GEOLOGY OF CLARKE COUNTY

BY

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INTRODUCTION

LOCATION AND AREA

Clarke county is in the southcentral part of Iowa. It is just west of a north and south line through the central portion of the state and in the second tier of counties from the Iowa-Missouri state line. It has Madison and Warren counties upon the north, Lucas upon the east, Decatur upon the south, and Union upon the west. The twelve congressional townships are everywhere conterminous with the civil townships, each containing thirty-six sections, a total of 429 square miles instead of 432 square miles (since one series of sections is fractional), comprising Townships 71 to 73 North, Ranges XXIV to XXVII West of the Fifth Principal Meridian.

PREVIOUS GEOLOGICAL WORK

Previous geological work within the bounds of the county is very meager; but geological work outside of the county bearing upon formations within the county is extensive. In the field work of 1855-7, confined largely to the northeastern and eastern portions of the state, the unconformity between the Carboniferous and what is beneath it was noted[1]. Hall quotes Professor Swallow's Geological Report of Missouri[2] in which the fossiliferous limestones and calcareous shales found along Missouri river south from Clarke county are referred to the "Upper Coal Measures"[3], or Missouri stage, as it is now called. When White published his "Geology of Iowa" in 1870 he found it necessary again to combat a previous error that had gained further prominence since the Hall report was published, and to offer substantial proof that these same limestones did in reality belong to the Missouri stage[4] and not to the St. Louis stage. His

[1] James Hall, Geology of Iowa, Vol. I, Part I, p. 117 and p. 120, 1858.
[2] G. C. Swallow, Geological Reports of Missouri, I and II Reports, p. 81, footnote, 1855.
[3] James Hall, Geology of Iowa, Vol. I, part 1, p. 135, 1858.
[4] Charles A. White, Geology of Iowa, Vol. I, pp. 242-245, and note on p. 248, 1870.

own work was largely on the outcrops near Winterset, Madison county, but he recognized and applied his deductions to all of the corresponding limestone in Iowa to the south and west, which area includes Clarke county. White's description of Clarke[5] county occupies less than a page and a half, due to the very brief time permitted for the work. In several other parts of his report he makes incidental reference to the county. Opposite page 32 he includes all of Clarke county in the region of the "Upper Coal Measures". Neither on page 256 nor elsewhere does he mention the beds of limestone northwest of Osceola, possibly because they are a little to the east of the direction which he names. On page 265 Clarke county is mentioned with other counties underlain by the "coal measures", and on page 312 it is mentioned with reference to stone. The discussion on page 262 with reference to search for coal is as applicable now as when it was written. On page 93, Vol. II of the same report, reference is again made to the border outcrops of the Missouri stage. On page 408 certain railroad levels are named within the border of the county, and in the final map the county is again represented as entirely within the bounds of the "Upper Coal Measures".

In the present series of reports Keyes[6] mentions Clarke county as a county underlain by coal measure strata, in which prospecting for coal need not go below a depth of 400 feet; and Hinds[7] mentions it in a similar manner, with additional reference to recent borings at Leon. Beyer and Williams[8] in the Geology of Iowa Quarry Products give a page to the quarry sections near Osceola, three analyses of limestone, one of shale, and a directory of Clarke county limestone quarries. In eight of the reports on Mineral Production in Iowa[9] the county is listed as a producer of stone, and in one report (Vol. XI) as a producer of clay and brick, with the value of the output given in each report. Bain[10], in tracing the limestone of the Missouri stage, refers to the "fragmental limestone" at the base of it as unfossiliferous near Osceola, and Leonard[11] refers to several trips to Clarke county

[5]Charles A. White, Geology of Iowa, Vol. I. pp. 316-318. 1870.
[6]C. R. Keyes, Coal Deposits of Iowa: Iowa Geol. Surv., Vol. II, p. 451, 1894.
[7]Henry Hinds, The Coal Deposits of Iowa: Iowa Geol. Surv., Vol. XIX, p. 217, 1909.
[8]S. W. Beyer and Ira A. Williams, The Geology of Quarry Products: Iowa Geol. Surv., Vol. XVII. See pages 486-7, 532, 538 and 563.
[9]Iowa Geol. Surv., Vols. VIII, IX, XII, XV, XVI, XVII, XVIII and XIX.
[10]H. F. Bain, Limestone at Bethany, Mo.; Am. Jour. of Sci., Vol. V, June, 1898.
[11]A. G. Leonard, Iowa Geol. Surv., Vol. VII, p. 29, 1896.

to study the Missouri limestone. In the Geological Map of Iowa, 1905, the county is represented as almost entirely within the area of the Missouri limestone.

On areas outside of Clarke county much has been done since the "White Survey" (1870) that contributes to the comprehension of conditions found within the county. On the north, Madison[12] and Warren counties have been described in this series of reports, and on the south, Decatur. The Aftonian gravels and bogs in Union county on the west have attracted widespread attention. The stratigraphic work in Kansas especially, and in northern Missouri[13], assist in the correlation of the Des Moines and Missouri strata in Iowa; and the extensive work throughout the northern states in recent years has led to rapid advance in knowledge of glacial and interglacial deposits and relations, all of which discussions and reports present principles that find their application and illustration right here in Clarke county. Other reports than those named are too numerous and on areas too distant to be listed here.

PHYSIOGRAPHY

Topography

To one riding along the upland and looking out over distant farms the country presents the appearance of an extensive plain, beneath the level of which the different streams have cut their way. The highest ground of this upland is a divide entering the county in the southwestern part of Madison township, curving southward to Murray, then east to Ward township, then south to Knox township, then east to near the eastern part of Knox township, and then south beyond the county line. To the north of this zigzag line the drainage is to the northeast, toward South river and the Des Moines. To the east it is toward White Breast creek and Chariton river. To the south and west it is toward Grand river and the Missouri. From this part of the great divide of the state the upland slopes gently to the east and

[12]Madison county is described in Volume VII of the present series, Warren county in Volume V, and Decatur county in Volume VIII. The Aftonian gravels of Union county are described in the Proceedings of the Iowa Academy of Science, Vol. V, pp. 86-101, and the Buried Peat Bed in the same county is described in the Proceedings of the Iowa Academy, Vol. XI, pp. 103-109.

[13]See especially the report of Hinds and Greene. The Stratigraphy of the Pennsylvanian Series in Missouri, Missouri Bureau of Geology and Mines, Vol. 13, Second Series.

to the southwest, reaching out as lobes between the river valleys, with smaller lobes between the tributary creeks, and still smaller lobes between the ravines, all a part of the extensive and rich upland that slopes east from one divide to the next toward the Mississippi on the east; and more unbrokenly in a line west and southwest along parallel divides to Missouri river. Could we but view this wide domain in one broad glance we should see it as a part of the dissected Kansan plain extending out over all of southern Iowa to the moraines of the Illinoian drift on the east, to the faint margin of the Iowan drift plain northeast, to the Wisconsin drift plain north of Des Moines, and northwestward to the distant corner of the state. Southward we should see it stretch out into Missouri toward a part of the great upland plain to which Marbut has there given the name, Gentry Platform[14]. Marbut's terms, based as they are on structural features concealed in Clarke county by heavy deposits of drift, are not here serviceable. If the drift were removed the northeast half of the county would unquestionably form a part of the "Warrensburg Platform", the uplands of the southwestern half a dissected part of the "Gentry Platform", and a narrow margin from one-half to three miles wide between these two parts and extending westward along valleys would form a part of the "Lathrop Plain", maintained by the resistance of the Hertha (Fragmental) limestone.

Could we but look back in time we should behold this beautiful upland as a part of a low-lying ground moraine left as the great Kansan ice sheet gradually melted away and lakes and pools on the uneven surface sluggishly sought outlet from one depression to another. In the course of untold centuries we should see the surface deposits of this extensive[15] plain gradually converted into its present rich gumbotil[16] soil, then uplifted and subjected to rapid stream erosion. While changes occurred elsewhere as one sheet after another crept into the state and melted away, the effect here is largely recorded only in long-continued erosion,

[14]C. F. Marbut, Missouri Geological Survey, Vol. X, pp. 45-49, 71, 72, 1896.

[15]Geo. F. Kay, Some Features in the Kansan Drift in Southern Iowa: Bull. Geol. Soc. America, Vol. 27, pp. 115-117.

[16]Geo. F. Kay, Gumbotil, a New Term in Pleistocene Geology: Science, N. S., Vol. 44, pp. 637-638, 1916.

though in the earth movements the valleys formed here were later slightly silted up and then retrenched to their present condition.

As we view the landscape now we find that the ravines are near their heads first depressions sloping from the upland, then shallow valleys with rain water trenches, then deeper valleys without streams except in wet weather, then larger flat bottomed valleys; then, along the largest of the creeks, broad bottom lands made flat in part by alluvial deposit, from which the surface in many cases slopes gently upward toward distant high ground, or rises steeply to the crest of a neighboring lobe from the upland.

White Breast creek presents an excellent illustration of conditions near the head of a stream. Close to the west boundary of Ward township are the first low sags in the upland, here at 1,216 feet above sea level, that direct present drainage toward the creek. Three miles to the east the channel is about twelve feet deep and carries all of the drainage except in severest floods. Then the overflowing waters erode rather than deposit. In another three miles the trench is 120 feet below the upland. In those three miles the insides of the bends are found to contain deposits like enlarged sand bars, with partly buried trees reaching out of them; and narrow border plains appear here and there about two feet below the wider bottom land with lobes from the upland fading out toward the creek bottom. Even in this short distance what was an erosional flood plain has become a small flood plain containing alluvial deposits. Throughout the remainder of the course in the county the sweep of the bends becomes larger, the flood plain more noticeable, and pools of water that occupy only favored places in dry weather overflow in minute rills as rain comes on, at times the rain filling the trench with a rushing torrent. South of Woodburn the bottom of the trench is 158 feet below the upland. Thus in the first five miles the creek bed has been cut to its general depth below the upland and has begun to develop evidence of a flood plain. The upland (Kansan plain) slopes from about 1,160 feet above sea level west of Osceola to 1,053 feet south of Woodburn, as determined by a barometer and the railroad elevations at Osceola and Woodburn.

The extreme relief in the county, between the creek bottom east of Woodburn and the upland at the west county line, is 281 feet.

ELEVATIONS.

	Gannett's Dictionary of Altitudes	Barometric Levels From Railroad
Woodburn, railroad station	961 ft.	
Upland south of Woodburn		1100 ft.
Creek bed at Woodburn		943
Osceola	1132	
Murray	1216	
Bottom of large ravine beneath railroad bridge near west county line		65 ft. below track
Upland, west county line, near track		25 ft. above track
Base of Hertha limestone (Fragmental) northwest corner of Osceola township		1012 ft.
Weldon, close to south county line	1147	

Drainage

The courses of some of the creeks deserve attention. In Ward township Squaw creek flows southeast for a mile in section 10, then south for a mile, then nearly east for a mile and a half, then north for two miles and a half. This is the most pronounced peculiarity in the county, but there are several less conspicuous ones along Squaw, Otter and White Breast creeks. How much such peculiarities are due to irregularities in the original surface of the Kansan drift independent of Aftonian topography, how much to the imperfectly concealed hills and valleys over which the Kansan drift was laid down (Aftonian topography), how much to disclosure of concealed valleys and of hills of resistant rock as erosion progressed, modifying the drainage plan since the disappearance of the Kansan ice, and how much they were favored by crustal movements, it is impossible to say. That the present drainage plan is really post-Kansan is evident, since the ravines are trenched through the Kansan drift into the Nebraskan drift, leaving the Kansan drift exposed along the ravine sides. How much the Aftonian topography influenced the post-Kansan lines of erosion it is impossible to determine since it cannot generally be ascertained whether the drift beneath the larger valleys is Nebraskan drift, or Kansan drift filling pre-Kansan valleys; though with Nebraskan on the hillside we may reasonably infer that drift beneath the valley is also Nebraskan.

There is little evidence within the county as to the general direction of preglacial drainage. The great thickness of drift from northwest to southeast along the east of the Missouri limestone in the central part of the county, indicates the presence of a preglacial valley lying along the front of the limestone; and the presence of other valleys now filled with drift reaching back into the area of the Missouri limestone, as north of the quarries northwest of Osceola, indicates drainage from that direction toward the front of the limestone; but these preglacial valleys have not determined the post-Kansan drainage lines. Even in the Missouri limestone region northwest of Osceola the creeks are in places on beds of limestone and in others on drift filling the old valleys.

In the northeastern and eastern portions of the county the streams flow over thick drift with scarcely an outcrop of underlying strata. The valleys there are wide, and the beginnings of flood plains are evident. The streams that flow south from the divide flow through valleys that are narrower but not deeper, with drift everywhere evident, and in one region (west of Murray) with late Aftonian interglacial bogs marking concealed valleys.

Such relations all support the conclusion that the present drainage does not conform with either the pre-Kansan (Aftonian) drainage, nor with the preglacial, but is post-Kansan. Along minor lines the ravines are in the gumbotil, that was developed in the former surface portions of the Kansan drift, and bear evidence of erosion renewed under local and present conditions.[17]

A few other features claim attention. Here, as in other counties in this part of the state, valleys extending north and south have sides with but slightly different gradient; valleys extending east have south facing sides with gentle slope and north facing sides that are steeper. Doubtless this latter characteristic,

[17]John L. Tilton, Pleistocene Deposits of Warren County, Iowa, p. 39. 1911.

often noted elsewhere, was best explained by Calvin[18] who attributed it to more rapid disintegration due especially to more frequent freezing and thawing in a south facing slope than in a north facing slope. Such gentler slope back to the north than to the south is more noticeable along South river in the northern part of the county and along Otter, White Breast and Chariton creeks in the eastern portion of the county, but even here the feature is not so pronounced as it is farther down along the valleys of the same streams. While the effect of the earth's rotation and of possible uplift in Western Iowa can be tested in the region of which Clarke county is a part, it does not seem advisable to attempt a discussion here. Clarke county is not sufficiently extensive in area to contribute much information.

STRATIGRAPHY

GENERAL RELATIONS OF STRATA

The formations in Clarke county represent three series: the Pennsylvanian, Pleistocene and Recent series. The lowest portions of the Pennsylvanian series are the shales and sandstones of the Des Moines stage. These are not now to be found outcropping within the county though at times erosion may bring small portions of them to light. They are now concealed beneath heavy deposits of drift. It is the upper division (Pleasanton) of the Des Moines stage which immediately underlies the drift in the entire northeastern half of the county. The strata of the Des Moines stage where found in adjacent counties give evidence of deposition in shallow and brackish water, with swampy conditions at times where the remains of plants were left that formed coal, and where sluggish streams wound their way to outlets beyond. Such conditions alternated with those of more open water along shore, where mud was deposited that later became shale, and even alternated with still more open water suitable to the formation of calcareous deposits that later became limestone.

Next above the strata of the Des Moines stage in the southwestern half of the county, but wanting in the northeastern half of the county, are the limestones and shales of the Missouri stage.

[18]S. Calvin, Geology of Johnson County: Iowa Geol. Surv., Vol. VII, p. 51, 1896.

To these belong the limestone beds that are quarried in a few places. That these beds are marine in origin is evident from the numerous fragments of marine forms of life which they contain, the heavy beds ten and more feet in thickness giving evidence of prolonged conditions of open sea suitable for the growth of the lime-secreting plants and animals from whose remains the rocks are so largely made. With these beds of limestone are also beds of shale, from mud formed when widespread conditions in the same area either did not favor abundant growth of marine forms or favored thicker deposits of mud than of more calcareous deposits. The surface of the Missouri formation (and of the Des Moines formation where it is exposed elsewhere) is found to be disintegrated by processes of weathering which were in progress prior to the time when the surface was covered up by the later Pleistocene deposits.

The second series, the Pleistocene, is represented by two bowlder clays, the Nebraskan and the Kansan, and by such other deposits as were formed prior to the advent of recent time. The bowlder clays are masses of clay, sand, pebbles and bowlders of many kinds brought here under glacial conditions. The weathering of the surface of the lower, or Nebraskan drift, into a gumbotil occurred in early Aftonian times; hence Nebraskan gumbotil marks the Aftonian stage.[19] Here also belong peat and muck formed in Aftonian time. Deposits of sand and gravel belonging to this stage have not been seen in place.

