The University of Chicago
FOUNDED BY JOHN D. ROCKEFELLER

THE PLEISTOCENE DEPOSITS IN WARREN COUNTY, IOWA

A DISSERTATION

SUBMITTED TO THE FACULTY OF THE OGDEN GRADUATE SCHOOL
OF SCIENCE IN CANDIDACY FOR THE DEGREE
OF DOCTOR OF PHILOSOPHY

(DEPARTMENT OF GEOLOGY)

BY

JOHN LITTLEFIELD TILTON

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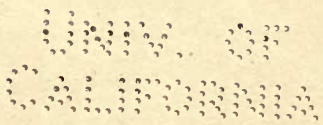

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INTRODUCTION

LOCATION

The northern boundary of Warren County lies five miles south of the city of Des Moines, and hence five miles south of the vanishing edge of the Des Moines lobe of the Wisconsin drift sheet, from which it is separated by the Raccoon and Des Moines rivers. These, after their union, form the boundary of the northeastern part of the county. The five hundred and seventy and one-half square miles of Warren County thus lie in that broad extent of southern and western Iowa where the surface drift is called the Kansan drift. The problems involved are those of the post-Kansan surface deposits, the Kansan drift,[1] the Aftonian interglacial deposits, the sub-Aftonian drift, the preglacial deposits on Carboniferous strata, and the several topographies that were developed.

PREVIOUS AND RECENT WORK

The Carboniferous strata of the county were examined in 1893–94 and described (by the writer) in Vol. V of the *Iowa Geological Survey*. While Vols. I–VII were in course of preparation it was generally supposed that there were but three different drift sheets in Iowa and that those described by McGee in his "Pleistocene History of Northeastern Iowa"[2] were the drift sheets present in southern Iowa. The differences found were considered local variations. The early volumes of the *Iowa Geological Survey* contain many interesting facts and general descriptions which can now easily be read in the present terms of Pleistocene classification. The accumulation of these facts led first to a comparison with the corresponding relations in Wisconsin, especially through the kindness of Professors T. C. Chamberlin and R. D. Salisbury,[3] and then in southeastern Iowa, through the kindness of Mr. Frank Leverett who, in his study of the "Illinois Glacial Lobe,"[4] had crossed over from Illinois into southeastern Iowa. H. F. Bain then worked out the general relations of the drift sheets and published his paper as a part of Vol. VI,[5]

[1] For map of the drift sheets of Iowa see *Iowa Geological Survey*, Vol. XIV, Plate III.

[2] *Eleventh Annual Report, U.S.G.S.*

[3] *Iowa Geological Survey*, Vol. VI, p. 434; Vol. VII, pp. 19–20.

[4] *Monograph U.S.G.S.*, Vol. XXXVIII.

[5] In Vol. VI, *Iowa Geological Survey*, pp. 434–37, 446, and 463–67, Bain gives an excellent summary of the development of the knowledge of the drift sheets of Iowa up to that time and references to reports on previous work.

Iowa Geological Survey, which was followed by a general classification of the Pleistocene deposits by Professor Samuel Calvin in the Administrative Report of Vol. VII. Since that time (December, 1896) the details of county work have brought to light evidence of a sub-Aftonian drift, a still older drift than McGee recognized as his oldest drift described in his "Pleistocene History of Northeastern Iowa."[1]

In the *Bulletin of the Geological Society of America*, March, 1909, Professor Calvin discusses the "Recent Phase of the Pleistocene Problem in Iowa." In a December bulletin of the same society Professor Shimek describes the "Aftonian Sands and Gravels in Western Iowa,"

WARREN COUNTY

R. XXV W.	R. XXIV W.	R. XXIII W.	R. XXII W.	
Linn	Greenfield	Allen	Richland	Tp. 77 N.
Jefferson	Lincoln and Greenfield	Lincoln and Palmyra	Union	Tp. 76 N.
Jackson	White Oak	Otter	Belmont	Tp. 75 N.
Virginia	Squaw	Liberty	White Breast	Tp. 74 N.

Diagram stating the combination of names used to designate the various government townships.

and in an October bulletin Professor Calvin describes the remarkable mammalian fauna[2] which had been unearthed by Professor Shimek in his work upon the Aftonian deposits along the Missouri River and tributaries in western Iowa.

The gradual accumulation of data in different parts of the state made it seem advisable to ascertain if possible whether the drift which had been called Kansan in Warren County presented evidence of a division into two drift sheets. The field work which was necessary to this paper occupied the summers of 1904 and 1905. During that time eight hundred and sixty-five well records were obtained, and further observations were made on innumerable exposures by the roadside and in ravines. Fortunately, at the very close of the field work, a well one hundred and twelve feet deep was bored on the campus at Simpson

[1] *Eleventh Annual Report, U.S.G.S.*

[2] S. Calvin, "Aftonian Mammalian Fauna," *Bulletin of the Geological Society of America*, Vol. XX, pp. 341–56.

College that afforded the most complete section through the Pleistocene deposits that it had been possible to obtain. This record is presented in detail and the data from other parts of the county are compared with it.

In the following pages it is frequently desirable to refer to the various townships by name instead of by number. In so doing the irregularity of the township lines in the central and northeastern parts of the county make it desirable to combine names as given in the accompanying diagram.

ACKNOWLEDGMENTS

I am especially grateful to Professors T. C. Chamberlin, R. D. Salisbury, and Samuel Calvin for careful criticism of both an earlier report and the present paper. While none of these gentlemen are responsible for any defects that may appear, much of what may be of merit is due to their keen and kindly criticism.

To Mr. J. C. Nash, Mr. John Tucker, and Mr. N. I. Bowen (who are in the well business) I am indebted for the records which they have given me of the depth of wells and the general character of material found in the various parts of the county, and also for their kindness and aid on a number of trips on which I have been with them to examine the material as it was removed from the ground. I am also indebted to the farmers throughout the county for their uniform courtesy and aid. To Professor W. B. Read I am indebted for a series of levels extending sixteen miles north and south through Indianola, obtained at my request by a class in surveying under his direction.

THE PLEISTOCENE DEPOSITS CONSIDERED AS A WHOLE, AND THE PREGLACIAL SURFACE

THICKNESS OF THE PLEISTOCENE DEPOSITS

The Pleistocene deposits as a whole, together with the recent and subglacial sands and clays, have a maximum thickness of two hundred and fifty-five feet, a minimum of zero feet, and an average of forty-nine and eight one-hundredths feet, in the three hundred and sixteen wells which extend either definitely through the deposits or into thin deposits resting on the Carboniferous. Of these three hundred and sixteen wells, eight reach the Carboniferous at depths of not over six feet, and forty-two at depths of one hundred feet or more. To this latter number should be added four which are one hundred or more feet deep but do not reach the bottom of the drift, and seven others which may possibly extend through the drift. There are also three others that reach the Carboniferous but at depths not ascertainable, two of which should be included with those indicating a depth of one hundred feet or more to the bottom of the drift, making fifty-five wells in all.

On comparing the different data it is noted that the tops of nearly all of the wells where the drift approaches a hundred feet in thickness are at or near the level of the upland. The tops of wells revealing very thin Pleistocene deposits are in various relations to the upland, four occurring on the upland, four on the lowland, and the others at intermediate levels; and all are where outcrops of the Carboniferous are most numerous. Nearly all of such wells and outcrops lie near or northeast of a diagonal line extending from the northwest to the southeast corner of the county.

MAXIMUM THICKNESS OF DRIFT COMPARED WITH THE PRESENT RELIEF

According to the following table in which a comparison is possible between the maximum thickness of the Pleistocene deposits and the present relief, the maximum thickness of the deposits exceeds the present relief in Jefferson and Virginia townships and about equals the present relief in Linn, Greenfield, and Jackson townships. In all the other townships the present maximum relief exceeds the present thickness of the drift.[1]

[1] The statement of present relief is based in part on the Des Moines and Milo topographic sheets, photographs of which have been received in season to be of use in revising this manuscript. Other data used in the estimates may be found in the "Geology of Warren County," *Iowa Geological Survey*, Vol. V, pp. 315–17.

Township	Present Maximum Thickness of Drift	Present Relief
Linn	142 ft.	130 ft.
Greenfield	125	140
Allen	115	140
Richland	68	186
Jefferson	180	140
Lincoln and Greenfield	115	163
Lincoln and Palmyra	118	163
Union	39	140
Jackson	167	170
White Oak	150	180
Otter	49	189
Belmont	43	190
Virginia	255	204
Squaw	73	137
Liberty	105	137
White Breast	52	190
Average	112	162

THE PREGLACIAL DRAINAGE

Attempts to determine the direction of the preglacial drainage are not satisfactory, partly because of uncertainty as to whether the lowest level of the Carboniferous surface beneath the sub-Aftonian as given by the well records marks the lowest parts of the preglacial valleys. The uncertainty as to exact level that existed all through the field work for lack of a topographic map, making it necessary to assume levels for the present upland based on a few railroad levels and determinations with a barometer, is now partly relieved by photographs of the completed Des Moines sheet and the partially completed Milo sheet which give levels for the extreme northern and eastern parts of the county. Estimates of the lowest portions of the upper surface of the Carboniferous where found beneath glacial deposits are as follows:

Township	Lowest Portions of the Upper Surface of the Carboniferous Found Beneath Glacial Deposits	Present Highest Parts of the Upper Surface of the Carboniferous
Greenfield	815 ft. A.T.	900 ft. A.T.
Allen	858	...
Jefferson	870	...
Jefferson	901	...
Jefferson	855	...
Lincoln and Greenfield	925	...
Lincoln and Greenfield	915	...
Virginia	1,030	...
Virginia	1,020	1,030
Liberty	897	...

Here the general slope of the lowest portions of the upper surface is toward the north, but the data are not sufficiently extensive to make a determination of the average gradient possible. The difference between the lowest level in Greenfield Township (815 ft. A.T.) and the highest level of the Carboniferous surface at the present time (900 ft. A.T.) gives a relief of 85 feet, which is less than the true preglacial relief because of Aftonian erosion of the upper surface of the Carboniferous. (The surface of the Carboniferous at that point was protected from post-Kansan erosion by the Kansan drift, which still remains.)

Further evidence with reference to the preglacial surface may be found in the regions of deepest drift bounded partially by irregular Carboniferous outcrops. These heaviest deposits of the drift make it evident that from the southern and eastern parts of Jackson Township a large valley extended southeastward across Squaw Township and northwestward across Jefferson. A branch of this valley extended eastward from Jefferson Township to Indianola, and another northeastward to the southwest corner of Greenfield Township. Another valley underlies the central part of Linn Township, from which there is an extension southwest and northwest. The distribution of the thick drift suggests an outlet to the northwest, but the direction of the preglacial valleys suggests an outlet more to the north through Greenfield Township.

