GEOLOGY OF STORY COUNTY.

BY

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CONTENTS.

INTRODUCTION.

LOCATION AND AREA.

Story county occupies the geographic center of the state, and comprises the usual sixteen congressional townships common to interior counties, containing approximately 576 square miles. It is bounded on the north by Hamilton and Hardin counties, on the south by Polk and Jasper, while Boone county bounds it on the west, and Marshall forms its eastern boundary. Geologically the county is of some interest, for, while lying wholly within the area credited to the coal measures, it is now known that a detached area of the Lower Carboniferous of considerable dimensions appears in the western portion. And it is, perhaps, worthy of mention that the county serves to connect areas already reported on; Boone, in volume V, and Polk and Marshall, in volume VII of this Survey; while the field work in Hardin is practically completed.

PREVIOUS GEOLOGICAL WORK.

In the early history of the state the area under consideration possessed little to attract the civilian, the geologist or the physiographer. The immature character of its surface, with its numerous ponds and marshes and its general prairie character, proved uninviting to the husbandman familiar with the wooded hills and dales of the east. The all but perfect concealment of the stratified rocks by the ice *debris*, and the general surface monotony, did not appeal to the pioneer geologist as the "land of promise." The chief thoroughfares across the continent lay outside its borders, and hence

specific geologic mention comes late in the history of the state, although the county was within the general area mapped by Nicollet as early as 1841.

The classic works of Owen and Hall, who laid the foundation for all subsequent geologic work in the Mississippi valley in general, and in Iowa in particular, possessed but a word concerning either the physical features or the natural resources of Story county.

The first specific reference to the geology of the county is to be found in White's* Geology of Iowa. Here the beds exposed along Onion creek are mentioned, and definitely referred to the Saint Louis and dismissed without further comment. In his discussion of moraines White makes mention of the ridges and knobs in northwestern Story, and intimates their probable morainal character.

A decade later Upham† visited the field, and definitely mapped the Gary moraine across the morthwest corner of the county.

Aside from the above reports, McGee‡ records certain observations concerning the Skunk river system, and considerable data as to the details of the region have been collected and recorded by the students in the geological department of the Iowa State College.

PHYSIOGRAPHY.

TOPOGRAPHY.

The region is almost entirely included within the area covered by the last drift sheet, and is characterized by general topographic immaturity. There is an entire lack of concordance between the drainage lines and the salient features, as the streams have exerted very little influence in shaping the topography. The surface is gently rolling, and, when viewed broadly, departs very slightly from a plane. It is the

*Vol. II, pp. 259-260.- Des Moines, 1870.

†Ninth Annual Report Geol. and Nat. Hist. Surv. of Minnesota, pp. 288, et seq. Saint Peter, 1891.

‡Eleventh Ann. Rept. U. S. Geol. Surv., p. 357. Washington, 1891.

typical saucer topography so characteristic of the younger drift sheet.

When examined in detail the surface is notably scalloped by crescentic chains of ridges and kame-like aggregations, which suggest interrupted recession of the ice and tend to break the monotony of the general surface relief. The most noteworthy of these ridges is the Gary moraine, which crosses the northern portion of the county. The Gary moraine enters the county from Boone, about two miles south of the Hamilton county line, traverses Lafayette township from northwest to southeast, just below Keigley's branch, crosses Skunk river at Soper's mill, trends north of east and joins the Altamont moraine almost due east of Zearing. Spurs are given off in the form of concentric loops, the first of which passes west of Roland between Long Dick and Beaver creeks, a second appears between Roland and McCallsburg, and a third separates the latter place and Zearing, thus showing that the contraction of the ice tongue was not only longitudinal but lateral as well. The continuation of the outer ridge of the moraine to the westward is known as "Mineral Ridge," an outlying spur of which bears the name of "Pilot Mound."

The width of the morainal tract varies greatly. In the western half of the county the belt extends almost to Ames, indicating that the recession was extremely dilatory. In the eastern half the ridged portion varies from one to three miles, and the differential relief is less pronounced.

A second morainal tract enters the county near the middle line of Washington township, appears as mild ridges at Kelly, fades out toward the river, but reappears much accentuated in northern Union and in southern Grant townships, where kame-like aggregations are a prominent feature. It continues across Indian Creek and Nevada townships, turns southward and spreads out over New Albany and northern Collins townships and fuses with the Altamont. Maxwell hill, a marked eminence rising more than 100 feet above the surrounding country and lying immediately west of the town

of Maxwell, appears to be an outlying spur belonging to this system. This hill is more than three miles in length, averages from one-half to a mile in width, trends northwest and, as revealed by road cuts, is composed of more or less stratified sands and gravels. Only bowlders of small size are present, and the hill possesses the essential characters of the kame.

Outside of the morainal tracts, and away from the immediate vicinity of the larger streams, the surface is but little dissected. Chains of kettle holes and swales with a prevailingly northwest-southeast trend, connected only in the springtime or during seasons of protracted wet weather, and separated by complimentary systems of hummocks and ridges, the local inequalities seldom exceeding twenty or thirty feet, — these are the features which characterize the great interfluviatile and inter-morainal areas of the region. The majority of the secondary streams have cut back but a few furlongs, or at most but a few miles, into this maze of kettles and sloughs, while well defined channels of tertiary branches are usually measurable in rods only. The most vigorous topographic features are to be noted where the lateral tributaries break through from the water-sheds to the valleys of the major streams. In short, the valleys of the master stream and its largest confluents are encompassed by belts of broken land which comprise the most rugged features to be found in the region.

In the extreme southeastern corner of the county, outside of the Altamont moraine, is to be found a sample of erosional topography, where the physical features are not only in harmony with, but are the result of, the drainage lines. The area comprises scarcely more than a square mile.

The highest point in the county is on the Gary moraine near Summit, with an altitude of 1,075 feet, and the lowest level is reached on the flood plain of the Skunk, where that stream makes its exit from the county, at an elevation of 830 feet above tide.

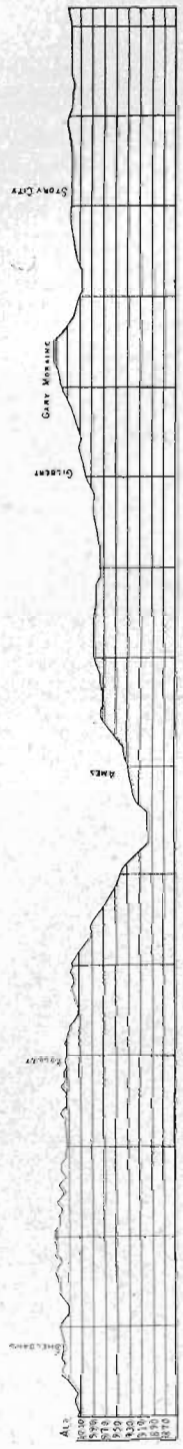


FIG. 16. Profile of the Chicago & North-Western railway.