The weathering of the surface of the Kansan drift into a gumbotil occurred in Yarmouth times, hence the Kansan gumbotil marks the Yarmouth stage.[20] Other deposits that may have been formed in Yarmouth time have been removed by later erosion, or are not to be distinguished from later deposits. Since the valleys in the Kansan drift began to form in Clarke county three other glacial stages later than the Kansan (the Illinoian, Iowan and Wisconsin) and two inter-glacial stages (Sangamon and Peorian) have intervened; their deposits are found in other parts of Iowa.

Loess is scarcely to be recognized as a deposit.

[19]W. C. Alden and M. M. Leighton, The Iowan Drift, a Review of the Evidences of the Iowan Stage of Glaciation: Iowa Geological Survey, Vol. 26, p. 57, 1915.

[20]Kay, Geo. F., Some evidence regarding the duration of the Yarmouth interglacial epoch: Science, Vol. 43, page 398, March, 1916.

The third series, the Recent, is represented by the alluvial deposits in process of formation in the valleys. At the present time the various deposits exposed at the surface are undergoing the processes of weathering. Much of the soil washed from the hillsides is carried away by the streams, but some of it is deposited on lower levels.

All of these formations will be described more in detail in the pages that follow.

The relation of these various formations is expressed in the following table:

SYNOPTICAL TABLE.

GROUP	SYSTEM	SERIES	STAGE	SUBSTAGE	CHARACTER OF ROCKS
Cenozoic	Quaternary	Recent			Alluvium and other surface soil
		Pleistocene	Yarmouth		Gumbotil (Kansan)
			Kansan		Drift (bowlder clay)
			Aftonian		Gumbotil (Nebraskan) Peat and muck
			Nebraskan		Drift (bowlder clay)
Paleozoic	Carboniferous	Pennsylvanian	Missouri	Westerville	Limestone
				Chanute	Shale
				De Kalb (Drum)	Limestone
				Cherryvale	Shale
				Winterset	Limestone
				Galesburg	Shale
				Bethany Falls (or Earlham)	Limestone
				Ladore	Shale
				Hertha (or Fragmental)	Limestone
			Des Moines	Pleasanton	Shale (not found exposed)
				Oswego (or Appanoose)	Limestone (not exposed)
				Cherokee	Shale (not exposed)

In the above table the universally accepted names of the groups, systems and series need no explanation. The stage terms Kansan and Aftonian are also universally accepted. For a long time the bowlder clay beneath the Aftonian interglacial deposits was called the pre-Kansan drift or the sub-Aftonian drift. In 1909 Shimek[21] proposed the name Nebraskan as especially appropriate for this drift, a name now generally recognized. In 1916 Kay proposed the term gumbotil.[22] The stage terms Missouri and Des Moines proposed by Keyes[23] have long been used in Iowa and have been recognized in other states. The Missouri is essentially White's "Upper Coal Measures", and the Des Moines essentially White's "Lower Coal Measures" and "Middle Coal Measures" combined; but the base of the Missouri is the bottom of the Hertha limestone (the "Fragmental", to be described later), and the base of White's "Upper Coal Measures"[24] is a one and one-half foot limestone seventy-seven feet below the bottom of the Hertha (the "Fragmental") as described in White's Winterset section. Bain,[25] in describing the "Upper" and "Lower Coal Measures" of the Western Interior Coal Field does not follow White's use of the terms in Iowa but makes the dividing plane between correspond to the plane marking a faunal break (at the base of the Hertha limestone), thus for Iowa, making "Lower Coal Measures" synonymous with Des Moines formation, and "Upper Coal Measures" synonymous with Missouri formation.

Westerville and De Kalb are adopted from the report on the Geology of Decatur County,[26] De Kalb replacing the descriptive name Fusulina limestone of the Winterset section. Both names are names of towns in Decatur county. Winterset, applying to certain heavy beds of limestone found in the uplands near Win-

[21]B. Shimek, Aftonian Sands and Gravels in Western Iowa: Bulletin of the Geological Society of America, Vol. 20, p. 408, 1909.

[22]Geo. F. Kay, Gumbotil, a New Term in Pleistocene Geology: Science, N. S., Vol. 44, pp. 637-638, 1916.

[23]C. R. Keyes, Iowa Geological Survey, Vol. I, p. 85, for 1892. See also American Geologist, Vol. XVIII, pp. 22-28, 1896, and Iowa Geological Survey, Vol. II, p. 68.

[24]Charles A. White, Geology of Iowa, Vol. 1, p. 246. 1870.

[25]H. F. Bain, The Western Interior Coal Field, Twenty-second Annual Report U. S. Geol. Survey, pt. 3, pp. 340-343, 1902, quoted by Bailey Willis in Professional Paper 71, Index to the Stratigraphy of North America, pp. 456-458, 1912.

[26]H. F. Bain, Geology of Decatur County: Iowa Geological Survey, Vol. VIII, pp. 268 and 276, 1897; also, The Limestone of Bethany, Missouri: Am. Jour. of Sci., Vol. V, p. 438, June, 1898. In Hinds and Greene's Stratigraphy of the Pennsylvanian in Missouri, published after the present report was completed, the Westerville is considered the equivalent of the Cement City, Broadhead's No. 90. See pages 27 and 115 of the report named.

terset, was proposed in the "Geology of Madison County".[27] Earlham was proposed in the same report for the beds of limestone quarried extensively at Earlham,[28] Madison County, a name that should now be replaced by Bethany Falls.[29] The name Bethany Falls limestone was originally given by Broadhead to his No. 78, over which the water of Big creek plunges at Bethany Falls, Missouri. For a time since then this name was applied to the whole series of formations exposed in the Winterset section.[30] Bain correlated Broadhead's No. 78 with the "Fragmental" (Hertha) at Winterset, a correlation that is now proven by F. C. Greene to be incorrect. Broadhead's No. 78 corresponds to the Earlham limestone. Hence the term Earlham should now give way to Bethany Falls, which name was proposed in 1862.[31] Fragmental, used by White[32] as an adjective in the description of his No. 4, Winterset section, and later used as a name in the reports on Madison, Guthrie and Decatur counties[33] is here replaced by the geographic name Hertha, proposed by Adams, Girty and White.[34] Ladore, Galesburg, Cherryvale and Chanute are names adopted from Kansas; also Cherokee, Oswego and Pleasanton.[35] Bain has used Appanoose[36] for an intermediate division between the Cherokee and the Pleasanton.

CARBONIFEROUS SYSTEM

Pennsylvanian Series

DES MOINES STAGE.

The Des Moines formation lies next beneath the drift northeast of a line drawn roughly from the northwest corner of Wash-

[27] Tilton and Bain, Geology of Madison County: Iowa Geol. Survey, Vol. VII, p. 512, 1896.

[28] Idem, pp. 511-512. See also Geology of Guthrie County, same volume, p. 449.

[29] John L. Tilton, The Proper Use of the Geological Name, Bethany, Proceedings of the Iowa Acad. of Science, 1913.

[30] See reports cited on Madison, Dallas and Decatur counties, Iowa Geol. Survey, Vols. VII and VIII; also the following: H. F. Bain, Am. Jour. of Sci., IV, Vol. II, pp. 221-225, 1896; The Bethany Limestone of Bethany, Missouri: Am. Jour. of Sci., Vol. V, p. 433, June, 1898; The Geology of Guthrie County: Iowa Geol. Survey, Vol. VII, p. 450, where the discussion is summarized up to that time, 1896. C. R. Keyes, Formational Synonomy of the Coal Measures of the Western Interior Basin: Proc. Iowa Acad. Sci., Vol. VII, p. 86, 1900. G. L. Smith, The Carboniferous Section of Southwestern Iowa: Iowa Geol. Survey, Vol. XIX, pp. 614-620.

[31] Broadhead, Trans. St. Louis Acad. Sci., Vol. II, p. 311, 1862. See also No. 78 in the Missouri Geol. Survey Report on Iron Ore and Coal Fields, pt. II, p. 77, etc., 1873.

[32] Charles A. White, Geology of Iowa, Vol. I, p. 246, 1870.

[33] Iowa Geol. Survey, Vol. VII, pp. 512-513 and 448; and Vol. VIII, p. 280.

[34] Bulletin 211, U. S. Geol. Survey, p. 35, 1903.

[35] Erasmus Haworth, Kan. Univ. Quar., Vol. III, p. 247, 1895; Univ. of Kan. Geol. Surv., Vol. I, pp. 150-151, 1896; Vol. III, pp. 21, 30 and 39; also correspondence with Mr. F. C. Greene. For early acceptance in Iowa see Iowa Geol. Survey, Vol. VIII, pp. 82 and 269. See also Bulletins 211, 238 and 296, U. S. Geol. Survey; and Professional Paper 71, table, p. 458, 1912.

[36] H. F. Bain, Geology of Appanoose County: Iowa Geol. Survey, Vol. V, p. 378, 1895

ington township southeast through Osceola to the southwest corner of Franklin township. There is but one place at present where the strata are visible, so completely is all concealed beneath the drift. That place is in section 4 of Franklin township (southeast quarter of the southeast quarter). Sixteen inches of a brownish clayey shale beneath the Hertha limestone appears to mark the top of the Des Moines strata. A few residents have mentioned localities where strata were once visible, or had been encountered in shallow wells, but in no case were strata found exposed. It is very probable that in the changing courses of the streams the shales of this formation may be slightly exposed in places at one time and concealed at another time. Nearly all of the wells within the area end within the drift, in which an abundance of water is obtained for ordinary needs except in extreme drought.

In sections 2 to 4 of Washington township the bottom of the Hertha limestone, and consequently the top of the Des Moines formation, is in the hillsides along the ravines. In section 24 of Washington township (southeast quarter of the southeast quarter) a well record gives no stratified rock at a depth of ninety-eight feet, in a location where limestone would have been encountered if the Missouri formation were present. At Osceola the well at the Howe hotel is said to reach a depth of one hundred and ninety feet without penetrating limestone; but at the new city well a block to the west twelve feet of limestone (Hertha) were encountered at a depth close to two hundred feet. In section 28 in Franklin township (northwest quarter of the northwest quarter) Mr. W. M. Wood reports the presence of eight inches of coal at a depth of fifty feet, which would be fourteen feet below the bed of Chariton creek near by. Half a mile east of Woodbine and near the railroad a shaft is said to have been sunk two hundred feet deep for coal twenty-five years ago. Of this shaft no record whatever is obtainable. The abundance of iron in the water of the city well at Woodbine strongly suggests the immediate proximity of iron in coal; but here also no record is available. Close beside a bridge in the northwest corner of section 6, Osceola township, the Hertha limestone is visible, beneath which and within a few feet is the top of the Des Moines formation. In section 4 of Franklin township a few square feet of limestone are visible which are thought to be Hertha limestone. If this judgment is correct the top of the Des Moines formation is a few feet below the bed of White Breast creek at this place. North of section 3, Washington township, at a point on the south bank of South river in Madison county, the top of the Des Moines formation is visible twenty-four feet above the bed of South river. Here it consists of two brownish, weathered sandstone layers each about a foot thick with a foot of clayey shale between.

MISSOURI STAGE

HERTHA LIMESTONE

A small exposure of Hertha limestone may be seen in the bed of South Squaw creek in section 6, Osceola township (northwest quarter of the northwest quarter), two hundred feet west of the iron bridge. Here one foot and eight inches of limestone is visible, as is shown in figure 18. It has

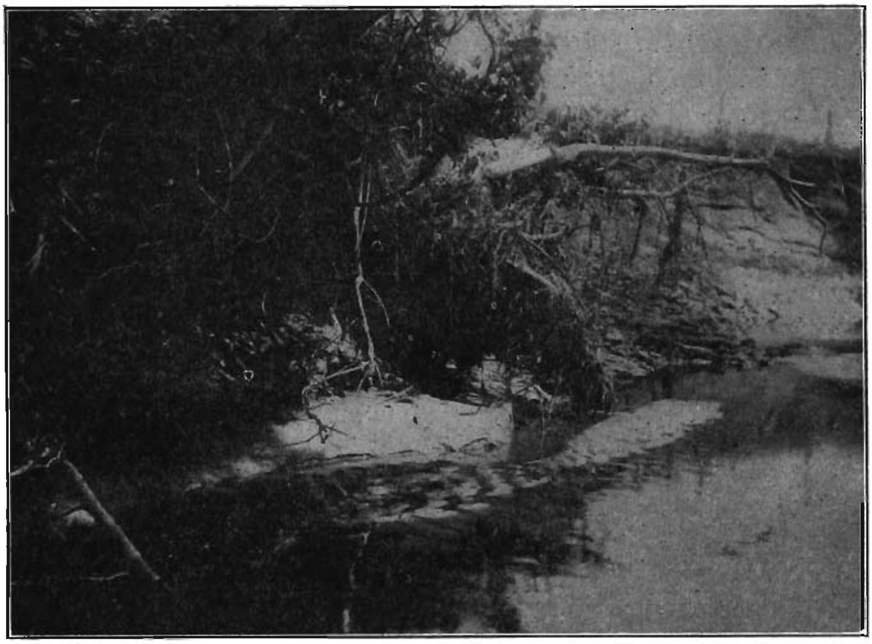

FIG. 18.—Hertha limestone: A small exposure may be seen in the bed of South Squaw creek in the northwest quarter of the northwest quarter of section 6 of Osceola township, Clarke county, about two hundred feet west from the iron bridge. At this point one foot and eight inches of the limestone is visible. It has the usual fragmental character and contains numerous *Composita (Seminula) subtilita*, the common fossil of this stratum.

the usual fragmental character and contains numerous *Composita* (*Seminula*) *subtilita,* the common fossil of this stratum. It is the only outcrop of the Hertha found in this portion of the county. It lies at 1,012 feet above sea level, about 57 feet below the bottom of the quarries of Bethany Falls (Earlham) limestone a mile west, and 120 feet below the level of the upland. To the south and west a gentle slope rises to the low escarpment of the Bethany Falls limestone a mile west, as if determined by the presence of resistant limestone at this level; but, though pieces of limestone are seen immediately above the limestone at the outcrop, no other evidence of it is found, not even in the valley sides down the creek. The sharp termination of this resistant stratum within so short a distance from the Bethany Falls limestone, with all strata to the east concealed beneath deep drift, is strong evidence of the great preglacial and pre-Kansan erosion to which these beds have been subjected.

In section 4 of Franklin township (northwest quarter of the southeast quarter) two thin layers of gray limestone with five inches of clayey shale between appear in the side of the creek bottom. The upper limestone is three inches thick, the lower limestone four inches thick. Half a mile down stream fragments of this limestone have been removed for use. Beneath the limestone at this point sixteen inches of a brownish clayey shale appears. Across the flat to the north the same layers of limestone are said to form the bottom of a well on low ground (northwest quarter of the southeast quarter of section 4). In the northeast quarter of the southeast quarter of section 4, near the bridge, limestone has also been quarried and used in the foundation of a house. Some of the pieces are eight inches thick, with scarcely a trace of fossils, though one, apparently *Chonetes,* was found. These outcrops occur four miles east of a small ledge that is thought to be of Bethany Falls limestone (Earlham) and seem to be the thinned out eastern margin of the Hertha. The purity and thickness of the limestone and the character of the fossil found forbid reference of the layer to the Des Moines formation.

In the center of section 34 of Ohio township, Madison county, immediately north of the center of section 3, Washington township, Clarke county, South river in cutting into the bluff has undermined six large masses of Hertha limestone, allowing them to settle twenty-four feet into the bed of the river. One of the fragments favorably situated for measurement gave a thickness of four feet and ten inches. On its surface were numerous fragments of *Composita* (*Seminula*) *subtilita* and of crinoid stems, a gasteropod with low spire (*Naticopsis?*) and *Hustedia mormoni*. This limestone is at the level of the river bed in section 5 of Washington township. East of the outcrop named no evidence of the limestone has been found in Madison county nor in adjacent portions of Clarke county. In Warren county there are outcrops northwest of New Virginia in outliers cut off by South river from the more extended strata between Truro and St. Charles.