Where the surface of the Carboniferous is penetrated the gradations due to weathering are frequently evident from the incoherent upper portions to the more consolidated portions below. The records of wells that penetrate the deeper-lying portions of the Carboniferous surface generally state that sand is found, but in a few instances old soil and fragments of wood. Such deposits are not Aftonian for they lie below sub-Aftonian drift, and at levels out of accord with Aftonian drainage lines.

THE RECORD OF THE SIMPSON COLLEGE WELL

In the summer of 1907 a series of four wells was sunk within a radius of fifteen feet on the campus of Simpson College, giving the best record which it has been possible to obtain in the county. This record, made as the material was removed, is here presented in detail. It serves as a typical record down to the Aftonian, beyond which the deposits described are not commonly reported within the county. The surface of the well is at 970 ft. A.T.

THE RECORD BRIEFLY STATED

2 ft.	Soil, black (loess and humus).	
28 ft.	Loess, yellow above, blue below; then blue clay (gumbo, a modified loess); then a grayish-blue sandy loess; no effervescence.	
2 ft.	Sand, yellowish and gray.	Sub-loessial
54 ft.	Clay, with pebbles, bowlders, and lime concretions; yellowish brown for one foot, then grayish blue for seventeen feet, then bluish black for thirty-six feet.	Kansan
25 ft.	Deposit, black, with old-soil plains and minute partings of vegetation, but no wood, and almost no pebbles.	Aftonian
1 ft.	Pebbles from sub-Aftonian.	Aftonian
112 ft.	(Ends on the Carboniferous.)	Carboniferous

THE RECORD STATED IN DETAIL

The Post-Kansan Surface Deposits

2 ft. Soil, a black loam (loess and humus).

28 ft. A brownish loam for ten feet, porous, a mixture of clay and microscopic particles of quartz, streaked with brown oxide of iron in rootlike tubes and with very thin layers of a dark-brownish sand; entirely free from pebbles. At thirteen feet from the surface the deposit is less clayey than above and contains more numerous streaks of a brownish sand. Two feet deeper (at 15 ft.) the deposit is slightly bluish; then for three feet is a dense blue clay free from sand and impervious to water, but still free from effervescence and free from pebbles. (The ground-water, the surface of which was encountered at eight feet, rests on the impervious clay at this level.) For the next eight feet (to 26 ft.) the clay is of a light grayish blue, still free from pebbles

and effervescence. At first (at 21 ft.) it is somewhat more gritty than above and contains traces of a brown oxide of iron. The first four feet of the eight caved badly, large water-soaked masses (wet from below upward) scaling in vertical sheets from the sides of the well, as the uppermost phase of the loess does by the roadside.

The first pebble, encountered at a depth of twenty-six feet, was a small angular red granite, dimensions $\frac{5}{16}\times\frac{3}{16}\times\frac{2}{16}$ of an inch. In the next two feet (to 28 ft.) the deposit (the lower loess) contains a fine sand and spherical grains of quartz $\frac{1}{16}$ of an inch in diameter. The remaining four feet to the sand (sub-loessial) is grayish in color and with a grayish and brown sand through it. In the bottom of this deposit was a pebble $\frac{3}{8}\times\frac{3}{8}\times\frac{1}{8}$ of an inch, and grains of quartz up to $\frac{1}{8}$ of an inch in diameter.

The Sub-loessial Sand

2 ft. Sand, pure, brown and gray. At the well to the east this sand is almost wanting. At the well farthest west the sand is nearly four feet thick. At the intermediate wells it is about two feet thick, the bottom of the sand sloping to the west.

The Kansan Drift

54 ft. Directly beneath the sub-loessial sand is a light brownish-blue stiff clay in which the first concretion of calcium carbonate was found, and two small pebbles of greenstone, then a bowlder too large to get into the auger, and, at 33 feet, a dark-blue clay with the first distinct effervescence of the clay itself, this effervescence continuing with each auger full for fifty-three feet till the bottom of the Kansan had been reached at a depth of 86 feet. Here at 33 feet were also found a rounded quartz and a sub-angular limestone pebble.

From 33 feet to 49 feet the clay varied from a brownish clay to a light-bluish clay and then to a grayish blue, with brown sand and gravel scattered through it, and with pebbles and bowlders. At 47 feet the surface of this grayish-blue clay was of a darker shade; at 48 feet there were patches of a dark-blue clay $2\times1\frac{3}{4}\times1$ inch grading outward into a lighter blue clay, thus forming pieces of a dark-blue clay surrounded by zones of the gray clay weathered in from the streaks of sand, the darker blue clay containing pebbles and scattered grains of sand, thus

resembling in all respects except color the grayish-blue clay and the bluish-gray clay above. In the next foot the pieces of dark blue were larger, the gray lying in distinct planes between the masses of dark blue.

From 50 to 86 feet, the bottom of the clay that effervesced, the clay was bluish black and dry (the unoxidized and unhydrated portion of the Kansan), with a fine brown sand in little pockets half an inch or so in diameter and in thin irregular bands similar to those along which the blue in the upper two feet is weathered into the irregular masses. There were numerous pebbles, lime concretions, and fragments of wood.

The Aftonian Deposits

25 ft. Beginning with 87 feet a part of the clay does not effervesce. In the next foot the effervescence is still less, and in the third foot (the 89th) the last lime concretion, one inch in diameter, appears. The clay is on the whole a dark grayish blue, but grades back and forth from black to light blue. Minute rootlike fragments of vegetation are scattered through it but no fragment of wood was found. At 95 feet is a layer of moss and black dirt about an inch thick; a foot deeper is a similar layer. In these old soils were a few small pebbles of greenstone, black chert, quartz, and limestone, to the last of which the slight effervescence seemed to be due. The largest greenstone pebble was $\frac{1}{2}\times\frac{1}{2}\times\frac{1}{4}$ inch; the fragments of limestone were $\frac{1}{2}\times\frac{5}{16}\times\frac{5}{16}$ inch and $\frac{1}{2}\times\frac{3}{8}\times\frac{1}{4}$ inch. In the next foot (the 97th) there was another layer $1\frac{1}{2}$ inches thick of this old black soil and moss, and in the next foot two inches more like an impure peat. Between these two layers was an angular fragment of limestone $1\times\frac{5}{8}\times\frac{3}{8}$ inch. In the next nine feet (to 106 feet) there were no pebbles and the grit was very fine, the largest particle being a particle of greenstone $\frac{1}{16}$ of an inch in diameter at 106 feet.

At 107 feet from the surface the grayish-blue clay contained traces of a brownish sand, the largest grain of which was a greenstone $\frac{1}{8}\times\frac{1}{8}\times\frac{1}{16}$ inch. A foot deeper (at 108 ft.) several subangular pebbles of greenstone were encountered, one, the largest, $\frac{3}{4}\times\frac{1}{2}\times\frac{3}{8}$ inch; another, $\frac{1}{2}\times\frac{3}{8}\times\frac{1}{8}$ inch; another, $\frac{3}{4}\times\frac{1}{2}\times\frac{3}{8}$ inch and subangular in shape. For the next two feet (108 and 109) the dark-grayish clay was streaked with brown sand and contained minute pebbles, the largest of which was a chert $\frac{3}{8}\times\frac{5}{16}\times\frac{1}{2}$

inch. The next half-foot was a grayish clay with streaks of brown sand, and with gravel at its base. Within the next few inches came a bed of gravel, described as follows:

The gravel was nearly a foot in thickness, coarse above, fine below, with a half-inch streak of red clay in the midst of it.

The greenstones of the gravel were rounded and subangular, all smooth and unweathered, four striated; one especially, flat and striated on one side, rounded on the other, and pitted in three places, the edges and solid angles rounded and polished—a typical glacial pebble. One limestone fragment contained part of a shell—like a fragment of *Productus muricatus*, the index fossil of the Des Moines formation.

The complete analysis of this gravel is as follows, all excepting the very finest material being used in making the analysis:

ANALYSIS OF GRAVEL FOUND IN THE BASE OF THE AFTONIAN DEPOSIT (DERIVED FROM SUB-AFTONIAN DRIFT)

	Number Found	Percentages All Material	Percentages Foreign Material Only
Limestone, gray, many angular, one with a fragment like *Productus muricatus*, the index fossil of the Des Moines formation. This is all to be classed as local material, and is possibly derived from the very stratum on which the gravel rests	63	18.4	0.0
Greenstone, four striated, many rounded and sub-angular	148	44.1	57.4
Sandstone, gray (local)	15	4.4	0.0
Sandstone (not local)	6	1.8	2.3
Granite, all but four light colored	29	8.6	11.3
Quartz	33	9.8	12.8
Chert, brown	15	4.4	5.9
Chert, dark	5	1.5	1.9
Chert, light	4	1.2	1.5
Quartzite, pink	2	0.6	0.8
Quartzite, dark	3	0.9	1.1
Quartzite, light	7	2.1	2.7
Schistose rocks	6	1.8	2.3
	336	99.6	100.0

In the above table the first column of figures expresses the exact number of pebbles found; the second, the percentages of all the pebbles; and the third, the percentages of the foreign material only.

If in the above that which is local in character be excluded, all the remainder are of a very resistant character, not a single specimen being found of the decomposed granite so common at the surface of the Kansan drift. The largest of the granites has a rough surface such as may be found in a granite of similar texture scaling under the action of frost. The almost complete absence of pink quartzites is also a notable fact when comparing the analysis with analyses of pebbles from the Kansan.