In the subjoined table the elevations of the most important points in Story county are tabulated alphabetically.

Table of Elevations.

PLACE.	Altitude above tide water.	AUTHORITY.
Altamont moraine near Collins	1022	Barometer.
Altamont moraine near Colo.	1016	Barometer.
Ames	926	C. & N. W. Ry.
Bloomington	1041	Barometer.
Cambridge	854	C., M. & St. P. Ry.
Collins	997	C., M. & St. P. Ry.
Colo	981	C. & N. W. Ry.
Elwell	983	C., M. & St. P. Ry.
Gary moraine near Summit	1075	Barometer.
Gilbert	1003	C. & N. W. Ry.
Huxley	1031	C., M. & St. P. Ry.
Kelly	1035	C. & N. W. Ry.
Maxwell	866	C., M. & St. P. Ry.
Nevada	1005	C. & N. W. Ry.
Ontario	1005	C. & N. W. Ry.
Sheldahl	1042	C. & N. W. Ry.
Slater	1032	C., M. & St. P. Ry.
Story City	1022	C. & N. W. Ry.
Summit	1056	Barometer.

DRAINAGE.

The drainage lines are but poorly developed. The larger streams have apparently reopened, in part at least, pre-Wisconsin channels, and have taken on the aspect of mature streams. They are, nevertheless, characterized by a dearth of small tributaries. Undrained areas are everywhere common on the upland, and at many points can be found within a stone's throw of the bluffs which border the best developed valleys. In scores of sections which constitute the watersheds, the water which falls upon them, save during periods of very high water, cannot escape save through seepage, evaporation or tiling. Many of these ponds persist throughout the year.

Seven-eighths of the run-off of the region finds its way to the "Father of Waters" through Skunk river, while small areas in the southwest and northeast corners of the county contribute to the Des Moines and Iowa drainage systems respectively.

The Skunk River System.—As has been said, the Skunk river with its tributaries afford a convenient outlet for the surplus waters which fall upon the major portion of the county. The Skunk proper traverses the county in a general north and south direction, separating the area into two unequal parts. It enters the county from the north and, crossing back and forth the line which separates the western tier of townships, has a general southerly course until reaching Union township, where the stream veers abruptly eastward and then continues southward, dividing the township into east and west portions that are almost equal in area.

On physiographic grounds the stream is readily divisible into two parts. The first comprises the portion from the point where the river enters the county to the great bend

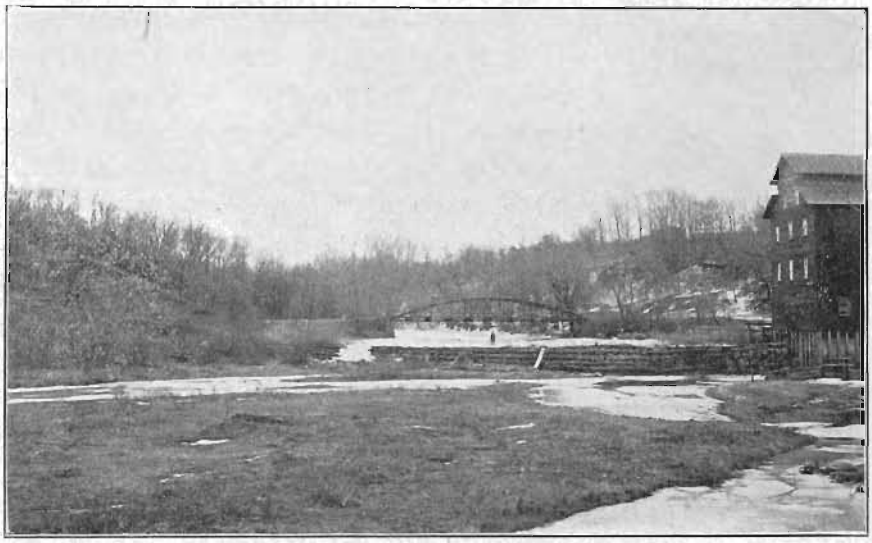


FIG. 17. Gorge on the Skunk river, at Soper's mill.

about two miles north of Ames, and is characterized by a comparatively narrow valley, which in places, as at Soper's and Hannom's mills, narrows to a gorge and is rock-walled. At such points the stream has all the characters of adolescence and is still in the channeling stage, or at most has made but little progress in the formation of a valley. At Story City the trench cut is scarcely more than twenty-five to thirty feet below the general upland. The channel deepens gradually to the southward until the Gary moraine is reached, where the bluffs rise from fifty to seventy feet and increase to upwards of 100 feet at some distance away from the stream.

FIG. 18. The Skunk river, below Hannom's mill. An example of an unstable channel.

Numerous embayments appear in the bluff boundary on the west. The most noteworthy of these appears at Hannom's mill. Here an embayment, occupying approximately a square mile, trends northwest from the great bend which marks the terminus of the newer portion of the stream.

The lower course of the Skunk is strikingly different from the upper. From Hannom's mill southward the valley rapidly

widens to a mile near Bloomington, nearly three miles at Ames, and averages about two miles in width throughout the remainder of its course in the county. In Polk county it attains an even greater width. Through this broad alluvial flat, outlined, but not confined, by low banks of its own making, the present stream pursues a most tortuous course, touching the restraining bluffs here and there, but at no point south of Ames revealing the country rock. Deserted channels in all stages, from crescentic lagoons, almost silted in, to the fresh cut-offs, attest the complicated meanders and the numerous attempts of the stream to straighten its course. When closely inspected the stream bottom is seen to be very uneven, and to consist of a series of basins separated by broad, fan-shaped sandbars. Often during the late summer season, or during periods of extended drouth, the stream consists of a series of detached ponds, some of which are ten feet or more in depth, and only connected by sub-surface circulation through the gravel fans. The entire assemblage of superficial features are those characteristic of an old stream. Wells sunk at Ames and Cambridge, on or near the flood plain, tell the same story. The country rock is reached only after penetrating from eighty to upwards of 100 feet of alternating beds of glacial and fluviatile materials. From the great bend in the Skunk, north of Ames, to the point where the river crosses the Polk county line, a distance of sixteen miles, as the crow flies, the fall is about sixty feet, or an average gradient of less than four feet per mile. To follow the stream meanders would more than double the distance, and hence halve the gradient. From the same starting point to the Hamilton county line, the direct route is about ten miles and the total vertical fall is 110 feet, or an average declivity of eleven feet per mile. Taking into account the sinuosities in the stream the gradient would be reduced, at low water, to about five feet per mile. In both sections the impotency of the stream is clearly due to lack of volume rather than to lack of gradient. Thus is readily seen the

reason for the stream's multiplied velocity and great destructiveness at flood time. This destructiveness is increased by the additional velocity gained by ignoring the great majority of the meanders and taking a direct route.