The eastern margin of the Hertha limestone.—While the eastern margin of the Hertha limestone, concealed as it generally is beneath heavy deposits of drift, cannot be traced with certainty at all points across the county, the above described outcrops fix certain places where the margin is known, two well records in the uplands determine the absence of the limestone at those points, and the erosion of river valleys and ravines below the level of the limestone with no trace whatever of the limestone in the hillsides, gives fairly trustworthy evidence that the limestone is there absent. The eastern border is judged to enter the county near the western line of section 1, Washington township and extend southward for about three miles where it is concealed beneath the drift. It lies west of the southeast quarter of the southwest quarter of section 24, where the well of Mr. Switzer, situated fifty feet above the level of Squaw creek, extends to a depth of ninety-eight feet without reaching solid rock. From this re-entrant angle the line probably runs parallel to the Bethany Falls limestone there exposed, to the northwest corner of section 6, Osceola township, where its location is fixed by the outcrop in the bed of Squaw creek. The line then curves southeast, passes east of the outcrops of Bethany Falls limestone (Earlham) in the hillside near the northwest corner of section 8, and then curves south passing east of Osceola. Somewhere in the divide south of Osceola it apparently extends past Concord and around the few small outcrops in section 4 of Franklin township, from which place it turns southwest through the upland. The margin is certainly west of section 28, where Mr. Wood reports coal fourteen feet below the bed of Chariton creek. It apparently turns southward in the upland and crosses the county line near the southwest corner of Franklin township. Only drift has thus far been found south of Chariton creek in Franklin township.

LADORE SHALE

The Ladore shale has been seen in but one part of the county. In section 1 of Ward township (northwest quarter of the northwest quarter) a recent trench cut by rain water reveals a foot and a half of gray shale beneath the limestone there quarried. As the distance vertically from the base of this limestone to the top of the Hertha where it is exposed a mile east is about forty-eight feet it may be assumed that this is somewhere about the thickness of the shale. Four feet of the shale is exposed also in a trench three-quarters of a mile to the southeast (section 1 of Ward township, the southeast quarter of the southeast quarter). The ease with which the shale was eroded compared with the difficulty with which the heavy beds of limestone below and above it were eroded led to the formation of a Bethany Falls escarpment in preglacial and pre-Kansan times. Now the glacial deposits largely conceal the escarpment and fully conceal the shale beneath the overlying limstone.

BETHANY FALLS LIMESTONE (EARLHAM)

The Bethany Falls limestone is well exposed at old quarries two to three miles northwest of Osceola. A series of exposures may be seen extending from a ravine side in section 36 of Washington township (southwest quarter of the southwest quarter) eastward around a lobe of the upland and then westward and southward along both sides of a ravine through section 1 and along the east section line of section 2 and the section line between sections 11 and 12. Traces of the limestone may also be seen for a few rods along the west center of section 6, Osceola township. Eastward the limestone ends in the upland of section 6. Along the ravine through section 1, Ward township, may be seen a short stretch of scenery unique for the county, equalled in this part of the state only by the gorges southwest of Winterset. For a mile the ravine is a canon cut through the limestone, with gorges that extend out through the cliffs to the south. Here the various ledges of limestone may be traced southward till they disappear beneath the bed of the creek. Several old quarry faces give excellent exposures of the limestone. This particular ravine is best found by going down a ravine north from school house No. 6, two miles west of Osceola.

In section 1 of Ward township (northwest quarter of the northwest quarter), the following measurements were taken:

	FEET	INCHES
9. Limestone, gray, weathered into irregular layers; *Composita (Seminula) subtilita*	1	6
8. Limestone, gray, shaly		2
7. Limestone, gray; numerous crinoid stems		6
6. Limestone, gray; crinoid stems	1	
5. Shale, gray		2
4. Limestone, somewhat buff, irregular layers; *Meekella and Chonetes*	1	6
3. Limestone, gray		9
2. Limestone, gray		2
1. Limestone, gray (15 feet above bed of Squaw creek)		8
	6	5

In the above section numbers 1 to 3 constitute essentially one bed of limestone with a parting between 2 and 3. Numbers 4 and 5 are essentially one layer, and also 8 and 9. Numbers 3 and 6 are dense. In loose fragments close by *Spirifer camerata* and *Phillipsia* were found. While numerous fragments of fossils are to be seen in the weathered portions of the limestone, perfect, or even identifiable fragments are rare.

Around on the south side of this projecting ridge of the upland (section 2, southeast quarter of the northeast quarter) a more extensive section is obtainable as follows:

	FEET	INCHES
15. Soil, with fragments of limestone	3	
14. Limestone, gray		10
13. Limestone, yellowish. (13 corresponds to 4 in the above described section and contains like fossil fragments)		11
12. Shale, gray		2
11. Shale and limestone		8
10. Shale, gray		1
9. Limestone, gray		10

8. Shale and irregular limestone; *Productus longispinus*	1	6
7. Limestone, gray	1	1
6. Shale, gray		5
5. Limestone, gray, dense		6
4. Shale, buff		8
3. Limestone, gray, dense		8
2. Limestone, gray, dense	1	2
1. Limestone, gray, dense, exposed		6
	13	0

These beds correspond to number 10 of the Winterset section, as described in the Madison county report;[37] numbers 13 and 14 correspond to numbers 5 and 6 of the Robertson quarry[38] section near Earlham, and apparently, also, to numbers 5 and 6 of the section in Decatur county.[39] This exposure is shown in figure 19.

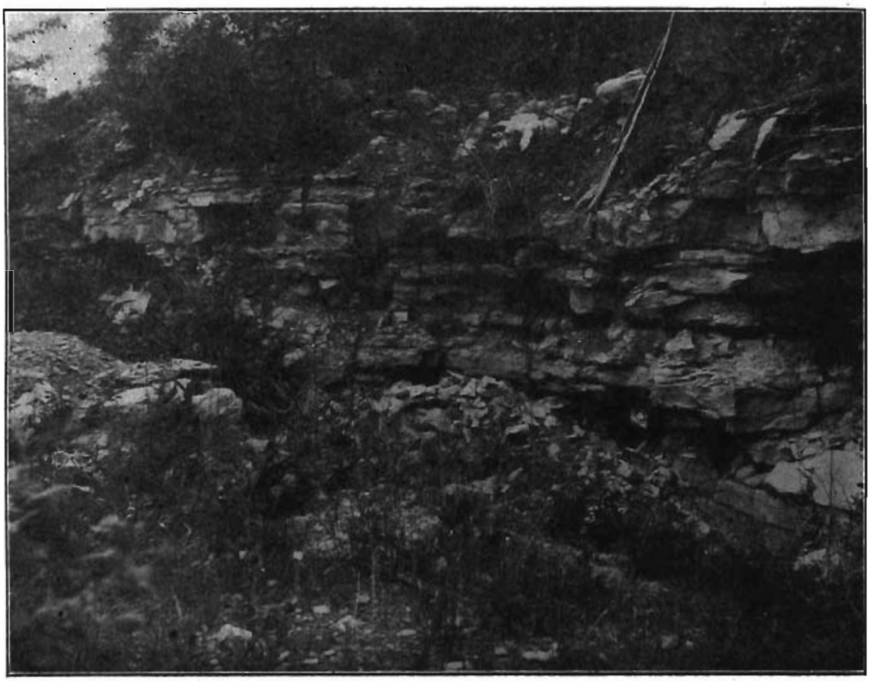

FIG. 19.—Bethany Falls limestone (Earlham): The exposure here illustrated is found on the south side of a projecting ridge of the upland in the southeast quarter of the northeast quarter of section 2 of Ward township, Clarke county.

[37]Tilton and Bain, Geology of Madison County: Iowa Geol. Survey, Vol. VII, p. 517, 1896.
[38]Idem, p. 515.
[39]H. F. Bain, Geology of Decatur County: Iowa Geol. Surv., Vol. VIII, pp. 279-280, 1898.

Just back of school house No. 1 (section 2 of Ward township, northeast quarter of the southeast quarter) the quarry face reveals:

		FEET	INCHES
4.	Limestone, weathered	2	
3.	Limestone, gray, with slight partings	1	
2.	Shale, gray		8
1.	Limestone, of various thicknesses with shaly partings, about 15 feet above bed of Squaw creek near by	6	6
		10	2

The creek bed crosses the lowest layers of the limestone in the southwest quarter of the northwest quarter of section 12, three-quarters of a mile south of the school house named, and in another mile up the creek has crossed all of the beds of limestone exposed in the valley.

To the east there is evidence of limestone in the hillside in section 1 of Ward township (southeast quarter of the southeast quarter), and also on the opposite side of the valley to the east, but there is no exposure at which a measurement can be taken.

Limestone referred to this same horizon is also quarried in section 14 of Green Bay township (northeast quarter of the southwest quarter). The section found is as follows:

		FEET	INCHES
6.	Limestone, yellowish (weathered) somewhat fragmental; *Composita (Seminula) subtilita* only	1	3
5.	Shale, yellowish		2
4.	Limestone, gray, many fossil fragments	1	
3.	Limestone, gray, many fossil fragments		6
2.	Limestone, gray, many fossil fragments		6
1.	Limestone, gray, somewhat fragmental, exposed (about 5 feet above creek bed)		3
		3	8

The exact relation of this limestone is somewhat problematical, though the argument seems conclusive that it is close to the base of the Bethany Falls limestone (Earlham). In the sequence of strata the outcrop fits fairly well the base of the limestone given in the second description of strata found in Ward township (section 2, southeast quarter of the northeast quarter); but numbers 1 and 6 are more fragmental than the strata in Ward township. The fossils found are Fusulina, Bryozoa, Crinoid stems, spine of *Archaeocidaris, Composita* (*Seminula*) *subtilita* (some very large) and *Spirifer cameratus,* an assemblage that might be found in either the Bethany Falls limestone or in the Hertha, but that strongly resembles that found in the Bethany Falls limestone near Davis City in Decatur county.[40] On the other hand there are fragments of limestone in the western part of section 1 which suggest ledges above this one that are concealed in the hillside above the level which the probable thickness of the Hertha could reach; and five miles east-northeast are thin outcrops of a limestone which from its light gray color, purity, and a fossil found there, is judged to be Missouri limestone rather than Des Moines. Further, in the Winterset section there is no limestone beneath the Hertha for a distance of seventy-seven feet, at which there is a "bluish, shaly, impure limestone" very different in character from the one found in section 4 of Franklin township. Consequently it seems best to refer this lower limestone in Franklin township to the Hertha, and the upper one, in section 14 of Green Bay township, to the Bethany Falls limestone (Earlham). At Bethany Falls, Missouri, this limestone is far more distinctly fragmental than it is at this place, and its fauna is closely related to the fauna here found.

The bed of South river in Washington township passes over the level of the Bethany Falls limestone in section 5. The best outcrops of the limestone beds in that vicinity are to be found on Clanton creek three miles east of Barney.

The eastern margin of the Bethany Falls limestone.—In attempting to trace the eastern margin of the Bethany Falls limestone the same difficulties are encountered as in the endeavor to trace the eastern margin of the Hertha. From the northeast quarter of section 6, Washington township, the margin extends southwest to the central eastern portion of section 12, Madison township, where it is crossed by South river. From here it turns eastward, and somewhere in the divide in the central portion of Washington township it turns southwestward, possibly to the northwest portion of section 18, for it must lie west of the margin of the Hertha, which in turn is not present in the south-

[40] H. F. Bain, Geology of Decatur County: Iowa Geol. Surv., Vol. VIII, p. 280, 1898.

west quarter of section 24, as determined by a well record. It then turns southeastward and then eastward to where it is crossed by a ravine in the hillside of section 36 (southwest quarter of the southwest quarter). The margin here turns southward into Ward township and appears on both sides of Squaw creek as far as the center of the section line between sections 11 and 12. It rounds the hill to the east, for it appears on both sides of the large ravine through section 6. It is possible that the limestone east of the ravine in section 6 is an outlier. If it is connected at all with the limestone to the west it is through the high ground at and near the southwest quarter of section 7, Osceola township. It was not found either in the well at Ward Hotel nor in the new city well at Osceola. East and southeast of Osceola there is no evidence whatever of limestone beneath the thick drift nearer than the western part of section 1, Green Bay township, where angular fragments on the side of a ravine suggest the immediate proximity of a ledge. The limestone is visible in section 14 (northeast quarter of the southwest quarter) at an outcrop already described. To meet these conditions the line is drawn southwest from north of Osceola and then nearly east to the southwest quarter of section 1, Green Bay township, parallel to and near the line for the Hertha limestone, then west and south past the outcrop in section 14, and through the upland to some point near but probably east of Weldon. From what can be seen of this limestone where it is exposed it has suffered greatly from erosion and may be completely wanting in places near the line as traced through the upland southeast of Osceola. There is no evidence at hand to indicate whether the outcrop in section 14 of Green Bay township is an outlier or not. South of Weldon the first evidence now obtainable is from the prospect drilling near Leon,[41] where neither the Bethany Falls nor the Hertha limestones are present.

THE GALESBURG SHALE

The shale between the Bethany Falls and the Winterset limestone is not very thick and was not found where a section of it could be seen in one place.

[41] Iowa Geol. Surv., Vol. XIX, pp. 247-251.

THE WINTERSET LIMESTONE

The Winterset limestone[42] has not been found exposed in the county except in section 11 of Ward township (northeast quarter of the northeast quarter):

	FEET	INCHES
5. Limestone, brownish, weathered; with two inclusions of chert	1	6
4. Chert		3
3. Limestone, yellow, decomposing, "magnesian"	2	8
2. Shale, gray	1	4
1. Limestone, not well exposed		1+
	5	10

Number 2 of this section may possibly represent the Galesburg shale. Number 3 is thought to be the "earthy magnesian limestone" described as number 20 in the Winterset section.[43] The fossils found near by are such as are found in the shaly partings in the Winterset limestone at Winterset: *Productus prattenianus* (large), *Meekella striatocostata, Spirifer camerata, Chonetes vernuilianus* (abundant in one layer), *Composita (Seminula) subtilita* (large) and a Pelecypod.

CHERRYVALE SHALE, DE KALB LIMESTONE (DRUM) AND CHANUTE SHALE

A Cherryvale shale such as is found near Winterset and near Bethany Falls, Missouri, has not been recognized in Clarke county. Just below the uppermost beds of limestone exposed in the southeast quarter of the southeast quarter of section 11, Ward township, there is a nonfossiliferous shale resting on an uneven and weathered portion of Winterset limestone, with no apparent difference in dip between the two sets of strata at this point, though the writer has found a difference in dip in Decatur county. The shale above the limestone seems to be Chanute shale, and the last limestone a quarter of a mile further south up the ravine is thought to be Westerville limestone. There is thus just above the Winterset limestone not only an erosional unconformity with the Cherryvale shale and the DeKalb limestone removed, but also a slight angular unconformity*. These

[42]A limestone bowlder 6x6x4 feet that is judged to be Winterset limestone is to be seen in section 33 of Knox township (southeast quarter of the southeast quarter). Its angular shape is evidence that it has not been transported far.

[43]Tilton and Bain, Geology of Madison County: Iowa Geol. Surv., Vol. VII, pp. 516-517.

