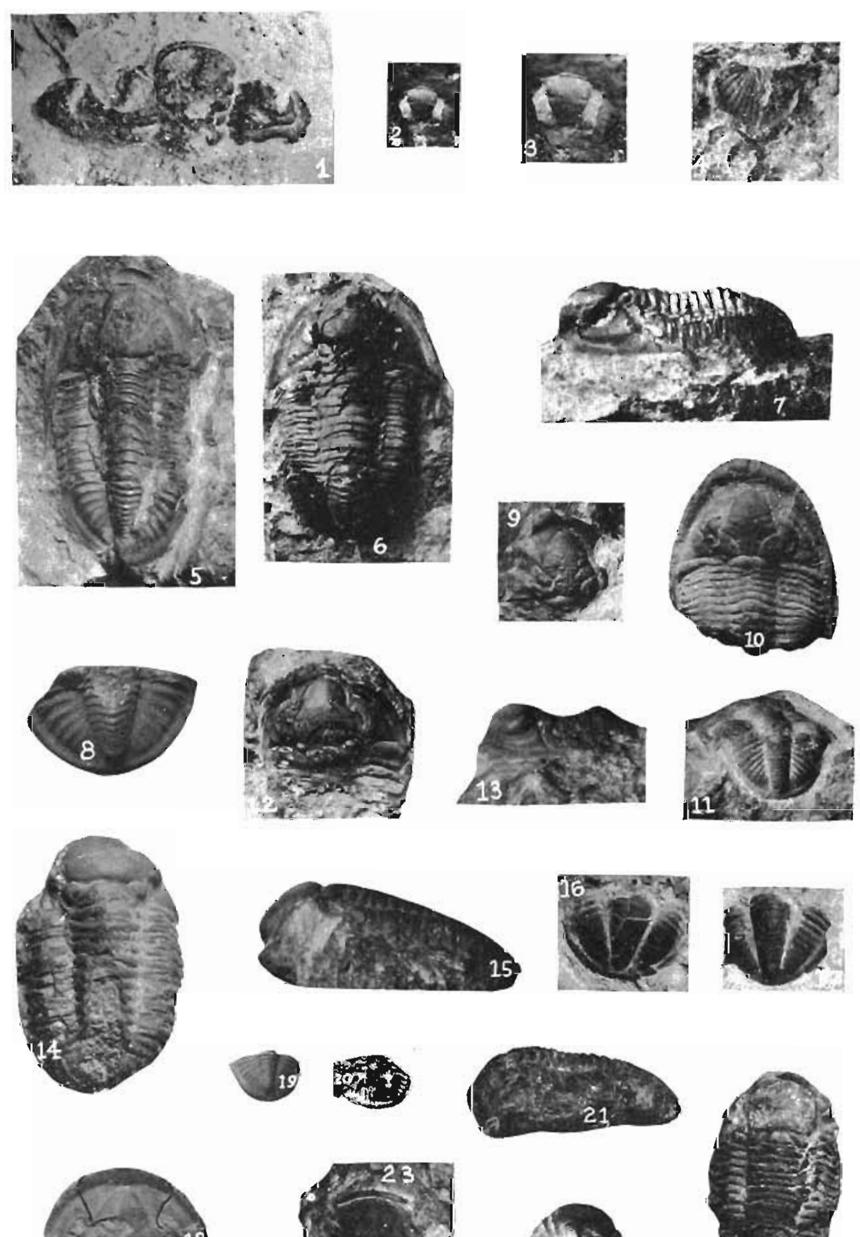
Fig. 17. View of another detached pygidium. No. 9125.



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Proetus haldemani Hall......................................295

Fig. 18. View of a separate cephalon. Facial sutures outlined in ink. No. 9093.

Fig. 19. View of a small detached pygidium. No. 9096.