At Bloomington the bluffs rise more than 120 feet above the flood plain; at Ames they are reduced to scarcely more than fifty feet, while in southern Grant, and in Union township, they again rise to fully 100 feet above the bottom land. The most important tributaries of the Skunk are Keigley's branch, Squaw, Walnut and Ballard creeks from the west, and Long Dick and Bear creeks from the east, while the various branches of the Indian, Clear and Willow creeks belong to the system, but become confluent outside the area under consideration.

Keigley's branch crosses Lafayette township diagonally, from northwest to southeast, and joins the Skunk at Soper's mill, about one mile south of the township line. The course lies just within the main body of the Gary moraine, and the creek has done little work in valley cutting. Near its *embouchure* it enters a profound depression, probably a preglacial channel. The Skunk is manifestly displaced at this point, and escapes, through the innermost ridge of the moraine, through a narrow, rock-walled gorge. The branch flows through a well marked artesian basin, and drains the major portion of Lafayette township. Numerous springs issue from its banks, many of which persist throughout the year.

Squaw creek is the most important tributary of the Skunk in this section. It enters the region near the middle line of section 7, in Franklin township, continues in a general southeasterly direction into Washington township, and joins the parent stream about two miles southeast of Ames. The Squaw is nearly as large as the Skunk above the junction, and has all of the more important characteristics of the latter. It meanders through an alluvial bottom which varies from a sixth to a half mile in width. This bottom is, in turn, included within a terrace-bordered valley, of much greater width.

Ames, in the main part, is built on a delta-shaped terrace which separates the two streams, and the combined depressions exceed three miles in width. On section 33, in Franklin township, is a marked constriction in the valley of the Squaw, and the stream bears evidence of being displaced to the southwest. North of the point where the creek turns strongly to the east a prominent hill rises more than sixty feet above the water level, its crest immediately overlooking the creek. This hill slopes rapidly away from the stream to a depression which crosses the bend. The termini of the depression are now occupied by small streams which issue from veritable peat bogs. The ridge itself is only one of many similar ones to the northward, and is, apparently, merely one of the advance guards of the Gary moraine. The elbow in the Squaw is probably due to displacement by the ice tongue.

Squaw creek drains less than a township in Story county, and its principal tributaries are Montgomery, Onion, Clear and College creeks, all entering from the west. Of these, Onion creek is rock-bound, the Saint Louis limestone appearing at numerous points along the lower portion of its course. None of these streams have done much work in the way of valley-making, although both Onion and Clear creeks possess narrow flood plains. All are dry throughout a considerable portion of the year, though the upper reaches of Clear and College creeks are fed by seeping springs, which issue at the base of the loess and persist in these parts, even through the driest seasons. Terraces do not appear along any of the tributaries, and it seems reasonable to infer that none of these had a place in the pre-Wisconsin history of the system.

Walnut and Ballard creeks have their sources among the swales and kettle-holes of the Skunk-Des Moines water-shed. From this water-shed they take their sinuous easterly courses across Washington and Palestine townships respectively and enter Union township, where they parallel, and finally join, the master stream. Both have high gradients, and have cut from fifty to seventy feet below the upland level in their

lower courses. Neither has succeeded in exposing the country rock. In all probability both are post-glacial streams. The areas drained are about twelve and thirty square miles respectively.

Long Dick and Bear creeks, which enter the Skunk from the east, are long, branchless streams, which are little more than prairie sloughs through the greater portion of their courses, and lie almost wholly within the Gary moraine. Both have their sources in Hardin county, cross Howard township diagonally to the southwest, and have done but little cutting save near their junctures with the greater stream. Bear creek has cut through the drift, exposing the coal measure shales at Roland and the Saint Louis limestone at a number of points before escaping from Howard township. Both creeks cease to flow during the dry season. Both show evidence of appearing at a late date in the history of the system.

Indian creek, with its two unequal branches, known as the West and East Indian, of which the former is the smaller and joins the larger at Iowa Center, almost completely monopolizes the drainage from the tier of townships terminated by Warren and Indian Creek townships on the north and south respectively. The stream is a vigorous competitor of the Skunk for a considerable portion of Grant and Milford townships on the west, and has invaded Sherman, New Albany and Collins townships on the east. It is an outlet for the superficial waters of more than a third of the area of the county. In vertical cutting the work done by the Indian compares favorably with that done by the Skunk; the latter, at its exit, having cut less than twenty feet lower than the former where it makes its exit from the county. In lateral trenching the Skunk is greatly in the lead. The terrace-bordered valley of the Indian varies from a fourth of a mile to a mile in width from Iowa Center, the junction of the east and west forks, to the south line of the county. North of the junction the west fork has done very little in the way of depositing alluvium,

while the valley of the East Indian gradually narrows until at the north line of Nevada township the flood plain is scarcely mapable. Indian creek has more and better developed tributaries in the southern half of its course than any stream in the region, and hence Nevada and Indian Creek are the best drained townships in the county. The more mature drainage of this portion of the county is not so much a question of stream gradient, but is rather the result of a difference in surface materials. In Indian Creek and adjoining townships the Wisconsin drift is comparatively thin, merely a veneer over the older drift sheets, and the present features are dominated largely by the pre-Wisconsin topography. Cuts along the roadways reveal the loess in many places, with the ferretto zone of the Kansan oftentimes appearing at a lower level. Palestine and Union townships are equally as well circumstanced, so far as drainage lines are concerned, as is Indian Creek, but the old topography is almost completely obscured by the later drift.

Wells sunk on the Maxwell terrace show more than sixty feet of alternating alluvial and glacial deposits, and indicate that Indian creek has, at least at this point, partially reopened an old valley.

Above the forks characters suggesting an extended career are not so apparent. Terraces follow the East Indian to the middle of Nevada township, and it seems safe to conclude that a considerable stream occupied the valley up to this point at the time of the retreat of the Wisconsin ice. Northward there is no reason to doubt the post-Wisconsin character of the stream. Long finger-like projections of the system extend across the northern half of the county and even enter Hardin county, but afford very inadequate drainage for the area through which they pass.