*Further discussion of this important feature is reserved for a paper on the Subdivisions of the Missouri Stage in Southwestern Iowa, now in preparation by the writer.

strata have not been found exposed elsewhere within the limits of the county, but the presence of the Westerville limestone in the bed of Grand river just west of the county line, with evidence that this limestone underlies a portion of the low ground in the southwestern portion of the county, is evidence that somewhere these strata might be found but for the drift. This portion of the sequence of strata as found near De Kalb is described in the Decatur county report,[44] and as found at Winterset is described in the Madison county report.[45]

WESTERVILLE LIMESTONE

Reference has already been made to the presence of an exposure of limestone in Ward township that is thought to be

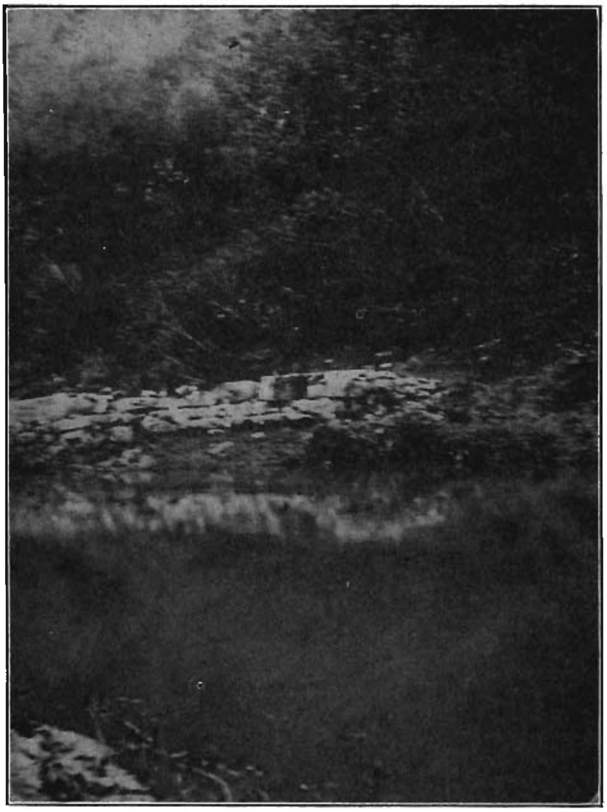

FIG. 20.—The Westerville limestone as seen at the ford at Grand river immediately west of section 31, Doyle township, Clarke county. The river flows to the left, toward the southeast.

[44] H. F. Bain, Geology of Decatur County; Iowa Geol. Surv., Vol. VIII, p. 278.
[45] Tilton and Bain, Geology of Madison County: Iowa Geol. Survey, Vol. VII, p. 516.

Westerville limestone. The low upland seen in the western part of section 31 of Doyle township (southwest quarter of the northwest quarter) is said to have beneath it a bed of limestone at a depth of about thirty feet, which is approximately the depth of the limestone exposed at the ford at Grand river directly west, half a mile beyond the county line. See figure 20. Here the section found is as follows:

	FEET	INCHES
5. Limestone fragments suggesting a stratum above number 4		
4. Limestone, blue, with Crinoid stems and *Composita (Seminula) subtilita*		6
3. Limestone, blue	1	
2. Limestone, irregular, fragmental	1	9
1. Shale, blue (exposed above low water in river)	1	
	4	3

Numbers 3 and 4 are essentially one bed of limestone, and correspond to Bain's number 2 of the Westerville limestone.[46]

At the bridge over Grand river directly west of Hopeville, the following section is to be found, figure 21:

	FEET	INCHES
6. Only slightly exposed, but apparently limestone, gray, shaly, down to the foot of the piling of bridge	2	
5. Limestone, gray, separated by thin parting into two equal layers; many fragments of crinoid stems	2	
4. Shale, gray		6
3. Limestone, irregular		4
2. Shale, blue	2	2
1. Not exposed, to low water in river	2	
	9	0

Half a mile east is a closely related section where eight feet of thin bedded limestone were formerly quarried. Number 5 of this description seems to correspond to number 5 of Bain's description.[47]

The exact relation of these beds was determined by Bain who found the entire Missouri section from the Hertha to the Westerville (inclusive) exposed along Grand river from the south to the north of the county and compared it in his report on Decatur county, with the section exposed at Winterset, to which reference has already been made.

[46]H. F. Bain, Geology of Decatur County: Iowa Geol. Surv., Vol. VIII, p. 277, upper description.

[47]Idem, p. 277, upper description.

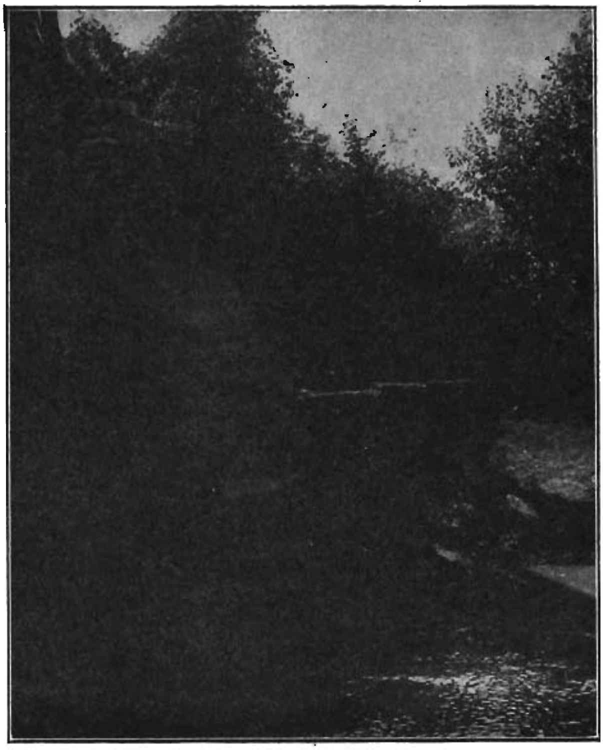

FIG. 21.—The Westerville limestone as it is exposed at the bridge over Grand river directly west of Hopeville. The topmost portion of the limestone exposed is but nine feet above the water. The most resistant stratum (No. 5 of the description) is that adjacent to the lower portion of the cement pier. The stream flows to the left, toward the south.

Except as above described there is little evidence of the presence of Missouri limestone in Clarke county: In section 11 of Madison township (northwest quarter of the northeast quarter) is a well ninety-two feet deep which is said to end in what is evidently decomposed limestone. This is undoubtedly Bethany Falls limestone. Stratified rock is said to have been reached at a depth of 189 feet in section 35 of the same township (northwest quarter of the southeast quarter). It is stated that rock was reached at a depth of 294 feet in section 20 of Washington township (southwest quarter of the northwest quarter). It is said that the Walter Bundy well in Troy township reached limestone at a depth of 200 feet. It is said that the Lacelle well situated in the upland (Knox township, section 17, northeast quarter of the northeast quarter) struck limestone at a depth of 200 feet. Concerning the depth of the limestone at Hopeville, Doyle township, there is disagreement, reports giving the depth to the limestone as from 100 to 200 feet. In section 34 a single large rectangular block of limestone near the roadside has evidently not been moved very far.

The above data and the deeply cut ravines make it evident that the limestone which lies beneath the surface in the southwestern half of Clarke county is deeply concealed by drift. Doubtless there have been cut in the limestone deep preglacial valleys, the locations of which cannot now be determined, and extensive beds of limestone have been eroded away from the preglacial divides. The fact that it is the Westerville limestone that is found in the extreme southwest corner of the county while in no other part of the county except one small portion is anything found above the Bethany Falls limestone, points to extensive preglacial erosion.

DIP

The measurements of dip were obtained largely at the quarries north of Osceola. The best places to be found were selected but even then there is considerable difference in the measurements due to local irregularities. The figures obtained are as follows:

Ward township.

Sec. 1, Nw. ¼ of the Nw. ¼.	2½° S. 17 ° W.	Bethany Falls limestone.
Sec. 1, Nw. ¼ of the Nw. ¼.	1¼° S. 26½° W.	Bethany Falls limestone.
Sec. 1, Nw. ¼ of the Nw. ¼.	9 ° S. 10 ° W.	Bethany Falls limestone.
Sec. 1, Nw. ¼ of the Nw. ¼.	5 ° S. 10 ° W.	Bethany Falls limestone.
Sec. 1, Nw. ¼ of the Nw. ¼.	6 ° S. 10 ° W.	Bethany Falls limestone.
Sec. 1, Nw. ¼ of the Nw. ¼.	1 ° S. 10 ° W.	Bethany Falls limestone.
Sec. 1, Se. ¼ of the Se. ¼.	2 ° S. 20 ° W.	Bethany Falls limestone.
Sec. 11, Ne. ¼ of the Ne. ¼.	5 ° S. 7 ° W.	Winterset limestone.
Sec. 11, Ne. ¼ of the Ne. ¼.	5½° S. 7 ° W.	Winterset limestone.
Average	4.1 ° S. 13 ° W.	

Doyle township.

Ford, ½ mile west of Sec. 31,	1¾° S. 5 ° W.	Westerville limestone.
Bridge, west of Hopeville,	3¼° S. 10 ° W.	Westerville limestone.

In section 14 of Green Bay township the strata were apparently horizontal. No measurements were obtained here nor in section 4 of Franklin township.

An average dip of 4.1° gives a fall of 378½ feet per mile, which, in the direction of the outcrop of the Westerville limestone at the bridge three miles west of Hopeville (from quarries north of Osceola) would be 189¼ feet per mile, since that direction is 45° west of the direction of the dip. This for the distance of fifteen and a half miles gives a fall so much in excess of the actual fall of the strata that it is evident the average dip for section 1 of Ward township does not hold as an average for the strata in the southwestern half of Clarke county, but is much in excess of the average for that region.

The thickness of the several portions of the Missouri formations as found in Madison, Clarke and Decatur counties gives an average which may be assumed to be correct for those formations in Clarke county.

	I.	II.	III.	IV.	V.
Westerville limestone	..	..	10	8 (exposed)	8
Chanute shale	..	..	24½	..	24
De Kalb limestone	4 (exposed)	..	70	..	70
Cherryvale shale	32	..	30		31
Winterset limestone	17	21	10	6 (exposed)	19
Galesburg shale	7	17½	10	..	10
Bethany Falls limestone....	12	14	10½	13	13
Ladore shale	..	18	10	48 (?)	48
Hertha limestone	..	17	10	10	14
			185		237

I is from the section described on pages 509-510 of the Madison county report[48] and obtained in a ravine where the part above the Winterset limestone is better exposed than it is at Winterset. II is from the Winterset section as given in the same report, pages 516-517. III is from the Decatur county report.[49] IV is from data obtained in Clarke county. V is the average which may be assumed to be correct for Clarke county.

Assuming the level of the upland at Hopeville to be the same as that of the upland at Murray (1216 feet above sea-level), the top of the Bethany Falls limestone should be 848 feet above sea level, 154 feet below low water in Grand river near Hopeville, and 368 feet below the level of the upland. In section 1 of Ward township the top of the Bethany Falls limestone is 1,073 feet above sea level, or 59 feet below the level of the upland. From

[48]Tilton and Bain, Geology of Madison County: Iowa Geol. Survey, Vol. VII.
[49]H. F. Bain, Geology of Decatur County: Iowa Geol. Survey, Vol. VIII, pp. 277.

this level to 848 feet above sea level is a fall of 225 feet, which, in the distance of fifteen and a half miles, gives a fall of fourteen and a half feet per mile. This corresponds to a dip of 9′ 26″ in that direction, and of 18′ 52″ in the direction of the average dip.

QUATERNARY SYSTEM

Pleistocene Series

GENERAL

In Iowa as a whole there are five distinct glacial deposits, left by five distinct glacial invasions and separated by four interglacial deposits. The relation of these is expressed in the following table, in which the oldest is at the bottom.

Wisconsin stage.
  Peorian (interglacial) stage.
Iowan stage.
  Sangamon (interglacial) stage.
Illinoian stage.
  Yarmouth (interglacial) stage.
Kansan stage.
  Aftonian (interglacial) stage.
Nebraskan stage.

Of these glacial stages but two are represented in Clarke county: the Nebraskan and the Kansan. Of the interglacial stages but two can be recognized: the Aftonian and the Yarmouth, though in Clarke county stream action under varying conditions has continued from Yarmouth time to the present. Deposits distinctly of these other stages are found elsewhere in the state.

THE NEBRASKAN STAGE

In the descriptions that follow it will be noted that the Nebraskan drift varies from a weathered clayey drift nearly free from pebbles near the horizon of the Nebraskan gumbotil to a less weathered, more pebbly, distinctly glacial drift at lower levels. The weathered portion is so thick that the dark, unweathered bowlder-bearing portion that lies deep beneath the topmost weathered portion is rarely seen where it can be definitely proven that it is Nebraskan and not Kansan drift.

The question naturally arises, should the Nebraskan gumbotil, which by the explanation of Kay has lost its pebbles and bowlders because they have been completely leached out in Aftonian time, be classed as Nebraskan or as Aftonian? While the material may have settled somewhat in the process of leaching, the gumbotil that is left has not been brought there from other sources. In this sense it can be recognized as Nebraskan; but such a change as took place, converting a bowlder-bearing deposit left by the Nebraskan ice into a gumbotil, has taken place in Aftonian time. This gumbotil then, a surface deposit in early Aftonian time, dissected later by stream action, marks the level of the Aftonian upland. It is therefore classed as an Aftonian deposit, along with such other deposits as were formed on the Aftonian surface.

The character of the Nebraskan drift as found will be made evident in the following descriptions.

At the Siegel brick and tile works on the outskirts of Osceola (southeast quarter of the southwest quarter of section 20) is a nearly pebbleless oxidized bowlder clay, the surface of which is sixty-eight feet below the level of the upland. The clay has been used in the manufacture of brick. The pit shows ten feet of the clay exposed, with faint partings perhaps due to slipping, with very little grit, but with a few pebbles up to two inches in diameter. This is judged to be a weathered Nebraskan drift close to the gumbotil horizon, with what is more distinctly a leached drift just beneath it.

In the gully by the school house a mile and a half west of Osceola four feet of this gumbotil appear fifty-eight feet below the level of the upland (or at 1,113 feet above sea level). Above it in the school house yard are five feet of oxidized Kansan drift studded with numerous bowlders of all sizes. Below it is a brown Nebraskan drift, largely concealed by wash from the hillside.

The four feet of gumbotil (Aftonian in age) is of a dark blue color and the body of it does not effervesce where exposed though lime concretions are found within the clay. The few small pebbles which considerable search brought to light were as follows: 3 gray chert, 1 dark chert, 2 quartz, 2 light quartzite, 1 dark quartzite, 1 greenstone.

In Union county at the old quarries half a mile east of the bridge over Grand river three miles west of Hopeville, the drift has a specially peculiar character. Close to the low upland there are exposed eight feet of a brownish clay free from fossils and apparently free from pebbles. Beneath this is a foot and a half of sand which is brown and buff in color. This overlies four and a half feet of another clay which is lighter in color than the uppermost clay and contains root marks, but is like it in all other respects. This overlies thirteen feet of a bluish clay free from pebbles, the bottom of the portion exposed lying twenty-five feet above the level of low water in the river close at hand. The loesslike manner in which the yellow clay flakes off vertically is especially suggestive of loess, but the clay is too clayey in character to be satisfactorily classed as a loess. It is judged to be a weathered Nebraskan drift. Near at hand, about fifteen feet above the river bed, there is a layer of sand and gravel over a clay on which are pebbles and cobbles of red quartzite, black and red chert, granites and white quartz.

In section 28 of Franklin township (northwest quarter of the northwest quarter) a deposit very similar to the weathered Nebraskan drift just described is to be seen close beside the creek. A somewhat similar deposit was noted at another point two or three miles down the creek. Both of these are judged to be weathered Nebraskan drift.

AFTONIAN INTERGLACIAL STAGE

The surface of the Nebraskan drift was evidently a continuous plain originally, remaining in that condition for a great length of time, sufficient to permit the reduction of its surface materials into a gumbotil by the gradual solution and removal of the soluble portions, including the reduction in size of such siliceous bowlders as may have existed in this part of the drift. None of the pebbles left in this gumbotil are striated. This process, changing the glacial material into a gumbotil, occupied the first portion of the Aftonian interglacial stage.

The gumbotil at the surface of the Nebraskan drift is visible at many places. The following list of exposures is not intended to be complete, but it is sufficient to indicate the general distribution of such exposures. By the barometer these are found to be fifty-five to sixty feet below the upland, at a level of about 1,040 feet above sea level in the eastern part of the county, about 1,113 feet above sea level in the central part of the county, and about 1,156 feet above sea level in the western part of the county. Many other places were passed by as uncertain because of wash from the hillside which obscured the surface.

LOCATION OF SOME OF THE EXPOSURES OF NEBRASKAN GUMBOTIL BY THE ROADSIDE.