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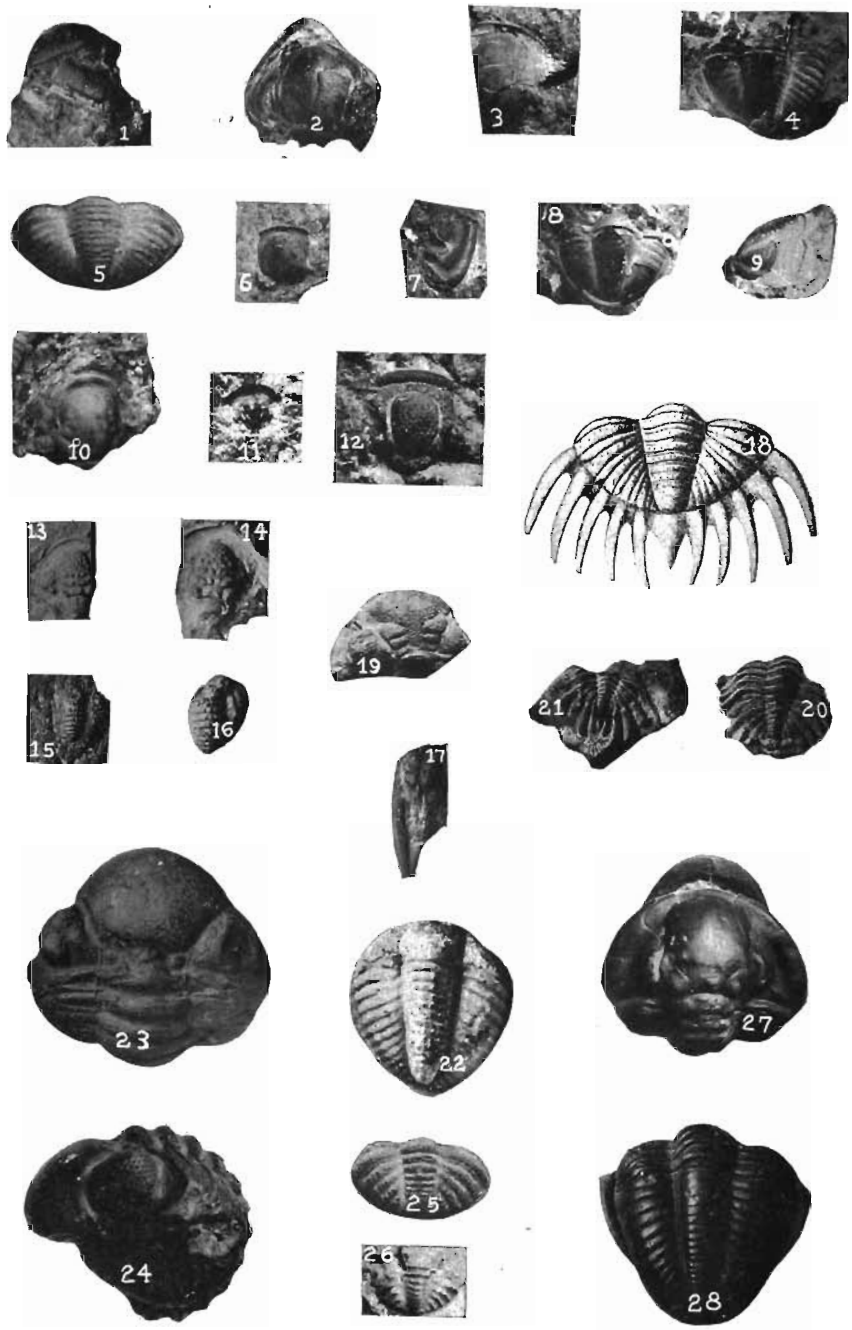
Proetus cf. *P. missouriensis* Shumard..................318

Fig. 10. The cranidium collected by C. A. White and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referred by Winchell to *Phillipsia meramecensis.* This specimen was kindly loaned to the University for study. It is now in the Paleontology Collection at the University of Michigan, Mus. No. 4908. The figure is enlarged times 9/5.

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Asteropyge barrisi (Hall)....306

Fig. 18. "A pygidium, enlarged to three diameters, and showing the round, terete marginal spines, and the conspicuous terminal spine." After Hall, 1888, Pl. XVIA, fig. 18.

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kindly presented to the University by Mr. A. N. Harbert of Shellsburg.

24. A profile view of the same specimen.

25. A pygidium of a young specimen showing the character of the surface markings. No. 9117. Enlarged times 2.

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Phillipsia major Shumard.................................335

Fig. 27. Cephalic aspect of a nearly perfect specimen showing the facial sutures and the pygidium projecting beyond the cephalon. The genal spines are wanting. No. 9040.

Fig. 28. Pygidial aspect of the same enrolled specimen. This specimen was kindly loaned to the University for study by Prof. T. J. Fitzpatrick.

PLATE XXVII.

Griffithides wilsoni Walter.................................324

Fig. 1. A nearly complete cranidium somewhat distorted and with genal spines missing. The type specimen, No. 9082. Times two diameters.

Fig. 2. Pygidium of the same.

Fig. 3. A nearly perfect pygidium, No. 9024, showing sharp definition of segments and distinct submarginal groove.

Fig. 4. Specimen No. 9039, originally described by Dr. A. O. Thomas as *Phillipsia* species.

Fig. 5. Pygidium showing abnormal segmentation of pleuræ. No. 9023.

Fig. 6. Enlargement of the same.

Fig. 7. A free cheek, and fig. 8, a pygidium, both associated in the Ste. Genevieve limestone, at Ste. Genevieve, Missouri. The pygidium shows the sharp definition of segments as well as the marginal groove. These specimens and a number of others, not figured here, were

PLATE XXVII Continued

kindly loaned to the University for study. They are now at the United States National Museum.

Griffithides wilsoni var. *genevievensis* Walter....327

Fig. 9. The type specimen, No. 9056, showing smooth ungrooved margin and faint definition of segments.

Fig. 10. Another pygidium, No. 9083, for comparison.

Griffithides scitulus Meek and Worthen..............331

Fig. 11. Incomplete cranidium, No. 9035, sufficiently preserved to show generic characters.