Clear creek, with its tributary, Willow creek, drains the greater portion of New Albany and the northeast fourth of Collins township, and joins the Skunk at Mingo, in Jasper county. Willow creek occupies a profound depression, all

out of proportion to the insignificant stream which at present occupies it. The bottom of the trench is from sixty to eighty feet below the upland. But very little alluvium has been laid. On the Collins township line the stream impinges upon the Altamont moraine and is deflected west of south, then shifts east of south, and finally turns abruptly to the east and breaks through the moraine near the middle of the east line of the township. Clear creek has its source in Sherman township, occupies a less important valley, but has done about the same amount of cutting. Both streams fail to show any of the indurated rocks.

The Des Moines River System.—Big creek and Four Mile creeks make their way lingeringly among the ponds and glades of Palestine township, and are the only representatives of the Des Moines in the county.

Iowa River System.—Lincoln township and a small area in Warren belong to the drainage basin of the Iowa. South Minerva creek is the chief representative of that system, and has its source in the swales about McCallsburg. The stream occupies a narrow valley, and affords a convenient gateway through the Altamont moraine for the Story City branch of the Iowa Central railroad.

STRATIGRAPHY.

General Relations of the Strata.

Story county lies wholly within the great basin of the western coal fields. The frontier of the Iowa coal measures lies at least a dozen miles east of the county. In the west central part of the county there is an arching of the indurated rocks, and the Lower Carboniferous strata have been pushed up through the coal measures, assuming the role of country rock over a considerable area.

The Pleistocene series comprises at least two distinct drift sheets, which are included between and separated by pre- inter- and post-glacial deposits which give a clue to the

several climatic variations and surface oscillations to which the region has been subject. The physiographic features are almost wholly expressed in the Pleistocene deposits, as the older rocks are essentially below the level of the present stream beds, and hence almost entirely concealed.

The taxonomic relations of the formations represented are shown in the following synoptical table:

GROUP.	SYSTEM.	SERIES.	STAGE.	FORMATION.
Cenozoic.	Pleistocene.	Recent.		Wind deposits. Alluvium.
		Glacial.	Wisconsin Iowan. Buchanan? Kansan Aftonian?	Drift. Loess. Gravels. Drift. Gravels.
Paleozoic.	Carboniferous	Upper Carboniferous or Pennsylvanian.	Des Moin's.	
		Lower Carboniferous or Mississippian.	Saint Louis.	

It is obvious from the preceding table that the formations which occur in Story county belong to discordant series separated by an enormous time interval; a time unit of the first magnitude. The entire Mesozoic era is unrepresented in the stratigraphic column. The indurated rocks are exposed at but few points. The Saint Louis limestone appears sporadically along Skunk river, between Ames and Soper's mill, and at several points on Onion creek, in Franklin township, while the coal measures are sparsely represented by outcrops along Bear and Indian creeks.

Rocks older than the Carboniferous are not visible within the confines of the county, though the well sections at Ames and Nevada amply demonstrate that every great period of the Paleozoic is represented and appears in reverse order of deposition in a vertical section underlying the county.

At Nevada the following is the sequence and nature of the strata penetrated, as determined by Professor Norton, and published in his report on artesian wells:

NEVADA WELL.

Driller's Record.

	STRATA.	Thickness	Depth.
28.	Clay, yellow	30	30
27.	Clay, blue	6	36
26.	Clay, yellow	10	46
25.	Sand	55	101
24.	Clay, tile	20	121
23.	Shale	50	171
22.	Clay, black	75	246
21.	Slate	3	249
20	Coal and slate	1	252
19.	Clay, light gray		267
18.	Shell lime rock	15	282
17.	Lime rock, white, mixed with flint	50	432
16.	Granite, blue	50	482
15.	Limestone, blue	93	575
14.	Shale, red	8	583
13.	Limestone, blue	80	663
12.	Soapstone	8	671
11.	Limestone, white	90	769
10.	Limestone, blue	40	801
9.	Clay, blue	3	804
8	Limestone, blue	55	859
7.	Limestone, white	40	899
6.	Sand rock, dark	35	934
5.	Sand rock, white	10	944
4.	Sand rock, red	12	956
3.	Sand rock, white	8	964
2.	Sand rock, red	4	968
1.	Limestone, white	12	980

Interpretation by Professor Norton.

NOS.	FORMATION.	THICKNESS.	A T.
25–28.	Pleistocene	101	904
19–24.	Coal measures	166	738
16–18.	Mississippian	215	523
15.	Kinderhook	93	430
7–14.	Devonian	324	106
1– 6.	Silurian, penetrated	81	25

In the above section it is interesting to note the rather unusual character of the Pleistocene deposits. Numbers 27 and 28 are referable to the younger drift, while 26 and a por-

tion of 25, when considered in the light of recent developments farther west, show the presence of a considerable deposit of loess. The top of the coal measures is at least fifty feet lower than the west branch of Indian creek, while more than sixty feet lower than the uppermost shales exposed at the McHose clay pit, one mile west of the mouth of the well. The Silurian shows an unusually arenaceous facies, and is the principal source of water for the city supply.

The college well at Ames explores the earth's crust down to a depth of two-fifths of a mile, and is located about ten miles due west of the Nevada well. The following is a record of the beds penetrated in sinking the well:

DETAILED RECORD* OF STRATA PENETRATED IN SINKING THE COLLEGE DEEP WELL AT AMES.

NO. OF SAMPLE.	DESCRIPTION.	DEPTH OF SAMPLE.
1.	Till, yellow; sandy to gravelly; upper portion modified into soil	1–16
2.	Till, blue, sandy	16–32
3.	Till, blue with some yellow clay	35
4	Sand, yellow	40–50
5.	Till, greenish-blue, containing an abundance of gravel; numerous cherty limestone pebbles are present; matrix effervesces freely with dilute hydrochloric acid	40–50
6.	Silt, ash-brown, with a greenish tinge; calcareous and absorbent, loess-like, but finer	62–97
7	Silt, slightly arenaceous	102
8.	Sand, very fine, light yellow	105
9.	Sand with coarse gravel, water-bearing; limpid and vein quartz pebbles abundant; limestone fragments present	110–120
10	Shale, light, bluish-gray; calcareous and cherty	126
11.	Limestone, blue-gray, argillaceous and pyritiferous	151
12.	Limestone, gray, argillaceous, with some limpid quartz	160–170

*The record is based upon sample borings preserved by the foremen of the crews in charge of the work. The writer is also dependent on the drillers for the data concerning the depths at which the samples were taken. There is reason to believe that more than ordinary care was observed by those in charge in collecting and correctly locating the samples. Therein the record is more complete and reliable than is usual in such borings. Prof. W. H. Norton, of Cornell College, has generously lent his skill in unraveling the drillings, for which acknowledgments are gladly given.