MADISON TOWNSHIP.
- Ne. ¼ of the Se. ¼ of Sec. 7.

WASHINGTON TOWNSHIP.
- Se. ¼ of the Se. ¼ of Sec. 4.
- Nw. ¼ of the Nw. ¼ of Sec. 20.
- Nw. ¼ of the Nw. ¼ of Sec. 23.
- Nw. ¼ of the Se. ¼ of Sec. 25.

FREMONT TOWNSHIP.
- Nw. ¼ of the Sw. ¼ of Sec. 10.
- Ne. ¼ of the Ne. ¼ of Sec. 16.
- Nw. ¼ of the Nw. ¼ of Sec. 17.

TROY TOWNSHIP.
- Se. ¼ of the Ne. ¼ of Sec. 7.
- Se. ¼ of the Sw. ¼ of Sec. 17.
- Nw. ¼ of the Sw. ¼ of Sec. 21.
- Nw. ¼ of the Ne. ¼ of Sec. 23.
- Sw. ¼ of the Sw. ¼ of Sec. 25.

WARD TOWNSHIP.
- Sw. ¼ of the Se. ¼ of Sec. 10.
- Se. ¼ of the Sw. ¼ of Sec. 16.
- Ne. ¼ of the Ne. ¼ of Sec. 27.

OSCEOLA TOWNSHIP.
- Nw. ¼ of the Nw. ¼ of Sec. 21.
- Ne. ¼ of the Nw. ¼ of Sec. 27.
- Nw. ¼ of the Ne. ¼ of Sec. 36.

JACKSON TOWNSHIP.
- Se. ¼ of the Sw. ¼ of Sec. 17.
- Ne. ¼ of the Se. ¼ of Sec. 27.
- Nw. ¼ of the Ne. ¼ of Sec. 32.

DOYLE TOWNSHIP.
- Se. ¼ of the Se. ¼ of Sec. 6.
- Sw. ¼ of the Sw. ¼ of Sec. 13.
- Sw. ¼ of the Se. ¼ of Sec. 14.

KNOX TOWNSHIP.
- Sw. ¼ of the Sw. ¼ of Sec. 6.
- Se. ¼ of the Sw. ¼ of Sec. 15.
- Ne. ¼ of the Ne. ¼ of Sec. 22.

GREEN BAY TOWNSHIP.
- Nw. ¼ of the Nw. ¼ of Sec. 3.
- Sw. ¼ of the Se. ¼ of Sec. 6.
- Ne. ¼ of the Ne. ¼ of Sec. 29.

FRANKLIN TOWNSHIP.
- Ne. ¼ of the Ne. ¼ of Sec. 22.

In section 20 of Troy township (northwest quarter of the northwest quarter) Mr. Schull has fragments of cedar and dried peat obtained at a depth of ninety-five feet in the well twenty feet below the upland at his house. He reports the following well record:

FEET.	
3	Soil.
36	Clay, yellow; gravel and sand. (Kansan drift.)
8-10	Clay, blue; sand and stones. (Kansan drift.)
42½	Dirt, black; peat and wood. (Aftonian.)
3	Sand and gravel, dry. (Aftonian.)
5	Gravel, of stones two inches in diameter and smaller; fragments of cedar. (Aftonian.)
	Water spurted up and rose till it was ten feet deep.
100	

The gravel obtained beneath the Aftonian interglacial deposits was not at hand for examination to ascertain whether it was glacial (Nebraskan) or not.

The peat bog outcrops in the southeast quarter of section 20 in the bed of the ravine south from Mr. Schull's house, seventy-two feet below the top of the well and ninety-two feet below the level of the upland. It is said that in 1905 miners dug sixty feet into the bank expecting to find coal. At present the peat is nearly concealed by the drift which has slumped from above. Down the ravine (section 19) there are several boggy places that supply an unfailing abundance of water. The nearest of these is eighty-eight and a half feet below the top of Mr. Schull's well, which leads to the judgment that the water comes from sand and gravel beneath the peat. (Incidentally these measurements show the ravine bed to slope eighteen and a half feet in half a mile). Up the large ravine to the west as well as down it springs are to be found. In the southeast quarter of the northeast quarter of section 18 a small stream of water flows out of clear, white sand. Further north where two ravines come together (northeast quarter of the northeast quarter of section 18) is another spring. North of the railroad Mr. Cunningham of Afton in boring a well struck gravel at a depth of fourteen feet and secured a flowing well, said to flow twenty gallons per minute. All this was especially noticeable in the exceptionally dry summer of 1911 when water for stock was scarce. The seepage seems to indicate a line of Aftonian drainage from the western part of section 9, southwest to the northeast corner of section 18, to the northeast of section 19, then west to the northwest quarter of section 19.

The data from this portion of the county are remarkable in their significance with reference to Aftonian relief, along the ravine mentioned. The top of the Aftonian deposits encountered in the well at the home of Mr. Schull is ninety feet below the general level of the upland, while the gumbotil in the road to the north is about sixty feet below the upland, and the seepage from the bog along the ravine toward the west is not reached within a mile and a half. This gives a level of the seepage at 118 feet below the upland, and of 58 below the level of the Nebraskan gumbotil by the roadside to the north. It is of course more than possible that this is not the deepest part of the Aftonian valleys, but it is near enough to demand attention.

According to these figures the greatest Aftonian relief in this region was but 58 feet. This seems considerable if the bog were on the upland—the gumbotil plain; yet that is not impossible. If the bog formed in a valley eroded below the gumbotil plain, that valley was but 58 feet deep, and was later filled up 28 feet, leaving but 30 feet as the final Aftonian relief at the time the Kansan ice spread over the country. The present streams have cut below this level. That all drift between the level of this Aftonian bog (118 feet below the level of the upland) and the level of the present river trenches (84 feet deeper) is Nebraskan drift seems a conclusion of such far reaching import as to cause one to hesitate, but it is true for the central and western parts of Clarke county, and the writer knows of no facts that conflict in the county as a whole.

THE KANSAN STAGE

The Kansan stage is represented by the Kansan drift, or bowlder clay, which may be seen along the roadsides and ravines from forty to sixty feet below the general level of the upland. The portion ordinarily seen is the yellowish red clay with sand and gravel, and dotted with numerous pebbles and bowlders of many kinds. In the deeper portions that weathering has not as yet reached the drift is bluish in color.

With reference to the Kansan gumbotil the same question arises that was asked concerning the Nebraskan gumbotil: Shall it be classified with reference to its origin from a drift, or with reference to the date of its change into a gumbotil. Inas-much as the time element is what needs emphasis it is classified as Yarmouth in age.

The oxidized, bowlder-bearing portion of the Kansan drift is conspicuous throughout the county where erosion has cut beneath the gumbotil. Here the clay is yellowish red, due to oxidation and hydration of iron. The pebbles and bowlders include a considerable variety of granites, greenstones and quartzites, along with limestones of a local character, the most distinctive bowlders being purple and red quartzites and a dark, decomposing granite. These may be seen scattered along the surface of the Kansan drift in ravines where they are exposed by erosion, and are especially abundant along the trenches of ravines.

With the exception of two angular fragments of limestone that may possibly be bowlders, the largest of the Kansan bowlders are of very resistant rock: greenstone, granite and red quartzite, with dimensions ranging in size up to four and five feet, though bowlders of these largest dimensions are rare. One bowlder is remarkable for its size. This, the largest bowlder seen in the county, is exposed in the side of a gully in the southwest quarter of the northwest quarter of section 18, Fremont township. It is a reddish granite, composed chiefly of feldspar and quartz, with little mica. It is roughly five-sided. The east side is 17 feet in length, the west side 13 feet, the north end 14 feet, 10 inches and at right angles to the other two faces. The fifth face is at the southwest side, making oblique angles with the east and west sides. The rounded top is six to eight feet high. But one other bowlder of such large dimensions has been reported in southern Iowa. That one is in the northwestern part of Lucas county.[50]

Three determinations were made of the percentages of the different kinds of rocks found among the Kansan bowlders and cobbles, as follows:

	I.	II.	III.	
Coarse granite	...	1	..	
Dark granite	2	32	..	
Decomposing granite	..	1	16	
Light colored granite	26	16	..	
Pink quartzite	..	1	..	
Red quartzite	33	18	17	
Light quartzite	2	...	14	
Dark crystalline rock	..	2	..	
Greenstone	22	15	12	
Gneiss	1	..	..	
Schist	1	2	9	(Three kinds)
Chert	..	1	8	
Quartz	1	1	4	
Conglomerate	..	1	..	
Sandstone	6	8	20	(17 native)
Limestone	6	1	..	
	100	100	100	

[50]North of Churchville in Warren county are several very large granite bowlders, at least one of which in composition is much like the one above described.

I. was obtained in a small ravine in section 21 of Jackson township, southeast quarter of the northeast quarter. II. was obtained in a small ravine in section 3 of Osceola township, northeast quarter of the southwest quarter, where bowlders about a foot in diameter are unusually abundant. III. was obtained in the school house yard a mile and a half west of Osceola in the southeast quarter of the southeast quarter of section 14, Ward township.

The third or deepest phase of the Kansan drift is of a blue color because of the unweathered character of the clay. The pebbles and bowlders in it are generally not close together. This phase is found in some of the wells. It is so much like the corresponding deep phase of the Nebraskan drift that it is impossible to determine which drift is present except by the relation of the drift to the Aftonian horizon. The region of difficulty lies between the level of the Nebraskan gumbotil and the bottom of the Aftonian valleys, approximately the lower half of the large valleys.

The Kansan drift and gumbotil as seen along the railroads.—At the west county line and in two cuts between the county line and the railroad bridge in section 8, Troy township, eight or ten feet of Kansan gumbotil are evident above a bowlder-bearing Kansan drift. In the railroad trench along the north side of the track east of the bridge an exposure of Kansan drift is seen extending down along the hillside to near the bottom of the valley, the valley along which evidences of Aftonian deposits already described were found. Here the Kansan drift is judged to lie on the side of an Aftonian valley. In the railroad cut a mile west of Murray the section is completed to the upland. Here, near the center of the cut, two feet of soil is underlain by a clay which is reddish yellow above and lighter yellow below (gumbotil) and contains small pebbles. Beneath this is a thin layer of dark brown sand, over a more distinct Kansan bowlder clay. Between Murray and the west line of Jackson township the railroad is on the upland, the trenches revealing only the gumbotil and possibly a little loess with the soil. In Jackson township several railroad cuts give excellent exposures of drift in the upland. In section 19 of

Jackson township (northeast quarter of the southeast quarter) there is a gradation from soil down through yellowish brown and then bluish gumbotil containing a few grains of sand scattered through the deposit and a very few pebbles up to half an inch in diameter. Beneath this, at a depth of fifteen feet from the surface, lies four feet of a distinct Kansan drift with the usual bowlders. Just to the west of Woodburn where the railroad bed divides, pebble-bearing Kansan may be seen right up into the soil, though the pebbles are few and small. In the first long cut east of Woodburn it is the Kansan drift which is visible near the top of the cut from which much has slumped down concealing material beneath in the lower portion of the cut. Here as elsewhere along the railroads and throughout the county it is the gumbotil that readily slumps. Further east in section 25 (northwest quarter of the southwest quarter) several variations may be seen in the side of the cut, though here also the underlying material is largely concealed by slumping. The lower portion is thought to be Nebraskan drift.

At Jamison, along the railroad north and south through Osceola, it is only the weathered phase of the bowlder-bearing Kansan drift that can be seen opposite the station. A mile south of Osceola (section 21, the southeast quarter) the creek has cut into a hill just east of the railroad bridge, exposing there Kansan and possibly Nebraskan drifts. In six inches of soil at this point and in three feet of subsoil no pebbles were noted, but in the next five feet the pebbles were increasingly abundant. Next came a foot and a half of stratified sand stained yellowish brown with iron; then brownish yellow clay with small pebbles and cobbles, over a blue clay close to the creek. In the northwest quarter of section 21 (Osceola township) the bottom of the trench by the track reveals a dense, somewhat gritty phase of the Kansan with small pebbles of quartz and granite, and sheets of calcium carbonate filling cracks. Further down the hillside and near the river a drift like the Kansan drift is visible where washed soil permits observation. This is below the level of the Nebraskan gumbotil, and is more likely Nebraskan drift than Kansan drift. In the northeast quarter of the southwest quarter of the same section the deposit grades from soil through a yellow clay into four feet of brownish yellow clay with small pebbles, the usual gradation from soil into gumbotil. In section 24 of Knox township (the southeast quarter) a gully beside the track reveals three feet of gumbotil grading down into a distinct Kansan. Most of the way through Knox township the track is on the upland.

As described for hillsides along the railroads, so also throughout the other parts of the county the Kansan drift in its various phases may be seen, only a few more outcrops of which will be mentioned. In sections 4, 9, 10 and 12 of Washington township the drift contains an abundance of lime concretions. In the southeast quarter of the southeast quarter of section 4 a bowlder of stratified brown sand lies with its strata in an oblique position, the Kansan drift with its pebbles extending up into the soil.

THE YARMOUTH STAGE

The Yarmouth stage is represented by the Kansan gumbotil, which appears on all the hillsides about thirty feet below the level of the upland. It is the only deposit that is recognized as distinctly Yarmouth in age, having been formed from the surface deposits of the Kansan drft in the great extent of Yarmouth time.

During the glacial and interglacial ages that followed the Yarmouth, Clarke county was subjected to atmospheric action and stream erosion under varying conditions Erosion was the dominant process. If deposits then in process of formation are still in existence they cannot here be distinguished from those of recent origin.

The Kansan gumbotil contains a few pebbles here and there, rarely over half an inch in diameter, though occasionally one is found as large as two inches in diameter. Near the surface it grades upward into the soil. When wet it makes nearly impassable roads; when dry it forms very hard roadbeds. The gumbotil is found to extend through the upland from one divide to the next, the valleys revealing exposed portions along the hillsides. It is this Kansan gumbotil that marks the upland surface of the Kansan plain all through this part of Iowa. It is not found at a lower level except where washed there from above; and is to be distinguished from a second gumbotil (the Nebraskan) the top of which lies about sixty feet below the highest portions of the Kansan gumbotil. There is no question whatever as to the character of this gumbotil. It is distinctly a glacial drift in its origin. This is evident from its clayey character, lack of stratification, presence of pebbles here and there, with lower limit grading into a distinct bowlder-bearing Kansan drift with no plane of separation between the two in the upland[51] where the deposits are undisturbed. On the hillsides where the results of creeping are evident there is generally a marked change from the overlying gumbotil to the undisturbed oxidized portion of the drift below. In the heads of ravines large patches of gumbotil may be found that have been washed from the adjacent upland.

A surface characteristic especially worthy of note is the entire absence of all topographic features of a ground moraine. Though in places bowlders beneath the gumbotil are more numerous than in other places, and pebbles in the gumbo more noticeable in some localities than in others, there is no accumulation of such bowlders, and no rise of ground, such as might mark the site of a former drumlin or kame. Though there are places near the heads of ravines where there are deposits washed from the upland, there is no place that can be recognized as a filled-in kettle. This featureless extent of upland gumbotil marking the surface of the Kansan drift plain across Iowa certainly demands explanation. According to George F. Kay[52] and J. N. Pearce the conditions under which the bowlders and pebbles would largely disappear from a bowlder clay are those of a plain where conditions favorable to weathering existed for a long extent of time.[53] The erosion of valleys it is thought did not begin till elevation occurred, long after the upper part of the drift had been converted into gumbo. Gumbo thus derived from drift Kay has named gumbotil.[54]

[51]John L. Tilton, A Pleistocene Section from Des Moines South to Allerton: Proc. Iowa Acad. Sci., 1913. This gradation was repeatedly noted in the sections through the upland.

[52]George F. Kay, Some Features in the Kansan Drift in Southern Iowa: Bulletin Geological Society of America, Vol. 27, pp. 115-117.

[53]It was for this deposit in part that the name Dallas Deposit was formerly suggested in an earlier stage of the discussion before the significance of the weathering of the drift had been worked out by Kay. (John L. Tilton, Proceedings of the Iowa Academy of Science, Vol. 20, p. 218.)