Fig. 12. Pygidium of same and a part of the thorax somewhat distorted.

Fig. 13. A free cheek. No. 9214.

Fig. 14. A nearly perfectly preserved pygidium. No. 9031.

Lepidocoleus iowensis Thomas..............................315

Fig. 15. Lateral view of type. No. 9265a.

Fig. 16. Dorsal view of a somewhat larger specimen. No. 9265b.

Griffithides portlocki Meek and Worthen............321

Fig. 17. A complete but somewhat distorted cephalon. No. 9042.

Fig. 18. A complete pygidium. No. 9032.

Fig. 19. Profile view of figure 18 showing nodelike enlargement of the terminal axial segment.

Palaeopalaemon iowensis Walter..........................327

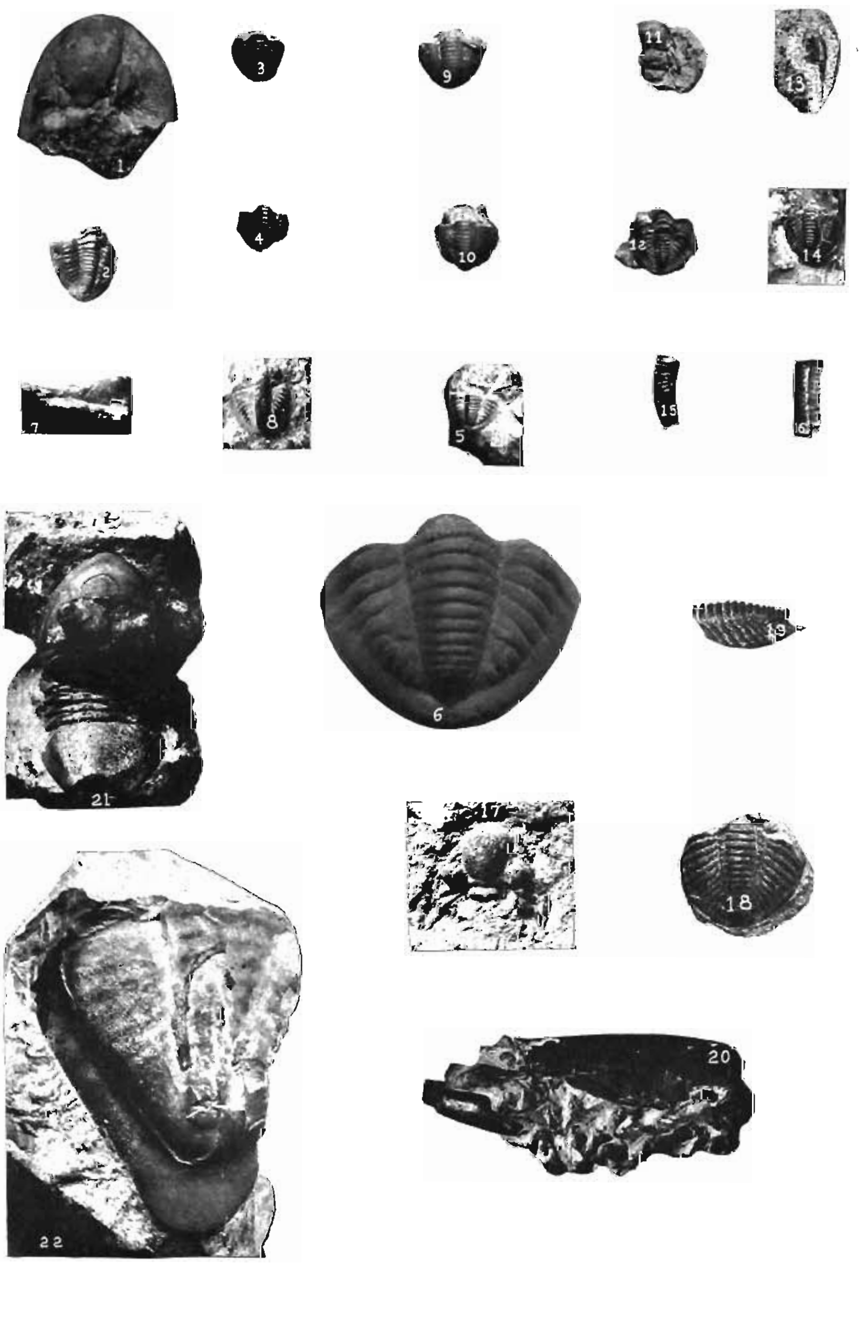
Fig. 20. Lateral aspect of the holotype. No. 9277.

Isotelus gigas DeKay..212

Fig. 21. Dorsal view of a small specimen to show the anterior configuration of the glabella. No. 9176. See also Plate XV, figures 1-3.

Ectenaspis beckeri (Slocom)..................................201

Fig. 22. A rather large pygidium showing well the posterior elongation of the concave marginal border. See also Plate XIII, figures 8 and 9.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