NO. OF SAMPLE.	DESCRIPTION.	DEPTH OF SAMPLE.
13.	Limestone, light gray, soft, even-textured and cherty; effervesces very freely with weak HCl	185
14.	Limestone, slightly argillaceous	200
15.	Limestone and shale	210
16	Shale and limestone	240
17.	Shale, blue, non-calcareous and pyritiferous	310
18	Limestone, argillaceous, tending toward an oolitic facies; effervesces strongly with dilute HCl	315
19.	Shale, with fragments of white limestone; fossiliferous and pyritiferous	320
20.	Shale, earthly-blue and arenaceous	325
21.	Shale, light, reddish-brown, with some green shale; slightly calcareous	330
22.	Limestone, blue-gray; green shale and brown limestone present	375
23	Limestone, brown, pyritiferous	385
24.	Limestone, brown, with fragments of white cherty limestone and angular quartz grains present	395
25	Limestone, brown, argillaceous	400
26.	Shale, light gray and highly calcareous	415
27	Shale, gray-blue, calcareous	416–420
28	Limestone, yellowish-gray, with some carbonaceous matter	420
29.	Limestone, white, compact	440–456
30.	Limestone, white, fossiliferous	460–475
31	Shale, light, bluish-gray	495
32.	Shale and limestone	540
33	Limestone, white and shale, greenish-blue, non-calcareous	550
34.	Shale, ash-blue, calcareous	560
35.	Limestone, gray-blue, with fragments of brown limestone and green shale	570
36.	Limestone, gray-blue	580
37.	Limestone, gray, and blue-green shale	590
38.	Limestone, fossiliferous	600–610
39.	Limestone, gray-brown, sub-crystalline	615–640
40.	Limestone, gray-brown, and shale	645–660
41.	Limestone, buff, sub-crystalline	660–680
42.	Limestone, buff, earthly luster, soft; effervesces moderately when treated with HCl	690
43.	Limestone, blue and buff; the latter is part vesicular and magnesian	700

NO. OF SAMPLE.	DESCRIPTION.	DEPTH OF SAMPLE.
44.	Limestone, drab, highly argillaceous	710
45.	Limestone, of various kinds; one a buff, earthy limestone, finely laminated, and effervesces slowly; the laminæ are marked by dark gray bands	720
46.	Dolomite, light gray	730
47.	Dolomite, brown and gray, sub-crystalline; varying in hardness and color	740
48.	Limestone, buff	750
49.	Limestone, buff, with fragments of olive green shale (the shale was at 775 feet)	775
50.	Limestone, buff	815–830
51.	Shale and limestone	840–850
52.	Dolomite, ash-gray	860
53.	Dolomite, white	870
54.	Shale, green, plastic, non-calcareous	880
55.	Shale, reddish-brown, slightly calcareous	890
56.	Shale, earthy brown, non-calcareous	900
57.	Shale, blue and green, non-calcareous	930
58.	Shale, brownish, slightly calcareous	940
59.	Shale, brownish, with white shale	950
60.	Shale, blue, non-calcareous	960
61.	Shale, earthy brown, calcareous	970
62.	Shale, blue	980–990
63.	Shale, earthy and calcareous	1010–1020
64.	Shale, blue, calcareous	1030
65.	Limestone, sharp drillings in an argillaceous powder	1040
66.	Limestone, white	1050–1060
67.	Limestone, white, with much argillaceous material	1080–1090
68.	Limestone, gray blue, with blue shale and white chert	1100
69.	Limestone, gray-blue, compact, with white chert in abundance; drillings sharply angular	1110–1130
70.	Limestone, same as above, but less cher	1140–1170
71.	Limestone, slightly earthy, gray blue	1180–1190
72.	Limestone, gray blue, marly	1200
73.	Limestone, buff, magnesian, marly	1210–1230
74	Limestone, ash-gray	1240–1260
75.	Limestone, ash-gray, with fragments of non-calcareous, black and green shale	1270
76.	Limestone, brown, soft	1280
77.	Limestone, gray and brown, cherty	1290