The sizes of the largest pebbles are as follows:

Limestone

$4 \times 1\frac{3}{4} \times 1\frac{3}{4}$ inches
$3\frac{3}{4} \times 3 \times 2$ "
$3\frac{1}{2} \times 2 \times 1\frac{1}{2}$ "
$3 \times 1\frac{1}{2} \times 1\frac{1}{2}$ "
$3\frac{1}{4} \times 1\frac{3}{4} \times 1\frac{1}{4}$ "
$2 \times 1\frac{1}{2} \times 1$ "

Greenstone

$4\frac{1}{2} \times 3 \times 2$ inches
$3 \times 3 \times \frac{5}{8}$ "
$3 \times 2\frac{1}{4} \times 1\frac{3}{8}$ "
$3\frac{1}{4} \times 3\frac{1}{2} \times 2\frac{1}{2}$ "
$2\frac{1}{2} \times 2 \times 1\frac{1}{4}$ "
$2\frac{3}{4} \times 1\frac{3}{4} \times 1$ "

Granite

$3\frac{1}{2} \times 3 \times 1\frac{3}{4}$ inches
$3\frac{1}{2} \times 3\frac{1}{4} \times 2$ "
$3 \times 2\frac{1}{4} \times 2$ "
$2\frac{3}{4} \times 1\frac{3}{4} \times 2$ "
$2\frac{1}{2} \times 2 \times 1\frac{1}{2}$ "
$2\frac{3}{4} \times 1\frac{1}{2} \times 1\frac{1}{2}$ "

Quartz

$4 \times 2\frac{1}{2} \times 1\frac{5}{8}$ inches
$3 \times 2\frac{3}{8} \times 1\frac{1}{2}$ "
$1\frac{1}{4} \times 1\frac{1}{4} \times 1$ "
$1\frac{1}{2} \times 1 \times \frac{5}{8}$ "
$1 \times \frac{7}{8} \times \frac{3}{4}$ "
$1\frac{1}{4} \times \frac{3}{4} \times \frac{3}{4}$ "

Pink Quartzite

$1\frac{1}{4} \times 1\frac{1}{4} \times \frac{3}{4}$ inches

Carboniferous

The bottom of the well is on a hard, flat rock, which is undoubtedly a Carboniferous stratum in place, and presumably the source of many of the limestone pebbles found in the gravel.

THE WATER

The character of the water obtained through the gravel bears evidence of the presence of partially decomposed vegetation (Aftonian). The water is so charged with free ammonia that the quantity of this ammonia was not determined. The albumenoid ammonia present was found to be thirty-two one-hundredths of a part per million.[1]

DISCUSSION

In the above description the material down to the weathered surface of the Kansan is what is commonly found throughout the upland in the central part of the county. Parts of it correspond to what has been described in other places where the Kansan is the surface drift.

[1] The analysis was made by Professor C. J. Holmes.

From the top of this drift, at thirty-two feet, down to the bottom of the drift, at eighty-six feet, the characteristics of the deposit are so like those of the Kansan drift, and the gradations so perfect from a weathered portion to an unweathered portion below, that there seems no possibility whatever that it includes more than one drift sheet. It is therefore all classed as Kansan.

The deposit that underlies the Kansan is peculiar. The color of the deposit and the presence of a few pebbles within the twenty-five feet, though the pebbles are only about half an inch in diameter, suggest sub-Aftonian drift; but the appearance of stratification, marked especially by the distinct layers of moss with accompanying black dirt, at least four of which were conspicuous, are not characteristics of drift at all but of a non-glacial deposit into which it seems possible such small pebbles may have been washed, though no stratum of gravel associated with them within the deposit was noted. Such a deposit, between a Kansan above and a sheet of gravel below that contains glaciated pebbles, is classed as a part of the Aftonian interglacial deposit. The deposit appears to be a unit, though varying slightly close to the gravel at its base.

The stratum of gravel with glaciated pebbles at the bottom of the well must have come from a glacial deposit antedating the Aftonian. It was therefore derived from the sub-Aftonian drift, for no other drift sheet is known from which it may have come. The conditions suggest that the well reaches the bottom of a ravine into which gravel from sub-Aftonian drift was washed.

The sub-Aftonian drift is wanting at this particular place, but it is not wanting in various parts of the county. The Kansan may be seen in its usual aspects in the higher ground, while along the deeply cut trenches in ravines may be seen the dense, bluish-black sub-Aftonian, largely free from bowlders and pebbles. The soil washed from the hillsides generally covers the dividing surface between the two drifts and whatever of Aftonian may remain.

THE SUB-AFTONIAN DRIFT

THE NAME

For sub-Aftonian, or pre-Kansan, drift several names have been proposed. Albertan seems inapplicable since the deposit that first received that name is found to be non-glacial in origin.[1] The Jerseyan of New Jersey[2] has been so traced in its relations to deposits in the Mississippi Valley[3] that that name may prove an acceptable term, but, though already used in Iowa,[4] the exact relation of the deposit as an equivalent of the sub-Aftonian drift of Iowa does not yet seem to be thoroughly established. Recently Shimek,[5] at the suggestion of Calvin, has proposed the name Nebraskan. This term has been applied to a "tough, impervious bluish-black till" containing pebbles of greenstone, white quartzite, and light-colored granite, and lying beneath the Aftonian interglacial deposits.

THE SUB-AFTONIAN DRIFT IN GENERAL

Till of such a character still visible in small exposures has been described as lying beneath the Aftonian near Thayer and Afton Junction, Iowa.[6] It is found near Council Bluffs, Iowa,[7] and across the Missouri River in Nebraska. It appeared in the railroad cut at Oelwein[8]

[1] Fred H. H. Calhoun, "The Montana Lobe of the Keewatin Ice Sheet," *Professional Paper, U.S. Geological Survey*, No. 50, pp. 50–51 and 57.

[2] Rollin D. Salisbury, "The Glacial Geology of New Jersey," *Geological Survey of New Jersey*, Vol. V, 1902, p. 189.

[3] Chamberlin and Salisbury, *Geology*, Vol. III, pp. 384–88.

[4] W. H. Norton, "Geology of Bremer County," *Iowa Geological Survey*, Vol. XVI, p. 362.

[5] B. Shimek, Addendum to paper on "Aftonian Sands and Gravels in Western Iowa," *Bulletin of the Geological Society of America*, Vol. XX, p. 408.

[6] H. F. Bain, "The Aftonian and Pre-Kansan Deposits of Southwestern Iowa," *Proceedings of the Iowa Academy of Sciences*, Vol. V (1897), p. 96; S. Calvin, "The Aftonian Gravels and Their Relation to the Drift Sheets of the Region about Afton Junction and Thayer," *Davenport Academy of Natural Sciences*, Vol. X (1907), pp. 22 and 29.

[7] B. Shimek, Addendum cited.

[8] Grant E. Finch, "Drift Section at Oelwein, Iowa," *Proceedings of the Iowa Academy of Sciences*, Vol. IV (1896), pp. 54–58; S. W. Beyer, "Evidence of a Sub-Aftonian Till Sheet in Northeastern Iowa," *ibid.*, Vol. IV (1896), pp. 59–62; S. Calvin, "Summary of Discussion," *ibid.*, Vol. IV (1896), pp. 66–68.

and in an excavation at Muscatine.[1] Evidences of the presence of a pre-Kansan drift have been found in other places.[2]

Such a bowlder clay differs from the tough bluish-black Carboniferous shale in the total absence of such stratification as is found in the shale, and in the presence of pebbles (though generally rare) found in the drift but not in the shale. It differs from the Kansan bowlder clay in the presence of a much lower proportion of fine sand and coarse grit than is found in the Kansan, rendering the Kansan much less impervious to water than the sub-Aftonian and much more easily eroded. Marks of a steam shovel, presumably made in the spring of 1903 when extensive work was done along the line of the Chicago, Burlington and Quincy Railroad, may still be seen (1910) on the sub-Aftonian drift exposed in the second railroad cut west of Thayer. No such evidence is now visible on the Kansan. The character of the pebbles seen in the gravel at Afton Junction appears to the eye to accord with the statement that they have a high percentage of white quartz and light-colored granite. In the pebbles found at the bottom of the Simpson College well, and carefully tabulated, the scarcity of pink quartzites was noted and the relative abundance of quartz and light-colored granites. The at least general absence of bowlders more than six or eight inches in diameter also seems to contrast the sub-Aftonian with the Kansan in which bowlders up to a foot or more in diameter are common.

The impervious and tough character of the clay that has enabled it to resist weathering so as still to bear the marks made by a steam shovel, enables steep sides of trenches cut in clay of this character in the valley bottoms to stand vertically for a long time. Along such trenches where the clay has been found weathered, the color of the sub-Aftonian changes to a seal brown, the toughness of the clay persisting, thus contrasting in color and tenaciousness with the light-yellow clay into which the Kansan clay weathers. The hills of sub-Aftonian still left standing, though mantled with Kansan and later deposits, are steeper than the hills of Kansan drift where the Kansan is thick. This relative steepness is noteworthy near Thayer and Afton Junction, and across the country northeastward into Warren County, throughout which distance the same type of topography and the same character of deep-lying clay (sub-Aftonian) are found.

[1] J. A. Udden, "Geology of Muscatine County," *Iowa Geological Survey*, Vol. IX, p. 338.

[2] See the following county reports in the *Iowa Geological Survey:* T. E. Savage, "Geology of Benton County," Vol. XV, p. 201; and "Geology of Fayette County," Vol. XV, p. 522; W. H. Norton, "Geology of Bremer County," Vol. XVI, p. 362.

THE DISTRIBUTION AND RELATION OF THE SUB-AFTONIAN DRIFT IN WARREN COUNTY

In all parts of Warren County a deep-lying bowlder clay of the character already described may be seen, especially in the southern and western portions. That a clay of this character should be classed as separate from the Kansan and entirely distinct from it, is a proposition difficult to prove in many parts of the county, but fortunately there are places where the relation is perfectly evident, as half a mile east of New Virginia, and four miles to the northeast (Sections 7 and 18 of Squaw Township), and a mile south of St. Marys.

Half a mile east of New Virginia (the N.W. $\frac{1}{4}$ of the S.E. $\frac{1}{4}$ of Sec. 27) the bed of the ravine is on the tough and impervious bluish-black sub-Aftonian clay containing small pebbles of greenstone, white quartz, chert, and granite. The section as a whole is as follows:

1 ft. Soil; pebbles to within two inches of the surface.
1 ft. Gravel, a recent surface wash.
5 ft. Clay, yellowish, very few pebbles; bluish in trench near by. Kansan drift
7 in. Sand, fine, mostly white but somewhat stained by iron. Top of Aftonian
$\frac{1}{2}$ in. Sand, deeply stained to reddish brown.
3 in. Sand, fine, black.
7 ft. Sand, fine, no stratification evident, reddish brown where damp, light yellowish brown where dry.
5 in. Sand, stratified, cemented by iron and calcium carbonate. Bottom of Aftonian
6 in. (Exposed.) Clay, bluish black, with small pebbles of greenstone, white quartz, chert, and granite. Sub-Aftonian

Erosion later (1910) than the above section was measured has brought to light two bowlders each a foot in diameter in the Kansan drift overlying the sand.