[54]Geo. F. Kay, Gumbotil, a New Term in Pleistocene Geology: Science, N. S., Vol. 44, pp. 637-638, 1916.

LOESS

There are no beds of loess to be found in the upland. It may be there is some loess in the soil, for it is almost impossible to distinguish soil made from loess from soil made from gumbotil when the soil alone is considered. The subsoil is distinctly of clay and not of loess, with grains of quartz here and there as from decomposed granite, and also with a few small pebbles half an inch in diameter. The lower portion of the deposit is less cohesive and slumps badly where exposed faces are at all steep. This is especially noticeable in all railroad cuts in the upland. It lacks the lamination which is noticeable in a good bed of loess, and it is free from loess fossils. Such a deposit, though it has been called a modified loess, evidently should not be called a loess if the term loess is held strictly to its original meaning. The beds which are most loesslike are not in the upland but in the river valleys, and are located three miles west of Hopeville, Doyle township; in section 28 in Franklin township, and two or three miles northeast of that deposit in the same township.

Recent Series

Along all of the ravines and creek valleys soil is being washed from the upper to the lower slopes of the hillsides where it may be seen three to six feet deep in the sides of freshly cut trenches. In the wider valleys, especially those of the creeks and rivers, the finer portions are carried further out forming nearly flat bottomed portions of the valleys, where the deposit much resembles the "gumbo" of the upland.

Chiefly in the northeast half of the county the streams in changing their courses are cutting on the outside of their bends, and filling in on the inside of their bends, as described for Chariton creek. These deposits when flooded are further built up, together with other portions of the valley, by the true alluvial deposit then laid down; but this alluvial deposit is not extensive nor thick within the bounds of the county.

ECONOMIC GEOLOGY

Soils

The term soil is properly applied to the surface deposits rendered black from decomposing vegetation (humus). The lighter colored portion beneath is the subsoil, and is as important in the consideration of land as the soil itself. The formation of soil is a slow process. Year by year the growing roots penetrate the earth, separating the portions mechanically by their growth, absorb mineral constituents dissolved from the ground, then, decaying, form humic acids which aid in the decomposition of mineral matter for plant food and furnish products of decay to darken the mixture and enrich it for further plant growth. The freezing and thawing of the ground aids in loosening the soil, allowing air to penetrate more readily. Moisture from below rises to the surface by capillary action supplying depleted moisture in the summer time and replenishing mineral food in the soil. Ants and earthworms further aid in rendering the soil porous and then add their decaying bodies to enrich the humus. Ground squirrels, gophers and larvæ of beetles also contribute their labors, though the sum total of their endeavors, especially of the last two, seems more harmful than useful to man. To these agencies are added the work of those numerous bacteria that cause decay, and particularly those on the roots of leguminous plants (clover, especially) that take nitrogen from the air and convert it into forms that are later taken up by the corn and wheat in the production of nitrogenous food. It is evident that good soil, formed by such slow acting agencies, even though assisted by fertilizers and labor and conserved by the rotation of crops, is an asset that should be guarded as carefully as possible, and not allowed to deteriorate nor to wash out in newly forming trenches.

While the Kansan drift is clayey it is not because it consists of clay washed from decomposing feldspathic rocks and laid down in beds impervious to water, but because it consists of fine deposits from various sources mixed with ground rock, all worked together by the Kansan ice which left it in its present location. Some portions of it are extremely clayey, and are converted into soil with difficulty; some are sandy and porous, and even stony; and some are fine grained and convertible into excellent soil. To this latter belongs the Kansan gumbotil throughout the upland, which forms the best of land for agricultural purposes.[55] From gentle slopes the soil there forming

[55]In classification the upland soil has been called "Southern Iowa Loess", though the soil is here glacial drift in origin, and not loess. It is also classified as "Marshall silt loam." See also the paragraphs on the Kansan and Nebraskan gumbotils, and on the Recent Series.

is but slowly washed away, but from steeper hillsides it rapidly disappears, leaving a yellowish hillside streaked with gullies. The washed soil on gentle slopes and flats along ravines and creek valleys is soil from the higher ground that is pausing in its journey away from the county. The more such loss can be delayed by plowing at right angles to the slope, where it is necessary to plow, and throwing the furrow up the hill, the better for the future value of the land. In many places deep gullies are forming into which the neighboring soil will quietly but surely and continuously wash if the waste is not prevented, as by planting of willows, by the dumping of brush and hay to check the erosion, and by the proper location of large tile. By proper care what would soon become a long, wide and deep trench can be converted into a series of low terraces and the soil saved from wash for rods away on both sides. In Clarke county the conservation of the soil is not receiving the attention that it deserves.

The various ravines throughout the county are excellently adapted to the pasturing of stock, which find ample food on the grassy hillsides, water from creeks and stock wells, and shelter beneath the native timber of red and white elm, sycamore, red and burr oak, hickory, walnut and hawthorn, together with the commonly introduced box elder, willow and osage. The flat upland and the gentle slopes of the lower ground yield rich returns to agriculture, especially in an exceptionally good year like that of 1912, when the yield per acre[56] was as follows: Corn, 44 bushels; Oats, 38 bushels; Spring Wheat, 15 bushels; Winter Wheat, 27 bushels; Barley, 24 bushels; Rye, 23 bushels; Potatoes, 78 bushels; Tame Hay, 1.3 tons; Wild Hay, .8 ton.

Water.

WATER FOR HOUSE AND FARM

The water on which the people of Clarke county must depend is the local rainfall, from which the various ordinary wells and the streams receive their supply. The distribution of precipitation by months is given in the accompanying table:

[56]Monthly Review of the Iowa Weather and Crop Service, report for November, 1912, p. 109.

HOPEVILLE—MURRAY[57]

YEAR	PRECIPITATION, INCHES													Temperature Degrees F.		
	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	ANNUAL	Mean	Max.	Min.
1891	1.60	0.87	2.50	2.72	3.93	6.14	4.53	3.75	0.13	2.14	1.05	1.49	30.85	48.1	------	------
1892	1.61	1.46	2.15	4.68	10.84	2.70	7.46	0.91	1.86	2.61	0.66	1.19	38.13	47.4	------	------
1893	0.17	0.42	0.63	4.03	3.35	4.05	1.99	3.40	3.27	0.21	0.60	0.53	22.65	47.7	------	------
1894	0.74	1.23	1.82	1.60	1.21	2.30	1.00	0.75	3.48	2.29	1.19	0.86	18.47	51.1	------	------
1895	0.30	0.25	0.50	3.64	2.98	6.03	3.55	5.39	3.61	0.06	1.15	1.65	29.11	48.7	------	------
1896	0.61	0.76	1.09	3.30	7.36	2.22	10.44	5.97	4.99	3.67	1.00	0.40	41.81	49.9	------	------
1897	1.23	0.84	3.57	8.92	3.13	4.09	1.20	1.62	3.32	0.73	0.63	1.82	31.10	49.4	------	------
1898	2.32	1.16	1.48	2.22	5.90	6.07	2.92	2.49	4.63	3.15	1.25	0.65	34.24	49.2	------	------
1899	0.15	0.59	1.35	4.08	5.89	3.77	4.37	3.44	0.59	1.48	0.67	1.68	28.06	48.8	97	—25
1900	0.17	1.20	1.33	2.50	4.64	2.50	7.29	2.83	5.26	5.78	0.76	0.26	34.52	49.6	------	------
1901	0.60	0.84	2.76	2.33	3.22	4.85	1.79	0.55	2.61	2.39	0.88	1.26	24.08	50.2	------	------
1902	0.53	0.61	0.98	1.59	4.70	5.67	7.89	8.37	8.60	4.62	1.90	1.69	47.15	------	------	------
1903	0.12	0.77	1.14	1.72	8.59	3.06	2.21	12.24	3.97	1.45	0.78	0.07	36.12	------	95	------
1904	2.43	0.04	2.74	3.90	5.04	2.28	5.24	4.97	2.35	0.90	0.02	1.33	31.24	48.1	95	—20
1905	0.46	0.68	2.63	4.20	4.76	4.64	3.01	3.25	5.68	3.68	2.92	0.18	36.09	------	------	—30
1906	1.01	1.08	2.27	2.88	2.00	2.26	3.01	1.56	3.19	1.18	1.79	1.77	24.00	50.5	100	—7
1907	1.26	0.52	1.29	1.35	2.20	4.67	11.65	3.27	1.89	1.70	1.31	1.31	32.42	49.6	96	—15
1908	0.28	0.99	0.78	0.83	9.64	3.83	3.42	5.94	1.75	5.19	2.58	0.23	35.46	51.2	98	—9
1909	1.25	2.06	1.55	6.31	3.82	8.83	7.36	1.49	1.83	3.26	4.60	2.07	44.43	49.4	97	—14
1910	1.66	0.39	T	1.14	4.99	1.76	1.70	1.57	5.67	0.37	0.58	0.15	19.98	50.3	98	—20
1911	0.51	4.31	1.17	1.90	3.24	0.47	0.63	2.66	3.53	3.06	1.39	2.88	25.75	------	109	------
1912	0.19	2.00	1.87	4.68	5.12	3.47	2.10	2.62	4.79	4.96	0.86	0.42	33.08	48.0	101	—31
1913	0.63	0.43	2.30	3.66	6.05	4.93	0.89	2.06	2.90	T	0	2.00	25.85	51.6	104	—13
1914	0.69	0.94	1.82	2.32	0.85	1.69	1.87	1.33	13.25	0	T	7.20	31.96	51.4	105	—10
1915	1.54	2.95	0.95	1.52	9.33	3.45	11.46	4.38	5.23	0	0.50	0.44	41.75	49.8	91	—21
1916	2.21	0.43	0.56	3.52	5.40	3.50	0.44	2.43	2.08	T	0.50	3.70	24.77	49.5	102	—22
1917	0.64	0.10	1.75	6.03	3.33	7.25	1.17	2.20	2.84	1.27	0.20	0.27	27.05	47.6	102	—22
Means	0.92	1.03	1.65	3.24	4.87	3.94	4.10	3.38	3.82	2.44	1.19	1.38	31.49	51.7	99	—19

[57]The data are the Weather Bureau records as reported by Mr. M. F. Ashley. The instruments were transferred from Hopeville to Murray in January, 1911.

WOODBURN[58]

YEAR	PRECIPITATION, INCHES													Temperature Degrees F.		
	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	ANNUAL	Mdan	Max.	Min.
1901	1.03	0.65	2.76	1.83	2.67	4.44	3.85	0.53	2.59	1.51	0.85	1.30	24.01	------	------	------
1902	0.98	1.15	0.92	1.96	4.68	6.60	9.83	6.80	7.10	4.66	2.45	2.40	49.53	------	------	------
1903	0.05	1.72	1.19	2.10	7.23	3.77	3.41	17.74	5.02	1.53	1.04	0.15	44.95	------	------	------
1904	2.70	0.22	2.24	4.64	4.55	1.61	5.01	4.33	2.77	0.50	0.12	1.50	30.19	------	------	------
1905	1.15	1.87	3.67	5.33	6.06	6.80	5.60	2.75	4.37	3.53	2.15	0.37	43.65	------	------	------
1906	1.73	1.60	2.56	3.14	2.36	3.59	2.29	5.55	4.30	1.26	2.30	2.05	32.73	49.2	------	------
1907	1.18	0.40	3.52	1.78	3.78	5.12	6.32	3.51	1.89	1.70	0.45	1.31	30.96	------	94	—18
1908	0.28	0.99	0.73	1.10	2.26	3.85	2.55	3.05	1.15	4.15	1.41	0.40	21.92	------	------	------
1909	2.17	1.36	1.80	5.72	5.45	8.94	6.51	3.15	3.61	3.03	4.66	2.09	48.49	48.9	98	—15
1910	1.96	1.00	T	0.57	5.29	1.94	1.07	1.32	4.53	0.56	0.69	0.20	19.13	49.0	99	—33
1911	0.51	4.84	1.28	1.59	2.88	0.50	0.50	3.04	4.60	3.15	1.17	2.38	26.44	52.0	107	—15
Means	1.25	1.44	1.88	2.71	4.29	4.29	4.27	4.71	3.81	2.32	1.57	1.29	33.82	------	------	------

[58]Weather Bureau records as reported by Mr. C. B. McDonough. A few omissions in the records are supplied from the Hopeville reports.

Of this rainfall a portion runs off in the streams and a portion evaporates. Though the amount of water that sinks into the ground varies it has an average which may be assumed to be constant. The general relation of run-off and evaporation to precipitation for the northeastern part of the United States is given in the following table,[59] there being no data for this portion of the country.

GENERAL RELATION OF RUN-OFF AND EVAPORATION TO PRECIPITATION

	Average Precipitation	Relation of Run-Off to Precipitation		Relation of Evaporation to Precipitation	
	Inches	From Soil Per cent	From Lake Per cent	From Soil Per cent	From Lake Per cent
Storage Period, Dec.—May	12.68	80	64.5	20	35.5
Growing Period, June—August	11.79	10	18	90	82
Replenishing Period, Sept.—Nov.	7.28	23.7	27	76.3	73

B. Shimek, in his Geology of Harrison and Monona Counties, Iowa Geol. Survey, Vol. XX, pp. 460-470, 1909, discusses rate of evaporation in its relation to flora, explaining the presence of plants which are able to stand drought (xerophytic plants) where other plants die. His explanations apply also to the distribution of trees and other plants in Clarke county on south facing slopes directly exposed to the sun's rays in summer as compared with the distribution on north facing slopes. There is a marked difference in growth in even the same kinds of grass upon the two sides of deep railroad cuts when one side is a south facing slope and the other a north facing slope.

The rates of evaporation which Professor Shimek has determined are significant even with reference to evaporation from reservoirs. The data are on evaporation from above the soil. His average for the daytime for two days and two places is 212cc. (12.9 cubic inches) in August, 1908, and 249cc. (14.6 cubic inches) in September, 1908, from pans a foot in diameter. This is 16.4 cubic inches per square foot in the first instance and 18.6 cubic inches per square foot in the second instance.

There is generally throughout the county no difficulty in securing an abundance of water for household purposes from wells from thirty to fifty feet deep, and ordinarily no difficulty in securing an abundance of water for stock from wells, artificial springs, and from pools along the creeks. In one portion of the county, from section 8, along the ravine two miles west of Murray, a number of springs give a constant supply of water even through the worst droughts. One spring is in section 8, one in section 17, one in 18 and several in the western half of 19. In August, 1910, Mr. William Cunningham from Afton

[59]These percentages are from data given in Water Supply and Irrigation Paper, No. 80, and used in the following: John L. Tilton, A Problem in Municipal Water Works for a Small City, Proc. Iowa Acad. Science, XII, p. 146, 1905.

bored into the muck a few hundred yards north of the railroad bridge (section 8, two miles west of Murray) and struck gravel at a depth of twelve feet, securing a flowing well said to yield twenty gallons per minute. All through the remainder of that unusually dry summer the neighboring trench was filled with water for half a mile, overflowing to the south.

While the water from all of the above named springs is clear and tempting it should not be used for continuous household purposes till analyzed. Peat of an Aftonian bog has been found near the springs, and it is possible the water may be charged with ammonia, in which case it would prove an irritant from which some people would suffer. For stock purposes it is most excellent. If on analysis the water proves suitable the town of Murray can easily obtain a municipal supply from this source.