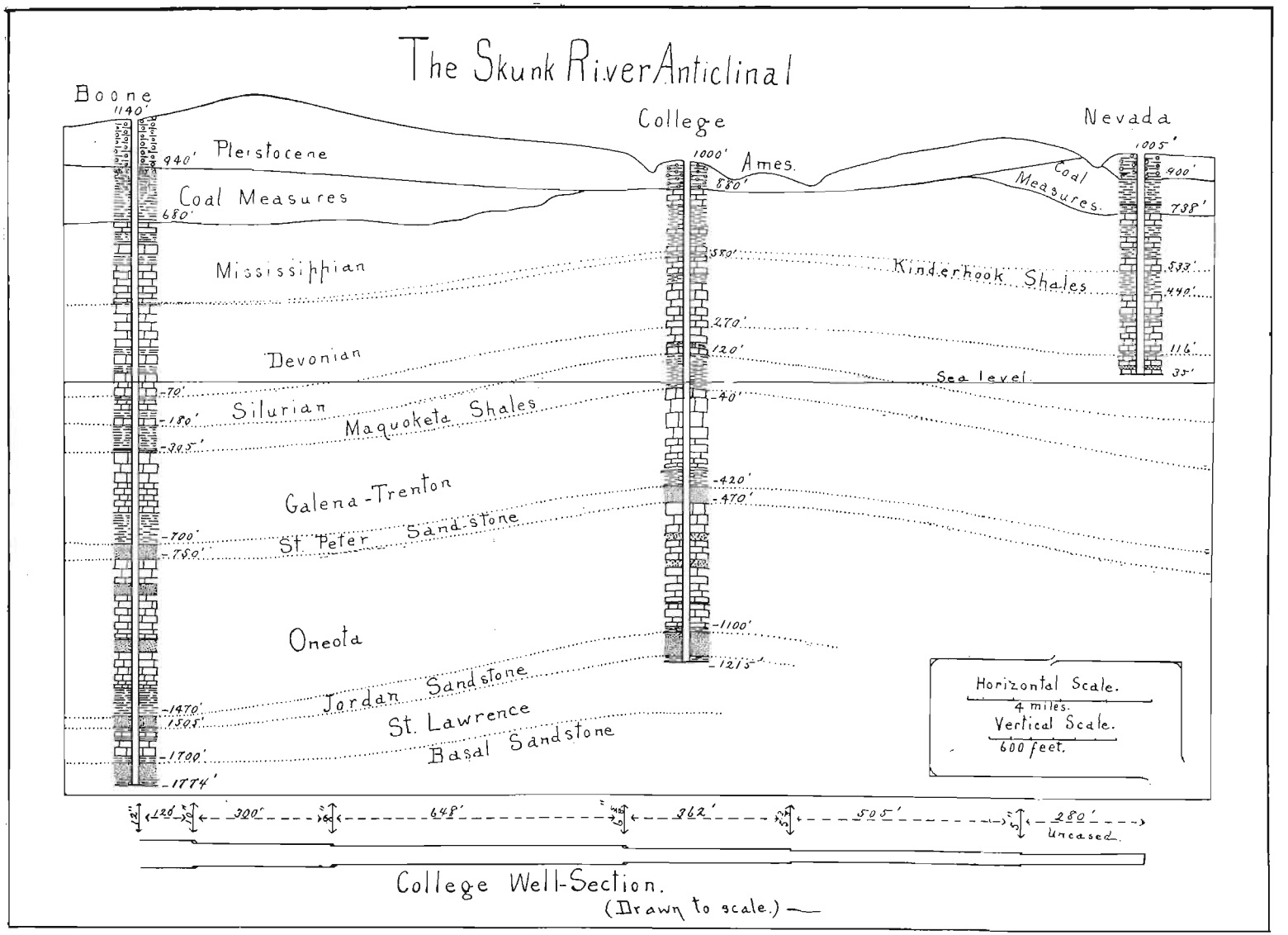
NO. OF SAMPLE.	DESCRIPTION.	DEPTH OF SAMPLE.
78	Limestone, gray, with considerable reddish-brown residual material	1300
79	Limestone, cherty	1310
80.	Limestone, gray, with green shale	1320
81.	Limestone, gray, siliceous	1330–1380
82.	Shale, green, fissile, non-calcareous; fossiliferous and pyritiferous	1385–1410
83.	Sandstone, fine textured, white; grains even and well water-worn	1420–1460
84.	Sandstone, calciferous	1470–1480
85.	Dolomite	1490–1500
86.	Dolomite and sandstone; beautiful doubly terminated quartz crystals present	1510
87.	Sandstone	1520
88.	Dolomite	1530
89.	Dolomite, some coarse sand and green shale present	1540
90.	Sandstone and dolomite; sand varying in grain	1550
91.	Sandstone, grains angular	1560
92.	Dolomite	1570
93.	Dolomite, arenaceous	1580
94.	Dolomite, arenaceous and cherty	1590–1600
95.	Sandstone, fine-grained, angular; calcareous cement	1610
96.	Sandstone, yellow, with much siliceous dolomite	1620
97.	Dolomite, highly arenaceous	1630–1640
98.	Dolomite, white, finely quartzose	1650
99.	Dolomite, arenaceous	1660–1680
100	Marl, yellow, in an argillo-calcareous powder; cherty and quartzose	1690
101	Dolomite	1700–1710
102.	Dolomite, highly arenaceous	1720–1730
103	Dolomite	1740–1750
104.	Dolomite, with chert and sand	1760
105.	Sandstone	1770–1790
106.	Dolomite	1800–1830
107.	Dolomite, arenaceous	1840
108.	Dolomite, argillaceous and arenaceous	1850
109.	Dolomite	1960–1880
110.	Dolomite and sand	1890–1910
111.	Dolomite, highly arenaceous	1920
112.	Dolomite	1920
113.	Sandstone	1930
114.	Dolomite	1950–1960

NO. OF SAMPLE.	DESCRIPTION	DEPTH OF SAMPLE.
115.	Dolomite, arenaceous; sand grains well water-worn	1970–1990
116.	Dolomite, arenaceous, with green shale	2000–2010
117.	Dolomite	2020–2040
118.	Dolomite, highly arenaceous	2050
119.	Dolomite	2060–2070
120.	Dolomite, argillaceous	2080
121.	Shale, blue, non-calcareous	2090
122.	Sandstone, with dolomite and a little blue shale	2100
123.	Sandstone, white and water-worn; a small percentage of the grains iron-stained	2110
124.	Sandstone, white; grains fine, sharp	2120
125.	Sandstone, as above, with coarser, well-rounded grains	2130
126.	Sandstone, white; grains fine, even, well worn	2140–2175
127.	Sandstone, white; texture variable	2185
128.	Sandstone, grains stained red with iron oxide; red and green shale present; grains larger than above, and more angular; iron pyrites and a black metallic mineral present	2195
129.	Shale, brownish-red, arenaceous	2205
130.	Shale, green	2215

Summary of Formations.

Number.	FORMATION.	Thickness—feet.	Elevation at top—feet.
1–9	Pleistocene	120	1000
10–27	Mississippian	300	880
28–45	Devonian	310	580
42–53	Silurian	150	270
54–64	Maquoketa	160	120
65–82	Galena-Trenton	380	—40
83–84	Saint Peter	70	—420
85–121	Oneota	510	—490
122–130	Saint Croix (penetrated)	115	—1100

The glacial debris is, perhaps, about the average thickness for Story county. The deposits of fine silt reached at sixty-two feet outcrops along Clear creek, about one-half mile west of the college, where it attains a thickness of twenty feet, and possesses the faunal remains, concretions and physical



College Well-Section.
(Drawn to scale.)

properties which characterize the loess in its typical development. The level of the outcrop is somewhat higher than its equivalent reached in the well. The silt grades downward into fine sand, similar to the sub-loessial sands exposed so freely along the southern margin of the Iowan till sheet in Polk, Marshall and Tama counties. The drift affords more than the usual proportion of sand and gravel. A water-bearing layer occurs within sixteen feet of the surface, a sand and gravel bed ten feet in thickness was encountered at forty feet below the surface, and the superficial deposits terminate in a bed of sand and coarse gravel which is also water-bearing.

The coal measures are not represented in the above section, although the utmost diligence was exercised in the search for the slightest clue to their presence. Coal is mined at Summit, about eight miles north of the college, and 165 feet of shales and clays represent the Upper Carboniferous series at Nevada, ten miles east; while at Boone, twelve miles west, 266 feet of sandstones and shales may be referred to this formation. It is reported that coal was found when sinking the well at the Experiment station, about a quarter of a mile northeast of the deep well. While this is altogether possible, and even probable, it seems reasonably certain from other data at hand that if coal *in situ* does really exist at that point it can be little more than a detached basin or "pocket," of very limited area. It is more probable that the fragments of coal which appeared in the slush bucket were derived from included fragments in the base of the drift.