In the railroad cut at the New Virginia station the Kansan drift is only ten feet thick, the Aftonian sand appears about the middle of the cut, and the sub-Aftonian clay is imperfectly exposed for about ten feet down to the level of the track.

A further relation of the sub-Aftonian is evident at and near Igo's stock farm in Squaw Township (the southwestern part of Section 18). Here the Aftonian sand extends over the brow of the hill down into the ravine to the west, thus mantling a hill of sub-Aftonian drift which rises about a hundred feet above adjacent valleys, where the sub-Aftonian drift is still so thick that it is not cut through in the bottom of the ravine.

The hill itself is covered by a thin deposit of Kansan drift, the latter where exposed completely weathered into a light-yellowish bowlder clay. Near the northeast corner of this section (but in the S.E. $\frac{1}{4}$ of the S.E. $\frac{1}{4}$ of Sec. 7) is a good exposure by the roadside. Here about six inches of sand deeply stained by oxidized iron lies immediately beneath a black layer-like old soil and rests on a clay that is undoubtedly sub-Aftonian.

A mile south of St. Marys the brown Aftonian sand lies by the roadside beneath yellowish and bluish Kansan drift filled with pebbles and cobbles, with a large Kansan bowlder perhaps four feet long near at hand. In a ravine to the east the sub-Aftonian has been trenched to a depth of perhaps twenty-five feet below the Aftonian without exposing the Carboniferous.

Along the deeply cut trenches of the southern and western townships of the county may be seen the tough bluish-black clay of the same general character as that above described, while the more sandy and more completely oxidized Kansan appears on the hillsides. The relation is well illustrated also near Churchville in the northwestern part of the county. The large granite bowlders to be seen by the track just north of the railroad station at Churchville are in the Kansan drift. Following down the ravine to the northeast other large bowlders appear on the side and even near the level of the valley bottom, but the trench itself is cut into a tenacious partly weathered clay. Here whatever Kansan may have previously mantled the sub-Aftonian drift is now largely removed and whatever may be left is now concealed beneath soil washed down the valley sides, with no Aftonian in sight. In one of the trenches south of Churchville no Kansan is in sight throughout the entire length of the ravine, though it may be found in a ravine to the west.

In the northeast half of the county exposures of Carboniferous are of frequent occurrence, but even here along the deeper portions of the valleys the Carboniferous is concealed by clay of the sub-Aftonian type. East of Milo and west of Lacona it lies along and beneath the ravines. On the county line southeast of Lacona it outcrops half-way up the hillside, just below Aftonian sand which lies below a thin Kansan.

While data of what lies beneath the Aftonian of the river valleys are scarce, it is apparently this same phase of clay that is found in the forty-five feet beneath the level of the river bed in the northeastern portion of Virginia Township, that fills at least a portion of the sixty-five feet down to the Carboniferous beneath the bed of North River in Greenfield Township, and that occupies the concealed valleys of Jackson,

Jefferson, Linn, Lincoln, and Greenfield townships, mentioned when describing the drift as a whole.

Such well records as are obtainable are not sufficiently detailed to be of service in determining what is sub-Aftonian as contrasted with Kansan, except where a definite Aftonian is so evident as to attract the attention of the one digging the well.

GRAVEL FROM THE SUB-AFTONIAN DRIFT, IN WELLS

Further evidence concerning the sub-Aftonian drift is recognized in the Aftonian gravel found in wells. In two of the forty-two wells in which Aftonian gravel was found the gravel is distinctly described as a coarse gravel, the stones of which are three or four inches in diameter. These are in Section 30 of Squaw Township and at the college well, the record of which has been given in detail. In the college well the sub-angular, polished, and striated condition of some of the pebbles gives conclusive evidence of glacial action, and the position at the bottom of an Aftonian deposit twenty-five feet thick indicates that these pebbles must have come from a sub-Aftonian drift.

A statement of the percentages of the different kinds of rocks among the pebbles of the gravel, at the base of the Aftonian deposits at the Simpson College well, may be found in the record already given. If this description be compared with that of the sub-Aftonian (pre-Kansan) pebbles of Muscatine County[1] in the eastern part of the state, one point of similarity and several points of difference are noted. In both places the limestone pebbles are the most numerous. In Warren County they are unquestionably local and probably not derived from a sub-Aftonian drift; in Muscatine County, at least a part of the limestone pebbles are local. The greenstones are the next most abundant, but they are more abundant in Warren County than in Muscatine County. The chert comes next in abundance at each place, and of material which is distinctly not local, it is present in about equal quantities in the two places. The quartz, the quartzite, and both dark and light granites are all relatively more abundant in Warren County than in Muscatine County. The schistose rocks, though few, are more abundant in Muscatine than in Warren County. Jasper is not found at either place.

If the statement concerning the Aftonian gravels gives the names of the rocks in the order of their relative abundance, the statement

[1] J. A. Udden, "Geology of Muscatine County," *Iowa Geological Survey*, Vol. IX, p. 336.

for Muscatine County,[1] "yellow chert, greenstone, white quartz, and red granite were the prevailing rocks," becomes the following for Warren County: greenstone, quartz, light-colored granite, and brown chert were the prevailing rocks.

GRAVEL FROM THE SUB-AFTONIAN DRIFT, IN OUTCROPS

In Section 16 of Jefferson Township (S.W. $\frac{1}{4}$ of the S.W. $\frac{1}{4}$) a bed of small Aftonian pebbles of dark chert and greenstone lies close to the Carboniferous and beneath Aftonian sand overlain by Kansan drift. The gravel was undoubtedly left from the erosion of the sub-Aftonian drift, but the drift itself is not visible at that point. Across the road, west of Section 30 of Virginia Township (but in Madison County), is a small deposit of gravel that is judged to be Aftonian because of the presence of a distinct Aftonian near by between Kansan and sub-Aftonian drifts. At numerous places along the roads in the northeastern half of the county and at some places in ravines, the Kansan drift thins out close to the Carboniferous. The pebbles and bowlders there found seem derived from the Kansan, but some of them may have come from the sub-Aftonian drift.

ON THE THICKNESS OF THE SUB-AFTONIAN NOW REMAINING

In the southern half of the county the sub-Aftonian drift frequently lies perhaps forty feet below the surface of the upland. In the northeastern half of the county the surface of the sub-Aftonian appears to lie much farther below the level of the upland, perhaps eighty feet. Assuming these estimates to be correct, substracting them from the present relief, and adding the approximate depth of the drift below the present river beds, and assuming that at some points the drift extends from the highest level at which it is found to the lowest level, we have an estimate of the present maximum thickness of the sub-Aftonian drift as follows:

	Feet		Feet
Linn	135	Jackson	175
Greenfield	145	White Oak	175
Allen	135	Otter	174
Richland	156	Belmont	175
Jefferson	140	Virginia	209
Lincoln and Greenfield	153	Squaw	142
Lincoln and Palmyra	153	Liberty	122
Union	130	White Breast	175

[1] J. A. Udden, "Geology of Muscatine County," *Iowa Geological Survey*, Vol. IX, p. 339.

On such an estimate the thickness of the sub-Aftonian (including possibly subglacial surface deposits) would now vary from 0 to 209 feet with an average maximum of 156 feet. This approximately coincides with the estimated present relief in each township; the average maximum thickness in the county as a whole is but six feet less than the average estimated relief (which is 162 feet). There is no evidence as to the amount eroded from the former surface of the sub-Aftonian drift, nor any evidence as to the character of that former surface, except as preserved in the present general plan of the drainage. No evidence whatever has been found of former kames or drumlins, the drift presenting the general appearance of a ground moraine from which all evidence as to former surface has been eroded.

This sub-Aftonian drift does not simply mantle the Carboniferous surface. In places it lies in Carboniferous valleys and in other places still exists as hills of sub-Aftonian drift, with no Carboniferous evident near at hand. In valleys cut in this deposit lies the present drainage plan, in almost complete disagreement with the preglacial drainage lines, with the sub-Aftonian thickest beneath the present upland above the preglacial valleys. With such a relation of the sub-Aftonain in position and in thickness, and with the Kansan drift in some places simply mantling the sub-Aftonian drift with little or no Aftonian interglacial deposits between, it is evident that the sub-Aftonian drift was thick enough to obscure the preglacial topography and to necessitate the development of a new drainage plan in Aftonian times.

THE AFTONIAN INTERGLACIAL DEPOSITS

THE NAME

The term Aftonian was first applied by Chamberlin[1] to the interglacial gravel lying beneath what is now called Kansan drift and over the sub-Aftonian near Afton Junction, Iowa.

THE GENERAL CHARACTER OF THE AFTONIAN DEPOSITS

Gravels of Aftonian age and peat bogs have since been found in other parts of Iowa and the deposits described, notably near Oelwein, Tama, and Council Bluffs. From the amount and state of preservation of the fossil contents of the gravels Calvin now thinks that both fossils and gravels were not laid down by floods at the beginning nor at the close of the interglacial interval, but "record conditions which existed at some time during the progress of the interval,"[2] a conclusion with which data with reference to the deposit in Warren County are in full accord.

In Warren County the Aftonian deposit may be divided into two portions, a lower portion consisting of gravel and stratified sand, and an upper portion which in the college well appears to be a low-ground deposit like old soil, but in other places on higher ground there is a fine sand; so that the deposits either change from a gravel into an old-soil-like deposit above, or grade from a gravel or coarse sand below into a finer sand above. The lower portions of the stratified sand contain layers of old soil and bands of oxide of iron, marking former surfaces, the whole resting unconformably upon the sub-Aftonian, or upon the Carboniferous where preglacial deposits and the sub-Aftonian have been eroded.

An old-soil-like deposit grading back and forth from black to light blue, with its bands of moss and black dirt, is minutely described in the record of the Simpson College well already given.

Thick beds of coarse gravel like those to be found at Afton Junction are not found in the county, though a small outcrop may be found a few feet west of the county line at Section 30 of Virginia Township. Deposits with fragments of trees have been found in places that are probably Aftonian, but in general the Aftonian in the upland of the county does not contain evidence of an extensive forest. Such evidence

[1] T. C. Chamberlin, Editorial, *Journal of Geology*, Vol. III (1895), p. 272.

[2] S. Calvin, "Present Phase of the Pleistocene Problem in Iowa," *Bulletin of the Geological Society of America*, Vol. XX (1909), p. 138.

seems confined to parts of the lower Aftonian water courses. The total absence of wood in the twenty-five feet of Aftonian in the college well is noteworthy.