Some of the wells are reported to be deeper than those ordinarily found. In section 35 of Madison township (northwest quarter of the southeast quarter) Mr. Louis A. Brown has a well drilled to a depth of 300 feet. The water is said to be somewhat mineral but usable. In section 20 of Washington township (southwest quarter of the northwest quarter) a 4-inch drilled well reaches a depth of 294 feet, where an abundance of mineral water is obtained. In section 5 of Fremont township (southeast quarter of the southeast quarter) Mr. Henry Nicholson's well is 80 feet deep, the top of the well being 110 feet above the bed of Squaw creek. An abundance of water was found in gravel at a depth of 60 feet. In section 29 of the same township (northwest quarter of the northwest quarter) a well 90 feet deep sunk at a place on high ground did not go deep enough to reach water. In section 20 of Liberty township (northwest quarter of the northwest quarter) Mr. John Williamson bored a well 105 feet deep in the upland. An abundance of water with unsatisfactory odor was obtained at a depth of 90 feet. At the old creamery at Murray is a 4-inch well drilled 260 feet deep. The water was pumped from a depth of 176 feet. Though abundant in quantity it was a mineral water not suitable for boiler use. The well of Mr. Walter Bundy, five miles southwest of Murray, is said to reach a depth of 274 feet. There is no statement as to the quality of the water. The well of Mr. Schull, two miles west of Murray (section 20, northwest quarter of the northwest quarter), is on ground about thirty feet below the upland and is 100 feet deep. The water comes from gravel beneath an Aftonian bog. At Howe Hotel in Osceola the well is 190 feet deep. At Woodburn the city well, depth unknown but apparently not great, supplies an abundance of water charged with iron. In section 5 of Doyle township (southeast quarter of the southeast quarter) a well 92 feet deep goes through blue clay into sand. At the Hopeville creamery the well is 300 to 400 feet deep, all below 100 to 200 feet being in limestone and shale. At Lacelle in Knox township a well is 325 feet deep, with record reported as follows:

	FEET.
Depth to stratified rock	200
Limestone	14
Alternating limestone and shale	66
Shale, red and white, and a 6-inch stratum of limestone	45
Abandoned at	325

WATER FOR MUNICIPAL PURPOSES

Creeks—The difficulties often met in southern and western Iowa in endeavoring to secure water for municipal purposes are well illustrated by recent endeavors at Osceola.[60] As no suitable creek was near at hand a ravine east of town was dammed for a reservoir to receive precipitation that fell on a drainage area said to contain 270 acres. In 1910 the water which accumulated in the reservoir during the spring supplied the city till June 18, 1910, in which part of the year the demand for water is not so great as later in the season. From July 18, 1910, the railroad supplied the water from its pond situated a mile northeast of town where the pond receives drainage from two square miles, and continued to supply the water till the latter part of February, 1911. During the following spring water was obtained from the city reservoir from the latter part of February, 1911, till May 24, 1911, when the water again gave out. From that date till September 20 the railroad again furnished water from

[60]For the dates and amounts here named I am indebted to W. N. Temple, Esq., City Clerk of Osceola, and to Mr. Clifton Sawash, the engineer in charge of the Chicago, Burlington and Quincy railroad pumping station in August, 1911. Compare also the report on Clarke county by H. E. Simpson, Underground Water Resources of Iowa: Iowa Geol. Survey, Vol. XXI, 1910 and 1911, available a short time after this chapter was written.

its pond, supplying the city from 65,000 to 70,000 gallons per day at ten cents per thousand gallons. September 20 the supply of water in the railroad pond gave out and the railroad was obliged to haul water for its own use from the eastern part of the state. It supplied the city with water thus obtained from September 20, 1911, till the first of March, 1912, at a dollar per thousand gallons, when again as the spring rains came on it was possible to draw on the city reservoir for a time.

These facts furnish conclusive evidence that a reservoir receiving drainage from one or two square miles cannot be relied upon to keep a town of from two to five thousand inhabitants supplied with the water which it requires for municipal purposes. The supply of water will fail when it is most needed. There seems to be a widespread belief that reservoirs almost anywhere in a ravine will receive underground water from sources other than rainfall, an opinion which here is absolutely unwarranted. It requires but little computation to ascertain the number of gallons of precipitation per square mile (years of minimum precipitation preferred), there being 231 cubic inches per gallon. Allowance can be made for evaporation as previously given. If the amount is divided by 30,000 to 35,000,[61] the average number of gallons per day which Osceola now requires throughout the year, the quotient will give the days that the supply will last if no water is wasted. In the summer time when precipitation is least and evaporation most the present demand already reaches 65,000 to 70,000 gallons per day. It is evident that if a single reservoir is to receive the volume of water required to last through the summer, especially in a year of drought, the drainage area must be large. Ordinarily river valleys can be reached within a few miles of the cities, but near Osceola there is no river valley. The nearest approach to the requisite condition is found in the northwest quarter of section 30, southwest of Osceola, above which location the drainage area is about eighteen square miles. The construction of large dams in clayey regions where good foundation is wanting, the disposal of the sediment that accumulates, and the filtration of the

[61]Large cities use fifty gallons per inhabitant where the use of meters is required, and more than double that amount where the use of meters is not required.

water, all present their own peculiar problems; but given the water the problems can be solved. When suitable drinking water is obtainable from household wells (in cities properly protected by the creation of sanitary districts) filtration of the municipal supply can, if absolutely necessary, be omitted and the people cautioned not to drink the unfiltered water. The first requisite for a municipal supply is water for sanitary purposes and for fire protection.

For a further discussion of water from shallow wells and from the creeks see volume 21, Iowa Geological Survey. On pages 128-131 and 923-928 may be found discussions of general conditions in this portion of the state. Pages 939-942 are especially on Clarke county. While no analyses of the mineral content of water from Clarke county are given, page 232 presents a comparison of analyses of well and river water in Iowa; and page 199, the average mineral content of waters in the southcentral and southwest districts of Iowa. This average for shallow wells is as follows, in parts per million:

Silica (SiO^2)	26
Calcium (Ca)	167
Magnesium (Mg)	43
Sodium and Potassium (Na+K)	374
Bicarbonate radicle (HCO_3)	363
Sulphate radicle (SO_4)	745
Chlorine (Cl)	62
Total solids	1,587

Two deep wells at Osceola.—In 1885, or thereabouts, a well was drilled in the court house yard at Osceola. Of this there is unfortunately very meager information. The well is said to be 2,100 feet deep, with water so mineralized that it is not acceptable. The well has stood unused, and the casing has been damaged. There has been no determination made as to quantity of water obtainable. The only statement as to quality of water rests on rumors of an analysis of which there is no record.

After this experience with a deep well, and after the experience with creek water for municipal purposes as above described, it was again determined to try a deep well. This new well, 1,300 feet deep, is located at the standpipe. It is ten inches for the first 300 feet, eight inches for the next 700 feet, and six inches for the remaining 300 feet. It is thought that the water is sufficient in abundance, but it is found to be too strongly mineralized for use. It was given a sanitary analysis in January, 1914, by Professor C. N. Kinney, with the following results:

	Parts per million
Turbidity, some; sediment, considerable.	
Nitrogen as free ammonia	4.22
Nitrogen as nitrites	.00010
Nitrogen as albumenoid ammonia	.0300
Nitrogen as nitrates	none
Chlorides	1025.
Phosphates	.15
Residue on evaporation	6472.
Volatile solids	606.
Fixed solids	5866.
Color and odor on ignition	some
Microscopical, considerable precipitation of iron-filled algae; numerous small animal forms.	
The analysis indicates water in a defective condition.	

An 85,000 gallon storage tank has been built, into which water is forced by air pressure with a Dean duplex electric pump operated by a 25 horsepower Westinghouse motor. From this reservoir a second pumping to the standpipe is necessary.

The cost of the well was $6,500—five dollars per foot. The total cost of the well, reservoir, and machinery was $16,000. The pump for the deep well now lies idle, but is kept in readiness for use in case of fire. The reservoir in the valley south of town is still relied upon for water, which is forced into the standpipe.[62]

The deep well problem for Clarke county.—Up to 1917 the possibility of a municipal supply of water from a deep well in Clarke county had not been demonstrated, even though it seemed possible that data from Corydon and Leon were applicable here. The probable depth to the best water carrying horizons indicated such an expenditure that no city seemed willing to be the first to undertake the task. Not only were the best water carrying strata very deep, but there was a possibility that some of those that are good water carriers further to the northeast in the state would be found replaced by shale or closed by cementation in this portion of the state. Furthermore the corrosive, sulphurous water from the Coal Measures must be cased out. The strong probability that water in the deepest horizons is highly mineralized made it clear that he who first undertook to reach the deepest horizons should do so with full recognition that there was a large element of speculation in such an under-

[62]For the above data I am indebted to W. M. Temple, Esq., the city clerk at Osceola.

taking in this part of the state, with a strong possibility of failure. So strong was the speculative character of such an undertaking that no one conversant with the difficulties has been willing to urge a city to make the venture.

The situation was presented by the writer to the citizens of Indianola in 1894 (see Indianola papers of April 26, 1894) and the approximate depth of the Saint Peter sandstone correctly estimated from data then available and the probable character of the water stated. (See also Proc. Iowa Acad. Sci., Vol. 12, p. 147, 1904). Later an operator who had purchased the city plant refused to undertake a deep well when he came to understand the difficulties involved. Osceola's old well in the court house yard had proved a failure. Later the well at Corydon was put down but 834 feet, that at Humeston only 500 feet, and that at Leon 765 feet. These do not reach the deepest water-carrying horizons. The new 1,300 foot well at Osceola also fails to reach the deepest water carriers, and gets water from strata in which the water is so highly mineralized that the water is not used.

The conditions at Stuart are so related to those at Osceola that data from Stuart are here presented and the bearing of them described.

Stuart is situated like Osceola on a high portion along the state divide, and near the margin of the Missouri limestone; but Stuart has been without a railroad lake on which to depend in time of drought. For a number of years that city sought to get its supply from a well but ninety-two feet deep. This supply was so inadequate that the city finally ventured to reach the horizons that are recognized as the best water carriers further northeast in the state A summary of the log of the well is as follows:[63]

THE WELL AT STUART, IOWA

Altitude of the well at Stuart...........	1205 Feet above sea level
Altitude of the well at Osceola..........	1137 Feet above sea level
Base of the Saint Peter sandstone, to which level water in the pipe could be easily baled out	2432 Feet
Test when the full depth of well was reached	3021 Feet
Eighty hours' test gave 60 to 80 gallons per minute. During the last 24 hours the average was 212 gallons per minute. During the entire test the water never dropped to the bottom of the pipe; there seemed to be no difference in the level.	

When the well was through the Saint Peter sandstone the water stood at 325 feet below the curb; at 2,736 to 2,833 feet it

[63]A complete record may be found on file at the office of the Iowa Geological Survey, Des Moines.

stood at 345 feet, at 2,830 feet it rose to 340 feet below the curb; and to the completion of the well (at 3,021 feet, a distance of 191 feet) the water remained at about the same level, when it was 345 feet below the curb.

RECORD OF CASING IN THE WELL AT STUART

12 inch line goes down from top to	305 feet
10 inch line goes down to	785 feet
8 inch line goes down to	1285 feet
6 inch line goes down to	1938 feet
12 inch line was left clear to top on completion.	
10 inch pipe was cut off at	200 feet
8 inch pipe was cut off at	690 feet
6 inch pipe was cut off at	1185 feet

The temperature of the water as it is pumped from the well is 63° Fahr[64]. During the spring of 1918 50,000 to 80,000 gallons were used per day. This is forced by air pressure into a reservoir holding 160,000 gallons, and then pumped into a tower the capacity of which is 80,000 gallons. The cost is as follows:

Cost of well, including drilling and casing, completed in the summer of 1917	$17,000
Cost of pumping outfit, including air compressor, drum and pipe	2,500
Cost of reinforced concrete reservoir, 36 feet diameter, 16 feet under ground, 4 feet above ground, capacity 160,000 gallons	3,800
Water tower, capacity 80,000 gallons	4,500
	$27,800

ANALYSIS BY THE DEARBORN CHEMICAL COMPANY, CHICAGO, NOVEMBER 26, 1917.

	GRAINS PER GALLON
Silica	.250
Oxides of Iron and Aluminum	.090
Carbonate of Lime	Trace
Sulphate of Lime	23.901
Carbonate of Magnesia	12.953
Sulphate of Magnesia	Trace
Sulphates of Sodium and Potassium	59.009
Chlorides of Sodium and Potassium	18.020
Loss, etc.	.124
Total soluble mineral solids	114.347
Organic matter	Trace
Suspended matter	.350
Total soluble incrusting solids, grains per gallon	37.194
Total soluble non-incrusting solids, grains per gallon	77.153
Total mineral matter, grains per gallon of 231 cubic inches	114.35
Pounds soluble incrusting solids per 1,000 U. S. gallons	5.31
Pounds soluble non-incrusting solids per 1,000 U. S. gallons	11.02

[64]The records of temperature, cost of equipment, and analyses are kindly furnished by Mr. G. F. Taylor, City Clerk, Stuart.

Water from the tower is mixed with exhaust steam in the heater, and the heated mixture is pumped into the boiler. From the analysis of this mixture the composition of the compound is determined that must be added to water pumped into the boiler.

ANALYSIS OF WATER AS PUMPED INTO THE BOILER; DEARBORN CHEMICAL COMPANY, NOVEMBER 26, 1917.

	GRAINS PER GALLON
Silica	.140
Oxides of Iron and Aluminum	.163
Carbonate of Lime	Trace
Sulphate of Lime	21.714
Carbonate of Magnesia	6.985
Sulphate of Magnesia	3.904
Sulphate of Sodium and Potassium	34.029
Chloride of Sodium and Potassium	14.790
Loss, etc.	.269
Total soluble mineral solids	81.994
Oil and Organic Matter	Trace
Suspended Matter	1.402
Total soluble incrusting solids, grains per gallon	29.002
Total soluble non-incrusting solids, grains per gallon	52.992
Total mineral matter, grains per gallon of 231 cubic inches	81.994
Pounds of soluble incrusting solids, per 1,000 U. S. gallons	4.17
Pounds of soluble non-incrusting solids, per 1,000 U. S. gallons	.757

Such a record impresses upon us the desirability of securing complete data whenever public money is spent for a deep well. The contract with the driller should require that he keep an accurate and detailed record, which requirement should be strictly adhered to. Such valuable information should be deposited at the office of the State Geological Survey, where it can be placed at the service of the various city councils if they will but ask for the information.

Osceola is but sixty-eight feet below the level of Stuart. The Saint Peter sandstone, a fine water carrier in the northeastern portion of the state is, as recognized at Stuart, of too close a texture to be a good water carrier at that place. At Osceola, likewise, it should be anticipated that the Saint Peter sandstone cannot be relied upon as an acceptable water carrier; but the location of the top of it is important, as marking an horizon already worked out for different portions of the state.[65] That horizon is given as at 1,050 feet below sea level at Stuart and at

[65]See Plate I, Vol 21, Iowa Geological Survey.

1,400 feet below sea level at Osceola, a fall of 350 feet from Stuart to Osceola. At Osceola this depth is 2,637 feet from the surface of the upland. The driller at Stuart reached the base of the Saint Peter at a depth of 2,800 feet, which at Osceola would be 3,150 feet. At Stuart the well was continued 221 feet further, when an abundance of hard but not very satisfactory water appeared. This depth corresponds to a depth of 3,371 feet at Osceola.

It is more than reasonable to anticipate that what is an excellent water carrier at Stuart is also an excellent water carrier at Osceola. This horizon is 1,271 feet deeper than the old well at the court house is reported to have been sunk, and 2,071 feet deeper than the new well at the standpipe.

The significance of this argument is conclusive: Osceola can get such mineral water as Stuart has obtained if it will sink a well to the depth of 3,371 feet, and install machinery of sufficient power to force water up by air under a pressure of 1,500 pounds per square inch; but the water will be mineral water, decidedly saline, not acceptable for drinking purposes, and a very hard water for other uses.

Since no analysis has as yet been made of the mineral content of water from the new 1,300 foot well at Osceola, no direct comparison is now possible between that water and water from the 3,021 foot well at Stuart. Certainly there is at present no inducement to reach the lower level.

Pit and Quarry Products

Stone.—For many years limestone has been quarried at the Carpenter, Short and Carter quarries northwest of Osceola, and to some extent also in section 14 of Green Bay township, at which places limestone up to fifteen inches thick has been obtained chiefly for building purposes. The following is the production summarized from the various volumes of the Iowa Geological Survey:

PRODUCTION OF LIMESTONE IN CLARKE COUNTY

Year	Producers	Paving, Curbing, Flagging	Rough and Rubble	Building	Miscellaneous	Total
1897			$237.50	$1,075	$35	$1,347.50
1898	3		755.	1,583		2,338.
1901		$232	75.	1,150		1,457.
1903	7			1,435		1,435.
1904	7	198	542.	2,368	80	3,186.
1905	5	900	40.	1,450	10*	2,400.
1907				1,138		1,138,
1908	4	600		745		1,345.