The Mississippian series consists of 100 feet of limestone, followed by 200 feet of alternating shales and limestones. The Kinderhook shales at the base of the series, which reach such a marked development in southeastern Iowa, rapidly feather out to the northwestward. The terrain is represented by 175 feet of shale at Marshalltown, 93 feet at Nevada, 20 feet at the college, and is scarcely recognizable at Boone.

The Devonian is represented, chiefly, by a series of limestones, and, as in the case of the Carboniferous, is not water-

bearing in this locality. The assemblage of beds thickens westward, reaching about 400 feet at Boone.

Dolomitic limestone, interbedded with thin bands of shale, constitute the Silurian. At Nevada arenaceous beds are present, and the city draws its water supply from this source.

The Maquoketa consists of non-calcareous green shales, earthy-brown and blue shales, varying in lime content from slightly calcareous to strongly calcareous at the base of the terrain. The formation thins slightly westward.

The Galena-Trenton is represented largely by a massive white limestone, highly siliceous in certain layers. The silica is chiefly in the form of cherty concretions and limpid quartz. The lower portion of the assemblage contains intercallated bands of green shale, and the Saint Peter sandstone is crowned by a thick band of highly fossiliferous green shale. The drill brought up fragments of this shale which contained in abundance the remains of a marine fauna. Pygidia of at least two species of trilobites: Dalmanites and Isotelus (Asaphus), resembling some forms of *I. gigas* DeKay, and several species of brachiopods were recognized. Impressions of the dorsal valve of *Rafinesquina alternata* are perfectly preserved. So, also, some very good specimens of *Orthis subæquata* and *O. fissicosta* were found, along with other small Orthides, which were not so well preserved, and not capable of specific determination. All of the fossils brought up by the drill are found in typical outcrops of the Lower Trenton shales, but *Orthis subæquata* is the only species whose range is limited to that horizon. The Maquoketa, with the Trenton shales, forms an impervious roof which effectually prevents the escape upward of the water in the great sandstone reservoirs of the Lower Paleozoic. Although the water thus imprisoned lies far below the sea level in central Iowa, hydrostatic pressure brings it within pumping distance of the surface when the shales are penetrated, and thus renders the storage supply available. The area of intake in Wisconsin

and Minnesota is higher than the average upland surface of Iowa.

The Saint Peter comprises about seventy feet of strata, the greater portion of which is composed of white beach sand. The constituent grains are remarkably uniform in size and well rounded. These layers of water-worn sands are but slightly compacted, the drill penetrating about thirty feet during a single "watch." The lower portion of the terrain contains a calcareous cement and is more highly indurated.

The Oneota is essentially a massive dolomite bisected unequally by a well-marked sand bed. Sandy layers appear at other points, and siliceous grains occur in greater or less abundance throughout the formation. The principal sandstone band is known as the New Richmond by the Minnesota geologists, and is one of the chief water-bearing horizons in that state. The Oneota grades downward into shales and arenaceous shales, which make an easy transition from the Saint Croix sandstone to the massive dolomite above.

The Saint Croix in central Iowa can be separated into three fairly well marked divisions: an upper sandstone, a median series of dolomites and shales, and a lower member, which comprises sandstones, marls and shales. The upper two are known as the Jordan sandstone and the Lawrence limestone member is the Basal sandstone, according to W. H. Norrespectively, of the Minnesota geologists, and the lower ton.* Of these divisions of the Saint Croix, the college well penetrates only the Jordan, which has a thickness of one hundred feet, and ends in the St. Lawrence. The Jordan sandstone, with the New Richmond and the Saint Peter, are the great reservoirs from which the well may draw. Their ability to contribute to the general water supply, according to pumping tests from these horizons, is in the proportion of 15, to 4, to 1, respectively.

*Iowa Geological Survey, vol. VI, p. 140.

Geological Formations.

MISSISSIPPIAN SERIES.

Of the above series, only the uppermost member known to occur in Iowa is represented, and appears in the west-central part of the county. White* mentions an exposure of impure limestone in this region, and referred the beds to the Saint Louis of Shumard, named after the city whose location is near where the rocks of this epoch are typically developed.

The Saint Louis is supposed to underlie the entire county, and to form the basement for the coal measures. It is known to be the country rock over an irregular area in Franklin and Washington townships, and perhaps extends into Milford and Howard. The chief outcrops occur along the Skunk and its immediate tributaries between Ames and Soper's mill, and along Onion creek, in Franklin township. The beds exposed consist, in the main, of impure limestone, but arenaceous layers and calcareous shales are usually also present.

Northward from Ames, an earthy, buff limestone appears above the river bed, about thirty rods south of the Washington-Franklin township line, and continues in view for a few rods. This is the southernmost outcrop of the Saint Louis limestone in the region.

Perhaps the most typical exposure occurs on the Se. qr. of the Sw. ¼ of Sec. 25, in Franklin township. Here the following section may be observed:

SECTION I, NEAR BLOOMINGTON.

		FEET.
5.	Drift	5–10
4.	Limestone, earthy, yellow; very much disintegrated and rubbly; bedding planes almost eliminated	4
3.	Limestone, fossiliferous	1

*Geology of Iowa, vol. II, pp. 259-60. Des Moines, 1870.

		FEET.
2.	Limestone, similar to 4; bedding planes apparent, but showing tendency to become marly and assume a fissile structure in places	3
1.	Limestone, buff to gray-buff when unweathered and massive; layers from ten to twenty inches in thickness; compact, lithographic in texture, fracture conchoidal to uneven; and earthy when weathered (exposed)	6