VARIOUS EXPOSURES OF THE AFTONIAN

The exposure of the Aftonian half a mile east of New Virginia will be mentioned first because of the relation there evident. The section is here repeated in full:

1 ft. Soil, containing pebbles to within two inches of the surface.
1 ft. Gravel, a surface wash.
5 ft. Clay, yellowish, very few pebbles, bluish in a trench near by. Later erosion revealed two bowlders each a foot in diameter, within the body of the drift. Kansan drift
7 in. Sand, fine, mostly white but somewhat stained by iron oxide. Top of Aftonian
½ in. Sand, deeply stained to reddish brown.
3 in. Sand, fine, black.
7 ft. Sand, fine, no stratification evident, reddish brown where damp, light yellowish where dry.
5 in. Sand, stratified, cemented by iron and calcium carbonate. Bottom of Aftonian
6 in. (Exposed.) Clay, bluish black, with small pebbles of greenstone, white quartz, chert, and granite. Sub-Aftonian
(In tests with acid at perhaps a dozen different places this is the only locality where the sub-Aftonian effervesced at its surface.)

In the railroad cut at New Virginia station the fine sand appears within ten feet of the top of the cut. In Section 7 of Squaw Township (S.E. ¼ of the S.E. ¼) six inches of sand stained deeply by oxide of iron lies immediately beneath a black layer-like old soil and rests on a clay that is undoubtedly sub-Aftonian. At Igo's farm previously mentioned (Section 18) a deeply stained brown sand lies beneath the general body of the sand. In the valley southwest the same relation is also evident, the entire relation emphasizing the fact that here the sand mantles a hill of sub-Aftonian drift. By the roadside a mile southeast of St. Marys and at the south end of the railroad cut at Churchville are deposits of this fine sand, though at present both deposits are concealed. In a ravine near the latter place (the S.W. ¼ of the S.W. ¼ of Section 16, Jefferson Township) and resting on three feet of Carboniferous shale, decomposed coal, and weathered sandstone, lies a deposit of stratified sand and gravel stained with oxide of iron, varying from two to ten feet in thick-

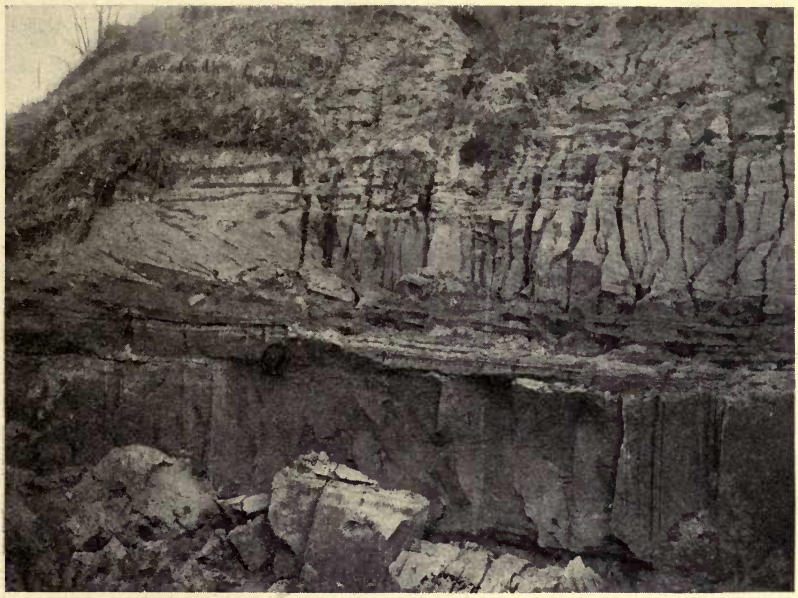
ness, above the highest level of which lies a bowlder about two and a half feet in diameter—a Kansan bowlder. The numerous small rounded pebbles near the base are, of course, from the sub-Aftonian drift, but that drift itself is not visible at this point.

AFTONIAN SAND AND GRAVEL

An exposure of Aftonian sand and gravel may be found in Section 16 of Jefferson Township (S.W. $\frac{1}{4}$ of the S.W. $\frac{1}{4}$). Here, resting on three feet of Carboniferous shale, decomposed coal, and weathered sandstone, lies a deposit of sand, thickness not known because of slumping, above the highest level of which lies Kansan drift partially imbedded in which is a bowlder about two and a half feet in diameter. At the base of the sand (back of the hammer) is a thin deposit of small pebbles (dark chert and greenstone). There is nothing left in sight of the sub-Aftonian drift from which the pebbles were derived.

At the Avon gravel pit in Polk County just north of Allen Township, a broad extent of Aftonian sand (continuous with the Aftonian sand found in all the river valleys of the county) is close to the surface in the low terrace generally extensively devoted to the cultivation of watermelons. At one point the sands have been excavated for railroad ballast. Across Allen, Richland, and Union townships are other numerous exposures, the most noteworthy of which are in Section 24 of Rich-

land Township (S.E. ¼ of the N.E. ¼) and the northeastern part of Section 3 of Union Township (S.E. ¼ of the N.E. ¼). While these sands rest in part on the Carboniferous and in part upon a sub-Aftonian drift which, so far as there is evidence, is thin, the surface of these extensive tracts of sand generally grades up into the loess without an intervening Kansan drift, but Kansan drift is found on the hillsides, and in some places about the sand.



AFTONIAN SAND

In Section 28 of Richland Township (S.E. ¼ of the N.E. ¼) are the thickest deposits of Aftonian sand to be seen in the county, about twenty-three feet appearing both in the road and in the ravine near the top of the hill. The direction of the view is southeast. The thick stratum near the bottom of the picture is No. 5 of the description in the text.

The deposit in Section 24 of Richland Township is the thickest deposit of Aftonian sand to be seen in the county. The deposit as a whole presents characteristics that are similar to what is found northeast of New Virginia. The lower portion has various bands of sand stained with oxide of iron, alternating with unstained portions and with other portions containing an admixture of black dust. The upper portions are free from these alternations.

Feet	Inches	No.	
2	3	8	Loess, sandy in principal part of exposure, clayey farther east; grading from sand up into loess in an excavation at a house close by on the opposite side of the road.
7		7	Sand, fine, light colored, horizontal.
5		6	Sand, fine in places, cross-bedded in eastern part of exposure, beds dipping southeast; horizontal in western part.
4		5	Sand, fine, gray, closely compacted, and somewhat cemented.
1	10	4	Sand, fine, upper three inches red, with half an inch of black included; alternating red and gray below.
	4	3	Sand, fine, black and gray above, reddish brown below.
3		2	Sand, fine, brownish gray, horizontally bedded.
?		1	Not exposed.

Section of Aftonian sand, Section 24 of Richland Township (S.E. $\frac{1}{4}$ of the N.E. $\frac{1}{4}$).

AFTONIAN SAND

The location is the same as that given in the preceding illustration, but the direction of view is east. Stratum No. 5 is near the middle of the picture.

All of the strata are of fine sand. The very evident lamination (in Nos. 2 and 4) is not due to marked difference in the size of the sand

grains but to the difference in the color of the material along with the sand. The layers of dark material are not layers of soil formed *in situ*, but of dark material deposited by the wind, as dust deposited by the wind may now be seen by the roadside, only in this ravine the dust is more sandy than that ordinarily found by the roadside. All is closely compacted. No. 5 breaks away in large blocks that roll to the bottom

AFTONIAN SAND

Aftonian sand outcropping in a road that had not been recently worked. (The N.E. ¼ of the N.W. ¼ of Section 27, Allen Township.)

of the ravine. No. 6 is not cross-bedded in the direction of the slope of the hill, nor in the direction of the drainage of the larger ravine of which this smaller ravine is a branch, but in the opposite direction, the southeast, the direction of transportation by a prevailing wind blowing from the northwest across the heavy deposits of sand near the mouths of North and Middle rivers and along the valley of the Des Moines. While this is the direction in which the Des Moines River flows, the deposit is on the edge of the upland, above the level of the sand found near Avon. The Kansan drift is above it to the north, east, and south.

Two miles south of Indianola (S.W. ¼ of the S.W. ¼ of Section 6, Otter Township) a deposit of sand at least six feet thick was exposed at one time in the side of the river trench, the surface of the deposit lying about four feet below the surface of the bottom land and about twelve feet above low water in the river. Between the railroad bridge and the wagon bridge south of Ackworth sand lies on the sub-Aftonian drift about six feet above the usual level of low water in the stream and extends south as a considerable deposit in the side of the hill. Southeast of Milo it forms a bed eight feet thick on the hillside in the southeastern quarter of Section 27 (Belmont Township) and supplies the larger part of the sand washed into ravines to the south. In White Breast Township it forms a conspicuous deposit at the church and cemetery (Section 36), where it overlies the sub-Aftonian drift at about the middle of the west slope of the hill and is overlain by a thin deposit of Kansan drift in the cemetery. The relation of all these deposits beneath near-by Kansan and above sub-Aftonian drift marks them as Aftonian.

Along all the rivers it forms a continuous deposit extending a few feet beneath the beds of the streams, evidently marking the lowest lines to which Aftonian erosion proceeded. With the aid of an over-deposit of later material it forms the low terrace along the rivers, best developed near Avon. Tongues of sand now extend from the upland down beneath the present soil of the large ravines to the sand of the river valleys.

FOSSILS[1] FROM THE AFTONIAN

In five well records wood is described as with the gravel or with sand closely associated with the gravel. In four places bones of animals were discovered: At Avon several years ago workmen in the gravel pit unearthed a tusk and several large bones thought to be of a mastodon (reported by Mr. John O. Baker, engineer), and later, fragments of other animals (reported by Mr. William T. Rich, conductor). One of these bones was a metapodial of some animal like a buffalo or ox, and one a vertebra which is thought to be of a deer. In Section 20 of Richland Township Mr. F. H. Stack while digging a well found at the bottom of it a bone four inches long which he thought came from the foot of some animal like a wolf, and sticks of brush that had been burned, a

[1] The "Aftonian Mammalian Fauna" is described by Professor Calvin in *Bulletin of the Geological Society of America*, Vol. XX, pp. 341–56.