*Crushed stone for road.

Analyses of this limestone and also of limestone belonging to these same strata but quarried at Winterset and Earlham are here inserted as representing the composition of similar limestone at the quarries northwest of Osceola. All data here given are from volumes XV and XVII, Iowa Geological Survey.

ANALYSES OF LIMESTONE.

Location	Composition						Authority
	Insoluble	Iron and Alumina	Calcium Carbonate	Magnesium Carbonate	Sulphur Trioxide	Moisture and Organic Matter	
Carpenter quarry, Osceola....	8.64	1.54	88.92	0.62			A. O. Anderson
Carpenter quarry, Osceola....	8.90	1.20	89.30	0.06		0.28	A. O. Anderson
Carpenter quarry, Osceola....	13.72	1.26	82.50	2.05		0.59	A. O. Anderson
Robertson quarry, Earlham (composite sample)	7.85	1.00	91.15	0.61			L. G. Michael
Earlham (composite sample)..	10.92	2.37	84.87	1.58			Geo. Steiger
Peru (composite sample).....	17.16	2.64	72.76	2.86	.95	0.30	L. G. Michael
Winterset	12.63	1.18	84.34	2.19		0.02	A. O. Anderson
De Kalb (partial analysis)...			91.96	1.99		0.07	J. B. Weems

In the crushing tests the limestone from Winterset failed at 4,588 pounds per square inch, a strength sufficient for all ordinary local purposes for which the limestone is likely to be used.

Analyses of shale from between the beds of limestone (I) northwest of Osceola, analyzed by C. E. Ellis, (II) and (III) at Winterset, analyzed by A. O. Anderson, are as follows:

	I	II	III
Silica (SiO_2)	55.52	26.72	64.74
Alumina (Al_2O_3)	14.51	3.83	18.07
Ferric oxide (Fe_2O_3)	9.09	3.11	6.90
Lime (CaO)	5.00	36.08	1.25
Magnesia (MgO)	2.60	0.48	1.30
Potash (K_2O)	1.50	1.12	1.09
Soda (Na_2O)	1.32	0.18	0.41
Sulphur trioxide (SO_3)	0.28	0.22	0.15
Moisture	.139	0.55	1.99
Loss on ignition	8.28	28.40	4.15
	99.49	100.69	100.05
Hydraulic Factor	.2809	....	.2578

Lime.—For many years limestone of the composition above described was burned for lime at Winterset and also at Peru. Partly because of the cost of burning, and partly because of the quickness with which the lime set (the stone used was low in magnesia), the slower setting lime shipped in from further east secured the market. One attempting to burn lime northwest of Osceola for the local market should first ascertain the amount of magnesia in the yellow uppermost beds, since these probably contain more than the lower and whiter layers. From an analysis of these beds and the analyses above given a mixture might be obtained that would set with the desired slowness. The conditions are, however, not encouraging for the manufacture of lime on anything more than a very small scale for local use.

Cement.[66]—The lack of water power for cheap power in grinding, the necessity of importing coal (from Lucas county or elsewhere) not only for calcining but also for power, and competition in the local market with cement shipped in from well located plants doing business on a large scale, preclude the possibility of a successful plant for the manufacture of Portland cement. The fact that Portland cement is better than natural cement and costs but little more in manufacture, seems also to

[66]On this subject attention is called to the admirable discussions of cements published in volumes XV, XVII and XXIV of the Iowa Geological Survey.

preclude the possibility of a successful plant for the manufacture of natural cement, even though mixtures of shale and limestone suitable for cement can easily be selected.

Good Streets and Country Roads.—It is doubtful if the prospective market for crushed rock and dimension stone in towns along the Chicago, Burlington and Quincy railroad will warrant the extension of a side track from Osceola two miles northwest down into the quarries, though the possibility of opening an industry is worthy of consideration. Whether or not the quarries are opened on a large scale, Osceola has near at hand a source of crushed stone of the quality commonly used in the foundation for asphalt, creosote block, and brick paving. It also has in the same quarries a source of material for cement which can be used to cement the crushed stone together, though at present it appears better to purchase cement in the open market. On this bed can be placed the imported asphalt, the creosote blocks or vitrified brick; or a cheaper surfacing material can be obtained in the limestone siftings from the same quarries, preferably mixed with cement, laid without the aid of a steam roller or the services of skilled bricklayers. For a surface binder to lay the dust the experiments of the U. S. Department of Agriculture as thus far completed indicate that waste sulphite liquor[67] is suitable where crude oil is objectionable.

For most country roads undoubtedly reliance must for many years rest on good drainage and crowning. For the general improvement of country roads the government tests suggest that in a clayey region like that of Clarke county sand be worked into the clay.[68] Sometime it may be possible to build good road beds twelve to twenty feet in width of crushed limestone, cement or brick in places that are now almost impassable as the ground thaws out in the spring.

On all questions of improvements there is a factor that must be dealt with. The voter has a right to test and to pass judgment upon the desirability of an undertaking. He may prefer an

[67]See Progress Reports of Experiments in Dust Prevention and Road Preservation, 1910; U. S. Dept. of Agriculture, Office of Public Roads, Circular No. 94, p. 28.

[68]Descriptive Catalogue of the Road Models of the Office of Public Roads; Bull. No. 47, U. S. Dept. of Agriculture, Office of Public Roads, p. 17, 1913; Sand-Clay and Earth Roads in the Middle West; Circular No. 91, U. S. Dept. of Agriculture, Office of Public Roads, pp. 15-16, 1910; and W. L. Spoon, Sand-Clay and Burnt-Clay Roads; Farmer's Bulletin 311, U. S. Dept. of Agriculture, pp. 13-16, 1907.

asphalt or a vitrified brick surface instead of the limestone siftings or sand-clay, and choose to pay the difference. A mile of good roadway tested for even a spring or two will prove a good roads argument that will attract the attention of people from all parts of the county, and help in the furtherance of improvements.

Bowlders.—Bowlders of various kinds of stone may be found in ravines and on hillsides in all parts of the county, affording material for rough work.

Sand.—Sand washed from the drift collects in small beds along creeks where it may be obtained for local use. It is in many cases mixed with soil, and is not in large beds. It may serve for plaster and also for cement when well selected or washed.

Clay Products

The record of brick manufactured in the years 1900 and 1903 state the total production for Clarke county to be four hundred thousand each year of common brick, with a total value each year of from $2,500 to $2,800.

The Siegel Brick and Tile Yard was operated for many years. It is located in the southeastern part of Osceola (southeast quarter of the southwest quarter of section 20), one hundred and twenty feet below the upland and about ten feet above the creek to the south. In the last year that it was operated (1911) 120,000 brick were burned.

The face of the clay pit showed ten feet of clay somewhat laminated, containing very little grit, but few pebbles, and these below two inches in diameter. Considerable oxidation is evident along planes in the clay. Beneath this clay (but not exposed at time of visit) Mr. Siegel states there is a yellow clay with pebbles and bowlders. The clay is gumbotil at the surface of the Nebraskan drift. In various parts of the county clay of equal value for common brick may be found; but shale, that can be worked stiff into the best of brick and tile, is not exposed in the county, however close to the surface it may actually be in places. Clarke county must rely on the products from other counties for its high grade building and paving brick.

Coal

In the discussion given of the Des Moines formation, which is the chief coal bearing formation in the state, it is evident that though that formation lies next beneath the drift in the northeastern half of the county, there is little evidence that the strata near the surface bear coal. In other counties to the northeast and east[69] of Clarke county most of the coal is reported from the lower portions of the Des Moines strata, though a few thin seams are reported in the upper portions, such as the one which Mr. Wood encountered in section 28 of Franklin township. About two miles east of the county are located the old Cleveland mines where a few years ago extensive mining operations were under way in which coal was obtained at a depth of 318 feet. At points further east there are several mines. To the south, at Leon, coal is found at a depth of about 500 feet. It is thus probable that one prospecting for coal in Clarke county must expect to penetrate not only the drift which extends even below the beds of the creeks, but also nearly the entire thickness of the Des Moines formation. As a datum plane from which to measure, the base of the Hertha limestone is especially valuable. In a line northwest-southeast across the county this plane is at the level of South river in section 5 of Washington township; a few feet (perhaps ten) below the bed of Squaw creek in section 6 of Osceola township, and at about the level of White Breast creek in section 3 of Franklin township. Beneath this plane the prospector should plan to penetrate a maximum of not less than four hundred feet and not more than five hundred.[70] In the northeast corner of the county the depth would be approximately one hundred and fifty feet less from the water level in Otter creek. Even at these depths the coal in this horizon is not found elsewhere to extend regularly but to lie in basins, with seams often only two feet in thickness and rarely over five.

While the present demand for coal does not warrant extensive prospecting, it seems certain that sometime the eastern part of

[69]For Warren county see Geology of Warren County: Iowa Geol. Survey, Vol. V, pages 320-350, 1895, and The Coal Deposits of Iowa: Iowa Geol. Survey, Vol. XIX. pages 168-181, 1908. For Lucas county see Vol. XIX, pp. 218-227. A complete report on this county will be published soon. For Decatur county see Vol. XIX, pp. 246-253, which report contains records of prospect drilling.

[70]See Henry Hinds, Coal Deposits of Iowa: Iowa Geol. Survey, Vol. XIX, p. 217, 1908.

the county, especially along the Chicago, Burlington and Quincy railroad, will be thoroughly prospected to ascertain whether the coal-bearing portion of the Des Moines formation is here productive and where the coal basins lie. With seams so irregular only the general location of the horizon can be predicted; all details must come from actual borings.

Southwest of the line described from the northwestern corner of Washington township, through Osceola to the southwestern corner of Franklin township, it does not seem probable that conditions of the market will ever warrant prospecting for coal. In this portion of the county not only do limestone beds of the Missouri formation in addition to the heavy deposits of drift overlie the Des Moines formation, but the beds, including the Des Moines formation with whatever of coal it may possibly there contain, dip steeply to the southwest, so that within so short a distance as Grand river, near the southwest corner of Clarke county, beds which are stratigraphically about one hundred and fifty feet above the limestone near Osceola are close to the level of low water in Grand river. Here a total of about two hundred and forty feet of the Missouri formation must be penetrated before the top of the Des Moines formation is reached, and then four hundred to five hundred feet of the Des Moines formation. On the upland the heavy drift which seems to occupy much of the distance from the upland to the river level also must be penetrated. (It is reported that limestone was reached at a depth of about one hundred and fifty feet at Hopeville. It is two hundred and fourteen feet from Hopeville down to the level of Grand river.)

Peat

Aftonian peat mentioned as found in section 21 of Troy township was pure enough to burn; but there is no evidence at hand that it is worth digging for fuel.

ACKNOWLEDGMENTS

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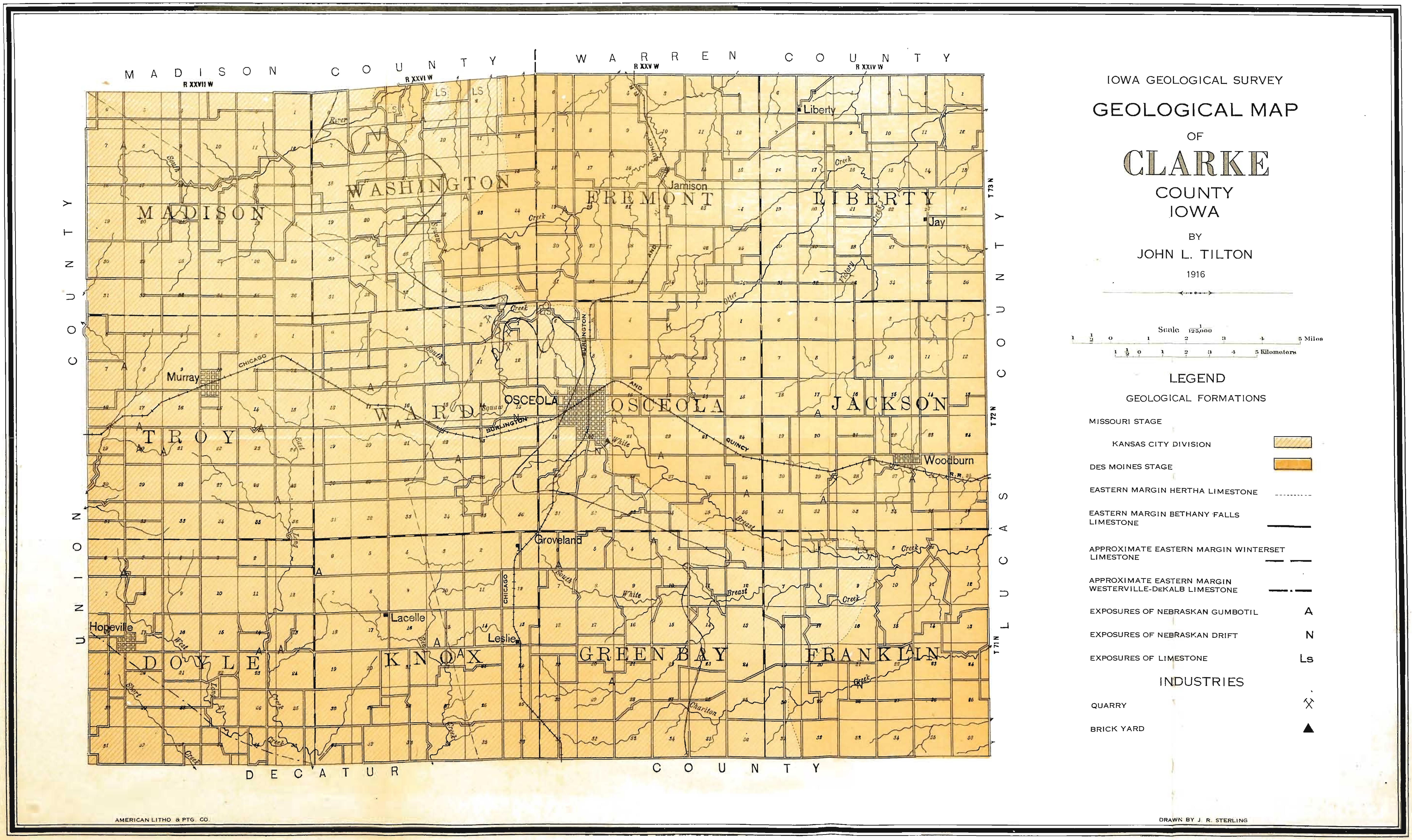
IOWA GEOLOGICAL SURVEY
GEOLOGICAL MAP
OF
CLARKE
COUNTY
IOWA
BY
JOHN L. TILTON
1916
Scale 1/125,000
5 Miles
5 Kilometers
LEGEND
GEOLOGICAL FORMATIONS
MISSOURI STAGE
KANSAS CITY DIVISION
DES MOINES STAGE
EASTERN MARGIN HERTHA LIMESTONE
EASTERN MARGIN BETHANY FALLS LIMESTONE
APPROXIMATE EASTERN MARGIN WINTERSET LIMESTONE
APPROXIMATE EASTERN MARGIN WESTERVILLE-DEKALB LIMESTONE
EXPOSURES OF NEBRASKAN GUMBOTIL A
EXPOSURES OF NEBRASKAN DRIFT N
EXPOSURES OF LIMESTONE Ls
INDUSTRIES
QUARRY
BRICK YARD
MADISON COUNTY
WARREN COUNTY
UNION COUNTY
LUCAS COUNTY
DECATUR COUNTY
R XXVII W
R XXVI W
R XXV W
R XXIV W
T 73 N
T 72 N
T 71 N
MADISON
WASHINGTON
FREMONT
LIBERTY
TROY
WARD
OSCEOLA
JACKSON
DOYLE
KNOX
GREEN BAY
FRANKLIN
Liberty
Jamison
Jay
Murray
OSCEOLA
Woodburn
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