On the identification of plants found in Aftonian peat see T. H. Macbride, "A Pre-Kansan Peat Bed," *Proceedings of the Iowa Academy of Sciences*, Vol. IV (1896), pp. 63–66; and T. E. Savage, "A Buried Peat Bed in Dodge Township, Union County, Iowa," *ibid.*, Vol. XI (1903), pp. 103–9.

part having been converted into charcoal. From Section 29 of Lincoln and Palmyra townships Mr. Herbert D. Perry brought in three specimens all of which are broken and worn. One is a first vertebra (atlas) five and three-fourths inches across; another, a lumbar vertebra $5 \times 4\frac{1}{2}$ inches across and $2\frac{1}{2}$ inches thick. These were found ten or twelve feet from the surface in a ravine where digging was in process for a bridge pier. In Section 19 of Liberty Township ten feet below the upland Mr. George Leeper in digging a well came across a thigh bone 3 to $3\frac{1}{2}$ feet long, and a rib.

None of these specimens have been seen by the writer excepting those brought in by Mr. Rich and by Mr. Perry, all of which are now deposited in the museum of Simpson College. Those brought by Mr. Rich were sent to the University of Iowa for identification.

THE SOURCE OF THE MATERIAL

Undoubtedly a considerable proportion, if not the larger part, of the Aftonian sands and gravels found away from the river valleys was washed out of the sub-Aftonian drift. That pebbles of the size of some of those found near Afton Junction did lie in the sub-Aftonian drift is evident from an occasional pebble and cobble found in it now, and evident also from the gravel found at the bottom of twenty-five feet of Aftonian in the college well. Much of the sand and gravel generally in the county is so coarse and so bedded as to preclude the possibility of any agency except that of water, which must have transported away the finer material and redeposited the coarser during the general progress of the erosion of valleys in the sub-Aftonian. Such material could not have been left in its present position by wash from a receding sub-Aftonian ice sheet, for the sands and gravels lie along valleys eroded in various directions in the sub-Aftonian, and not along lines which extend across the county north and south, independently of the present general lines of erosion. For the same reason they could not have been deposited in their present relation by water from an advancing Kansan ice. The later ice sheet known as the Wisconsin could scarcely have interfered seriously with the drainage from the county, for that ice sheet did not push south of Des Moines, and the chief drainage line between the Wisconsin ice sheet and Warren County (the Des Moines River south of Des Moines) had already been established.

The twenty-five feet of old-soil-like material found over the gravel in the Simpson College well is of such a character as to suggest derivation from the sub-Aftonian clay, perhaps by gradual wash from higher

ground and deposition on lower ground, much as at the present day the soil is gradually washed from the higher slopes to the lower ones where in places it forms deposits as much as six feet thick of a rich black loam. The several thin layers of peatlike growth suggest that the deposit may have been formed in that portion of Aftonian time in which the thicker peat beds found near Oelwein and Tama were formed. It is apparently to this same horizon that the gas-producing well in Madison County, about three miles west of Churchville, belongs.

The fine sand in thin bands in the old-soil-like deposit and also scattered through the other portions of it, the fineness of some of the other deposits, the position of beds of fine sand at least associated with Aftonian along the brows of hills south of each of the rivers and on hilltops where there is no evident source for the sand by water erosion and deposition, and the cross-bedding noted (Section 24 of Richland Township), opposite to drainage but coinciding with the direction of a prevailing wind, suggest the possibility of local eolian action; but such an interpretation seems out of harmony with descriptions of Aftonian deposits in other places where the deposits are not in the least of eolian origin.

It should be noted that the sequence of deposits in the Simpson College well coincides with the general relation of a coarser lower portion to a finer upper portion found in various parts of the county; and indicates that a time of marked erosion, accompanied by re-deposition of the gravel, was followed by a time of marked deposition in which the old-soil-like material in the well was deposited, and possibly at the time when a portion of the sand in other parts of the county was deposited. Such a relation of a time of marked Aftonian erosion followed by a time when the deeper portions of valleys were clogged, seems to represent two marked divisions in Aftonian time for this part of the country.

AFTONIAN RELIEF

The greatest Aftonian relief must have been at a time when the trenches formed by erosion had reached the lowest levels of which there is now evidence, while at least portions of the sub-Aftonian surface had as yet suffered little erosion. The lowest level is approximately ten feet below the present stream beds. The highest elevations could not have been lower than the present highest portions of the Carboniferous and the present highest portions of the sub-Aftonian drift. How much higher the highest portions of the hills actually were at the time we cannot now tell, but an estimate of the relief can be made that will be nearly

enough correct for a fair comparison with the amount of present relief in the same townships. This is obtained by adding to the present relief ten feet for the estimated depth of Aftonian deposits below the present beds of the streams, and subtracting thirty feet for the average level of the sub-Aftonian hills below the present level of the upland.

	Feet		Feet
Linn	110	Jackson	150
Greenfield	120	White Oak	160
Allen	120	Otter	169
Richland	166	Belmont	170
Jefferson	120	Virginia	184
Lincoln and Greenfield	143	Squaw	117
Lincoln and Palmyra	143	Liberty	117
Union	120	White Breast	170

Estimate of early Aftonian relief based on assumptions stated in the text.

While in the later portions of Aftonian time the valleys were clogged to about the present level of the river beds, the upper portions of the Aftonian hills were probably still undergoing erosion in many places, though the level of the uplands would be reduced very slowly.

To obtain an estimate of the closing Aftonian relief over which the Kansan ice pushed its way, we may subtract ten feet from the preceding estimate of early Aftonian relief for the silting-up of the river valleys, and leave the estimated level of the Aftonian hills unchanged.

	Feet		Feet
Linn	100	Jackson	140
Greenfield	110	White Oak	150
Allen	110	Otter	159
Richland	156	Belmont	160
Jefferson	110	Virginia	174
Lincoln and Greenfield	133	Squaw	107
Lincoln and Palmyra	133	Liberty	107
Union	110	White Breast	160

Estimate of the closing Aftonian relief based on assumptions stated in the text.

THE KANSAN DRIFT

THE NAME

The drift which is uppermost in south-central Iowa, H. F. Bain has traced southwest and found to connect with the surface drift in Kansas where it had been known as the Kansan drift.[1]

THE GENERAL CHARACTER OF THE KANSAN DRIFT

The clayey portion of the drift thus named is of a bluish-black color where not weathered, with fine sand and minute pebbles scattered through it. Though impervious enough where thick to form a substratum for the water horizon above it, it is not so tenacious as the sub-Aftonian drift, and contains a larger admixture of sand, pebbles, and bowlders than is found in the sub-Aftonian. The surface weathers into a yellow clay, the yellow color being apparently due to the oxidation and hydration of the iron which the clay contains. The general character of the clay, the variation in it from its surface down, and the way it weathers along cracks, may be found minutely described in a preceding chapter on the record of the Simpson College well. It is along these cracks that sand sifts in from above, forming passage ways through which water from above can percolate to the Aftonian below where the Kansan is thin.

The distance from the surface of the Kansan that effervescence begins is variable. Where the Kansan is thin and rain water has opportunity to soak down through it and away, the drift is thoroughly weathered and does not now effervesce at all. Where ascending waters bring lime even the weathered portions of the drift may effervesce clear to the surface, as at a point half a mile east of New Virginia near a limestone region. Here cracks in the clay near by are lined and even filled with calcium carbonate brought by water moving horizontally and vertically. At the college well effervescence begins at the top of the unweathered portion three feet below the surface of the Kansan and continues to the base of the Kansan. It is not known how much of weathered Kansan may have been eroded away, but at present leaching

[1] H. F. Bain, "Relation of the Wisconsin and Kansas Drift Sheets in Central Iowa, and Related Phenomena," *Iowa Geological Survey*, Vol. VI, p. 464; also T. C. Chamberlin, "The Classification of American Glacial Deposits," *Journal of Geology*, Vol. III, p. 271.

is not favored at this point. Here percolation downward through the Kansan is impossible and lateral movement is slow.

The pebbles and bowlders in the Kansan are of all sizes up to three and four feet in diameter. These very resistant bowlders are of light-colored granite, red quartzite, and greenstone, but the largest bowlders found are granites and red quartzites, not greenstones. Among the bowlders are dark granites which are soft through decomposition of ferromagnesian minerals. Where observed these lie in the weathered portion of the Kansan. The accompanying table will serve to illustrate a grouping of pebbles that may be found:

Granite, not decomposed	39
Granite, decomposed	2
Quartzite, red	13
Quartzite, white	9
Quartz	2
Greenstone	22
Chert	1
Hornblende schist and other hornblende rocks not granite	2
Sandstone, foreign	4
Sandstone, local	5
Limestone	1
	100

Table of percentages of the different kinds of rocks among the pebbles of the Kansan drift found just south of the fairgrounds at Indianola (S.E. $\frac{1}{4}$ of the S.E. $\frac{1}{4}$ of Section 26, Lincoln and Greenfield townships).

It is not possible to compare the distribution of pebbles in Warren County with the distribution in counties to the north and to the south since no records as to the distribution are to be found for counties in these directions; but the records prepared by Professor J. A. Udden give opportunity to compare the percentages of the different kinds of rocks among the pebbles of the Kansan drift of Warren County with the percentages found in the eastern and in the western parts of the state.[1]

Omitting the sandstone, limestone, and dolomite, all of which are here treated as of local origin, and reducing the remainder to a common

[1] For the eastern part of the state: J. A. Udden, "Geology of Clinton County," *Iowa Geological Survey*, Vol. XV, p. 417; "Geology of Muscatine County," *ibid.*, Vol. IX, p. 316; "Geology of Jefferson County," *ibid.*, Vol. XII, p. 427.

For the western part of the state: J. A. Udden, "Geology of Pottawattamie County," *ibid.*, Vol. XI, p. 253. In this last report Professor Udden compares the percentages of pebbles taken from the lower, middle, and upper portions of the Kansan.

basis of 100 per cent, the records of foreign pebbles from one to three inches in diameter are given in the accompanying table.

LOCAL MATERIAL OMITTED

COMPARISON OF THE PERCENTAGES OF DIFFERENT KINDS OF ROCKS NOT LOCAL FOUND AMONG THE PEBBLES OF THE KANSAN DRIFT IN WARREN COUNTY WITH THE PERCENTAGES FOUND IN THE EASTERN AND WESTERN PARTS OF THE STATE

	Eastern. Average of 1, 2, and 3	Central. Warren County	Western. Pottawattamie County
Granite	27.5	45.6	25.7
Quartzite, red and purple	9.1	14.5	4.3
Quartzite, white	0.0	10.0	3.9
Quartz	5.6	2.2	5.4
Greenstone (largely diabase)	41.6	24.4	37.2
Chert	8.3	1.1	11.5
Hornblende schist	1.8	2.2	1.9
Jasper	0.0	0.0	0.2
Other kinds of rocks	6.0	0.0	8.7
	99.9	100.0	98.8

No. 1, Clinton County; No. 2, Muscatine County; No. 3, Jefferson County.

According to this table the granites are more abundant in the center than in either the eastern or the western portions of the state, but from other records not here given they are distributed somewhat uniformly. Counting the purple quartzites with the red, since in other counties than Warren the purple quartzites are not mentioned separately, these colored quartzites are found to be more numerous in the central part of the state (Warren County) than in either the eastern or the western parts of the state. A comparison of the quartz and white quartzites does not seem advisable. Many of the stones that seem to the naked eye to be quartz are found when examined under a magnifier to be completely cemented quartzites. The greenstones are less abundant in Warren County than in either the eastern or the western parts of the state. The chert is more abundant in the western part of the state than in the eastern part of it. At the point selected in Warren County the chert is less abundant than in either the eastern or the western part, but at other points in Warren County the chert is even more abundant than in the western part of the state.

Whether such comparisons express general relations through the state cannot now be ascertained. They may serve as an aid in tracing the Kansan bowlders back to their original sources. For this purpose

certain of the bowlders seem more suitable than the others. The pieces of copper,[1] at least three of which have been found in Warren County, and other pieces reported from other counties, seem to be the best except that they are rare. Other distinctive rocks are the red and purple quartzites; also hematite, none of which happened to be among the pebbles here listed.

THE KANSAN DRIFT CONTRASTED WITH THE SUB-AFTONIAN DRIFT IN COMPOSITION AND TOPOGRAPHY

The Kansan drift differs from the sub-Aftonian drift in the presence in the Kansan of a larger proportion of grit, pebbles, and bowlders. The Kansan weathers from a blue to a yellow, while the sub-Aftonian often presents a dark appearance close beneath the wash of iron oxide that often covers its surface, and, where weathered, weathers into a brown clay of the same tenacious character as that of the unweathered mass. The characteristic bowlders of the Kansan are red quartzite and greenstone together with dark decomposing granites, while characteristic pebbles of the sub-Aftonian are light granites and white quartz. It is noted that the abundance of grit, pebbles, and bowlders in the Kansan is due not alone to the transportation of such material from a distance but also and probably largely to the incorporation of the sands, gravel, and bowlders found on the surface of the sub-Aftonian as the Kansan ice pushed its way southward.

The topography is also different in the portions of the county where the Kansan is found to be thick and the sub-Aftonian not conspicuous, from the topography where the Kansan is thin and the sub-Aftonian deeply eroded. Where the Kansan is thick the Aftonian valleys are still wholly or partially filled with Kansan not yet eroded, and the hillsides wash easily so that the hills are not so steep sided as where the Kansan is thin and the sub-Aftonian deeply exposed. Other factors than

[1] If the copper came from the Lake Superior region it must have first been transported west or southwest by an earlier ice sheet (Jerseyan?) so that the Kansan ice was able to secure it and transport it south or southeast to Warren County. This raises a question as to the exact contemporaneity of the earliest known Labradorean and Keewatin ice sheets. If the copper was not first transported westward then it is possible undiscovered deposits of copper have existed and may still exist somewhere northwest of Warren County toward the Keewatin region.

No striae have been found in the county, but at Peru, in the eastern part of Madison County, striae are reported to extend N. 27° W.: F. A. Brown, "A Contribution to Madison County Geology," *Proceedings of the Iowa Academy of Sciences*, Vol. XIII (1906), p. 204. Whether the striae were caused by Kansan or by sub-Aftonian ice is not discussed.

difference in structure of these two deposits are, however, involved; for, on the south-facing surfaces of the river valleys the sub-Aftonian drift, like later deposits, has been eroded to a more gentle slope than the north-facing surfaces; and the drift itself may have been deposited in greater thickness above the preglacial drainage lines in the southwest parts of the county than it was in the northeast parts. The distance from the master stream of the region (the Des Moines River) does not seem to be involved, for the difference in relief between that of Richland Township, nearest the master stream (186 feet), and that of Virginia Township, farthest from the master stream (204 feet), does not seem sufficient to account for the difference in topography. If the total fall in the upland surface (about 188 feet) be compared with the total fall along the bed of South River (186 feet), the difference is very slight indeed (two feet). Neither is the difference in the resistance of the Missourian limestone as compared with the resistance of the Des Moines shales and sandstone involved, for this difference in topography is noted in townships both to the north and to the east of Virginia Township in which the Missourian limestone is not found.

Both where the Kansan is thin and where it is thick the entire upland surface is completely drained, no natural ponds whatever remaining outside of the river bottoms.

THE KANSAN DRIFT CONTRASTED WITH THE WISCONSIN DRIFT IN COMPOSITION AND TOPOGRAPHY

The Kansan drift differs from the Wisconsin drift, the nearest overlying drift to the north, in the amount of stratified sand and gravel contained. The Kansan contains comparatively few masses of sand; such as have been found are bowlders of Aftonian sand included in the lower portion of the Kansan. The Wisconsin drift contains a considerable amount of stratified sand and gravel.[1] The surface of the Kansan is weathered to a much greater extent than the surface of the Wisconsin.

Weathered bowlders are common in the Kansan, especially in the upper portions of it. Among these are the dark granites that can be crushed in the hand. The bowlders of the Wisconsin drift are in general comparatively unweathered.

In topography the area where the Kansan drift is at the surface stands in marked contrast to the area where the Wisconsin drift is at the

[1] S. W. Beyer, "Geology of Boone County," *Iowa Geological Survey*, Vol. V, p. 304; "Geology of Carroll County," *ibid.*, Vol. IX, p. 94; "Geology of Story County," *ibid.*, Vol. IX, p. 203; H. F. Bain, "Geology of Polk County," *ibid.*, Vol. VII, p. 344.

surface. On the Kansan upland the drainage is complete, there being no swamps nor ponds. The topography is somewhat past maturity. On the Wisconsin there are undrained swamps and ponds occupying the depressions of a gently undulating surface varied by a few kames and gravel trains[1]—a youthful glacial topography.

THE DISTRIBUTION AND THICKNESS OF THE KANSAN DRIFT

The weathered phase of the Kansan is found in the upland throughout the county, along the hills of which it outcrops in conspicuous bands of yellow clay mixed with sand, bowlders, and pebbles. In the west range of townships it forms a veneering apparently thin over the tops of the Aftonian, covering hills of sub-Aftonian drift. Along the southern tier of townships it supplies material for the gravelly noses of divides. In the rest of the county generally it forms conspicuous bands of yellow clay mixed with sand, bowlders, and pebbles and stained by an oxide of iron. It is at this horizon that the large bowlders appear here and there in the fields. Much of the Kansan is so thin as to be completely weathered, simply mantling an Aftonian topography. Well records obtainable are not generally sufficiently detailed to make it clear just what is Kansan and what is sub-Aftonian, but from the character of the clay found in the deeper ravines it appears that the deep-lying clay in the preglacial valleys throughout the county is sub-Aftonian and not Kansan, especially in the western portion of the county; but it is clear that Kansan drift fills some of the minor Aftonian valleys, for at the Simpson College well the Kansan drift is fifty-seven feet thick, concealing a valley of which there is no evidence whatever in the present topography. On present evidence the thickness of the Kansan varies from 0 to 75 feet with an average that cannot be stated, though from relations in the county generally it appears to be nearer one-third of the maximum thickness found than it is two-thirds of that thickness. From the upland it frequently extends down the sides of ravines. Along the deeper ravines it is frequently wanting, so that one may follow the exposures of sub-Aftonian from the deeper-lying portions and trace it without a change to the dark clay beneath the washed soil in the shallower upper portions of the ravine, as in ravines between Liberty Center and Lacona, and one ravine south of Churchville. In the two ravines mentioned it appears that the Kansan may never have been present, for there are no traces of bowlders and pebbles that would have been

[1] Personal observation; also H. F. Bain, "Geology of Polk County," *Iowa Geological Survey*, Vol. VII, pp. 344–50.

left if the clay, sand, and smaller pebbles had been washed away, nor is there any stratified sand and gravel visible in the washed soil near the trenches. The clay presents the character of the sub-Aftonian drift.

In the northeastern half of the county the sub-Aftonian drift is largely absent from Carboniferous upland, the Kansan resting directly upon the underlying Carboniferous. In places the Kansan also is absent, allowing the Carboniferous to appear at the surface. This is seen at the west edge of "The Quarries" in Section 22 of White Oak Township.

The Kansan thus mantles the Aftonian topography, concealing some of the minor valleys but not the larger ones. Extending as it does irregularly down the sides of the hills of sub-Aftonian drift with its generally slight covering of Aftonian, and outcropping at various intervals, it presents a deceitful appearance of greater thickness than it really has, and conceals the sub-Aftonian drift.

THE POST-KANSAN DEPOSITS

THE POST-KANSAN DEPOSITS FOUND IN THE SIMPSON COLLEGE WELL, AND THE RELATION OF SUCH DEPOSITS THROUGHOUT THE COUNTY

In the previous chapter on the record of the Simpson College well may be found a minute description of the material that is post-Kansan. In that description the following sub-divisions should be noted:

a) 2 ft. Soil, a black loam (loess and humus).

b) 12 ft. Loam, the subsoil, brownish, porous, a mixture of clay and microscopic particles of quartz, streaked with brownish oxide of iron in rootlike tubes and with very thin layers of a dark-brownish sand; entirely free from pebbles.

c) 6 ft. The upper three feet grading from the loam above into a dense blue clayey deposit below free from sand and pebbles and impervious to water (3 feet).

d) 10 ft. Light grayish blue for eight feet, with more grit in the upper portion than in the more impervious deposit above and with traces of a brown oxide of iron.

The first four feet of the eight caved badly, large water-soaked masses (wet from below upward) scaling in vertical sheets from the side of the well, as the uppermost phase of the loess does by the roadside. The lowest four feet of the ten is grayish in color and with grayish and brown sand scattered through it.

In the middle and lowest portions of this deposit two pebbles were found (one at 26 feet and one at 30 feet), but each was less than half an inch in diameter.

e) 2 ft. Sand, pure, brown and gray, varying in thickness from 0 to 4 feet in wells located a few feet from each other.

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32 ft.

The deposit as a whole corresponds to that which is commonly found throughout the upland in the central portion of the county and at places even in lower ground. The black soil here found is of average thickness. In the county as a whole it varies from 0 thickness, where recent erosion is pronounced upon the hillsides, to four and even more feet in thickness along the lower slopes of hills and at the heads of ravines toward which a portion of the soil has been transported. Along the sides of the hills the character of the soil varies in composition, due to the admixture of sand and gravel washed out of various deposits. The

brownish porous subsoil (*b*) is also like that commonly found throughout the uplands and considered loess. The third division (*c*) lacks the loose porous structure of the loess above, so that it forms a layer impervious to water. This denser deposit is judged to be of loess that has settled in surface pools, much like the deposits now found in shallow depressions occupied by water along the river bottoms. The deposit

RECENT EROSION

A quarter of a mile south of the fairgrounds west of Indianola (S.E. ¼ of the S.E. ¼ of Section 26) a trench about four feet deep was formed in two years where there had been a wagon track.

varies in thickness. It is sometimes found changed to a yellowish putty-like layer over water bearing lower loess and sand. The structure of (*d*) is distinctly that of loess, gray in color. This deposit is also found in wells and in some ravines in the central portion of the county, both in high ground and in low ground. The sub-loessial sand (*e*) at the college well is distinctly post-Kansan in age. In other places where the Kansan is not present the sand may be in part Aftonian, or where the entire Pleistocene deposit is now absent, may possibly even be preglacial.

The deposit as a whole mantles the Kansan surface to a depth of

from 0 to 30 feet, maintaining the level character of the divides and sloping down the surface of the larger ravines and the river valleys. It is now being trenched along all the upland as the ravines work headward. Statements of several of the old settlers, that trenches from 12

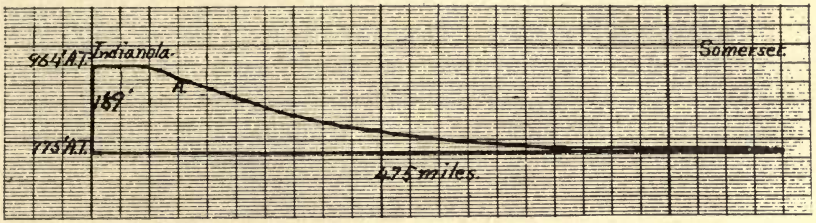
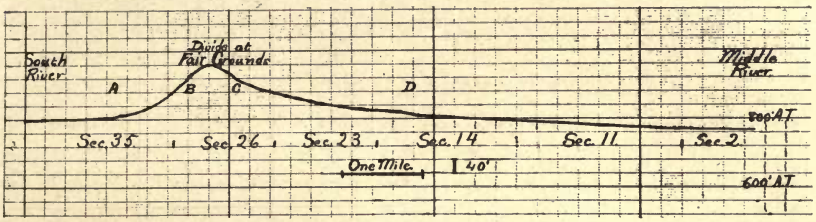


Diagram of profile along the ravine from Indianola to Somerset



A profile of the trench of a ravine from South River north to the fairgrounds at Indianola, thence down the trench of another ravine to Middle River, a total distance in a straight line of five and a half miles, but made seven miles by the windings of the trenches in the lower halves of their valleys. The change in grade at A is in part artificial. At B and C there is rapid headward erosion. At D there is a rapid fall of a few feet due to a thin layer of Carboniferous limestone which offers more resistance to erosion than is encountered in other parts of the trench. There are a few minor changes in grade too small to be represented in the diagram. The flood plain is evident for about half the length of each ravine. Note the unsymmetrical position of the divide.

For this profile I am indebted to Messrs. Fred H. Osborn and Leonard P. Dove, members of a class in geology under the instruction of the writer. The differences in elevation were obtained with a Y-level and the distances by pacing. The series was then connected with the known elevation of the Chicago, Burlington and Quincy station at Indianola.

to 16 feet deep have formed in ravines since their boyhood, together with the general appearance of the ravines and trenches, make it appear that the renewal of erosion has begun since the arrival of the white man, and is largely due to the breaking of the sod by cattle, and to cultivation

of the hillsides; and favored by replacement of the tall slough and prairie grasses by blue grass. The renewal of erosion is not referable to change in elevation.

ANALYSES—DISCUSSION

There are at hand three analyses of samples collected in the upland half a mile east of the college. These will give a chance to compare the composition of the loess just under the soil at the point (analysis No. 1) with that of the denser, yellow subsoil about four feet from the surface (analysis No. 2), and also with that of the blue phase of the deposit obtained about twenty feet from the surface (analysis No. 3).

ANALYSES OF LOESS*

	No. 1	No. 2	No. 3
Hygroscopic water	1.70	3.76	8.08
Combined water	3.33	6.89	5.48†
Silica (SiO_2)	72.24	63.31	66.779
Alumina (Al_2O_3)	12.58	16.51	19.525
Iron oxide as Fe_2O_3	4.02	4.06	0.72
Manganese oxide (MnO)	0.00	0.49	.....
Lime (CaO)	1.40	1.11	trace
Magnesia (MgO)	0.99	1.10	.....
Soda (Na_2O)	2.60	2.20	.....
Potash (K_2O)	1.54	0.96	.....
	100.40	100.39	100.584

* Samples No. 1 and No. 2 were collected by the writer and analyzed by Professor G. E. Patrick. The analyses were published in the "Geology of Warren County," *Iowa Geological Survey*, Vol. V, p. 357, and later republished in the report on clays, Vol. XIV, p. 546. Sample No. 3 was collected and analyzed by Professor L. A. Youtz and published in the *Proceedings of the Iowa Academy of Sciences*, Vol. III, p. 41.

H. A. Wheeler gives analyses of two samples of "gumbo," but I do not know whether the deposit corresponds to that in Warren County. (See *Missouri Geological Survey*, Vol. XI, p. 118.) Udden gives a table showing the percentages of different grades of coarseness in samples of loess and gumbo. (See *Iowa Geological Survey*, Vol. XI, p. 257.) About 5 per cent of the material found in what he calls gumbo is coarser than all the material which he found in the loess.

† Loss by ignition.

A comparison of these samples reveals a decrease in the percentage of free silica from the surface downward, an increase in the percentage of fixed silica[1] accompanied by an increase in the percentage of alumina (due to a higher proportion of clay) corresponding with the increase in denseness which is evident to the eye. The silica is greater in the blue phase (No. 3) than in the yellow phase above (No. 2). The iron oxide is about the same in Nos. 1 and 2 but much less in No. 3. It is because the quantity of iron in No. 3 is so small that this clay when

[1] The relation of the silica is stated by the chemists.

water soaked has a light-yellowish color instead of the deeper brownish red as in the yellowish phase above, where the iron is larger in amount. The absence of potash, soda, magnesia, lime (trace), and manganese, together with the absence of iron (in No. 3), makes it evident that the blue color is not due to the presence of undecomposed dark ferro-magnesian minerals. Neither can the blue color of the blue clay be due to the presence of iron carbonate,[1] for in the locality named, at least, the clay does not effervesce, nor do the analyses reveal the presence of any carbonate. The loss by ignition in No. 3 offers the only clue to the cause of the blue color. This includes both the combined water and the organic material, the former of which in the process of ignition would evaporate and the latter burn out. In Nos. 1 and 2, obtained in the oxidized and hydrated portions above, no organic matter was found. In No. 3 the loss by ignition was nearly as much as in No. 2, though the clay was denser and apparently equally exposed on the side of the clay pit. The loss seems largely due to the ignition of the organic matter; to which organic matter, therefore, the color of the blue phase seems to be due. The presence of such organic matter would keep the iron oxide in the ferrous state as long as percolating surface water failed to penetrate the deposit. The depth to this blue phase is near the depth to which the rain water percolates vertically from the surface through the general body of the loess where the ground is level. It is the depth at which the water was obtained (eighteen to twenty feet) in shallow wells in the upland prior to the drought of 1894, at which time it became universally necessary to sink all upland wells to a depth of twenty-eight to thirty feet.

[1] *Iowa Geological Survey*, Vol. XIV, p. 61, also pp. 70–71.

SUMMARY OF TOPOGRAPHIC HISTORY

The topographic history above described has recognized:

1. A preglacial topography wholly unlike that of the present, with drainage to which the present lines do not conform, in a country of essentially horizontal strata of different degrees of resistance to erosion in which a complete system of drainage was developed, the valley lines with preglacial sand and mud lying from 45 to 65 feet below the beds of the present streams, and the relief approximately like that of the present.

2. A nearly complete obliteration of the preglacial topography by the sub-Aftonian drift.

3. The development of a new topography in which only the main lines were affected by the larger of the preglacial valleys, accounting for the peculiar course especially of South River. The topography thus developed to at least maturity is the present one in all its major details (early Aftonian).

4. A partial silting-up of valleys by material washed from the hills, the sand along the rivers, now overlain by recent deposition, forming the basis of the low river terrace (late Aftonian).

5. The at least partial mantling of the late Aftonian topography by drift (Kansan) that obliterated the minor details of the late Aftonian topography but did not obliterate the major details.

6. The working-over of material on the surface of the Kansan, and of other material exposed, as erosion proceeded, accompanied by considerable deposition of loess, all of which has continued to the present, though under varying conditions.

7. Renewed erosion and waste of upland following changes brought about by man.

It should be observed that this history is of a region outside of that occupied by any of the post-Kansan sheets of drift, and of a region where drainage outlined as above stated in Aftonian time protected the county from wash from melting ice later than Kansan in age.

APPENDIX

The construction of a new railroad line from Des Moines to Allerton (studied in 1912) has given a series of excellent exposures through the upland, better than ever before available in this portion of the state. In some of these places the "gumbo" presents an unbroken sequence down into a distinct bowlder bearing Kansan drift; in places a few pebbles are found in the gumbo even up to two inches in diameter, though such pebbles are extremely rare; and in places there is washed sand and gravel instead of gumbo.[1] The evidence is conclusive that this deposit, long known as the gumbo of southwestern Iowa, is an upper portion of the Kansan drift laid down in the closing stages of the Kansan ice invasion. In accordance with this discovery, *c*, *d*, and *e*, pp. 7 and 37 should be transferred from the description of Post-Kansan deposits to the description of Kansan Drift, p. 30. The exposure at the railroad cut, New Virginia, and at Igo's farm (p. 15), at the cemetery (p. 26), and also that illustrated on p. 25, belong to this same horizon.

[1] John L. Tilton, "A New Section South from Des Moines, Iowa," *Science*, 1913; "A Pleistocene Section from Des Moines to Allerton," *Proceedings of the Iowa Academy of Science*, 1913. See also "Geology of Clarke County, Iowa," *Iowa Geological Survey*.

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