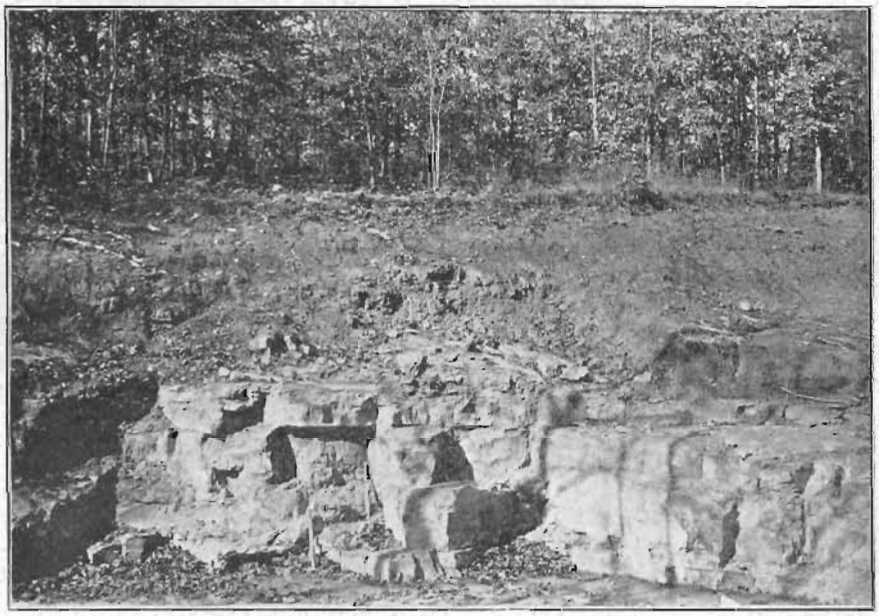


FIG. 19. Saint Louis, as viewed near Bloomfield, and described in Section 11. X, near the top, shows the position of the fossil horizon.

The lowest layers exposed lie about twenty-five feet above low water in the Skunk. The drift cannot be differentiated at this point, and apparently only the Wisconsin is represented. Limestone fragments are very abundant near the base of the drift, and in places the rubble layer graduates almost insensibly into undoubted till. The small stream which the quarry faces contains numerous masses of chert, which apparently belong to layers higher in the series. The parent ledge, to which these fragments belong, is not visible in this vicinity. Many of the masses are cavernous, and take

on a geode-like character; the cavities oftentimes being decorated with well developed quartz crystals, which project in towards the center. The cherty layers may be seen *in situ* at Soper's mill, where it appears from ten to fifteen feet above the water level.

The entire assemblage of beds is characterized not only at this point, but over the entire area, by a buff or earthy buff color when weathered, and gray-buff to blue-gray when unweathered. The beds are lithographic to earthy in texture, this depending on the various stages of weathering. A Fenestelloid Bryozoan and a Syringoporid coral occur throughout the upper half of the section.

The fossiliferous band is really a reef composed of Cyathaphylloid individuals of very complex forms and entwined in a most complicated manner. The internal coralline structure of the individuals represented is entirely destroyed, and the molds are filled with crystalline calcite. Associated with the corals are the following forms, which leave little doubt as to the Saint Louis character of the beds.

Productus marginicinctus Hall.
Athyris subquadrata Hall.
Spirifer keokuk Hall.
Terebratula (*Dielasma*) *turgida.*
Lingula Sp.(*?*)

All of the faunal remains are very imperfectly preserved and are obtained only with great difficulty. The fossil-bearing zone is very persistent and can be recognized throughout the area wherever the equivalent beds are exposed.

Two hundred yards north of the preceding section, the Saint Louis beds appear on both sides of a ravine which enters the small creek just mentioned. The beds equivalent to the upper half of the section just described have been removed, and the profoundly planed, grooved and striated surface presented by the indurated rocks is but the unmistakable imprint of the agent which effected the removal. The striæ maintain a constant direction and trend 32° east of south. Two

drift sheets and a gravel layer are present. The section is as follows:

SECTION II, NEAR BLOOMINGTON.

		FEET.
4.	Till, pale yellow, slightly oxidized and leached, and containing numerous limestone fragments and bowlders	6
3	Gravel and sand, more or less stratified and cross-bedded, and carrying numerous greenstone pebbles	1-2
2.	Till, blue, jointed; stained yellowish-brown along the joint planes; very compact; can only be removed by use of the pick; greenstones predominate	2
1	Limestone, gray-buff, compact and massive: the same as No. 1, in the first section (exposed)	10

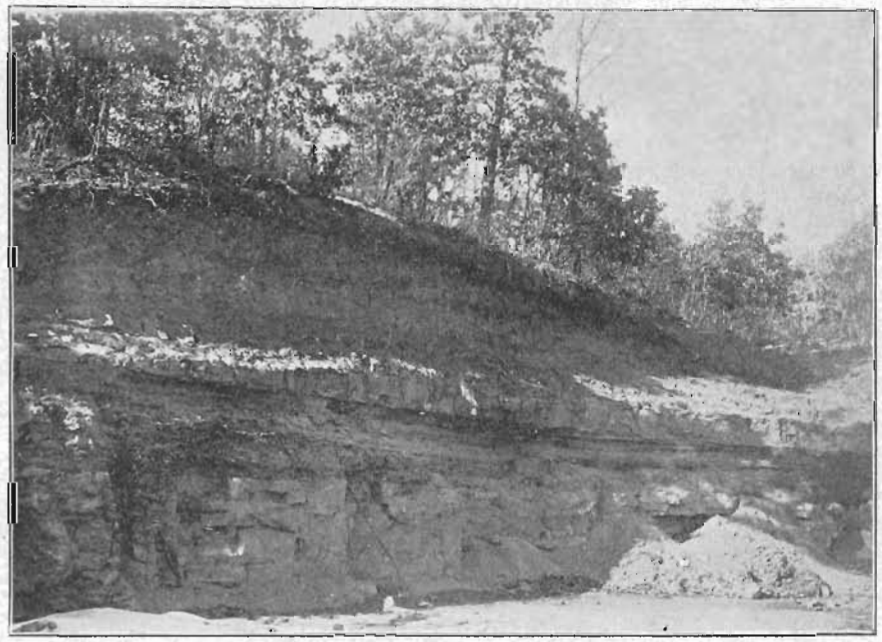


FIG. 20. Saint Louis, planed and scored; two drift-sheets, and inter-glacial deposits present; described in Section II.

It appears evident that the planing and grooving was done during the time of the first glaciation represented by No. 2, and that the ice which formed the later till did not touch the stratified rocks at this point.

In section 26, the low ridge which skirts the flood plain of the Skunk on the east appears to be rock-supported, but no indurated deposits are visible until the southwest quarter of section 23 is reached. East of the wagon bridge, the former site of Hannom's mill--and still known by that name—continuous outcrops appear on both sides of the flood plain; on the south, forming a low bench from which the drift has been almost entirely removed, and on the north, appearing at the base of the bluffs which have retreated some distance from the present stream channel. The river runs against the south bank, and the bench is bounded by an escarpment which exhibits the following sequence of beds:

SECTION III, AT HANNOM'S MILL.

		FEET.
6	Soil and bowldery wash	3
5.	Limestone, residual and concretionary	½
4.	Limestone, arenaceous, yellowish-gray to blue-gray, thinly-bedded and much fractured; in places argillaceous, while in others tends towards the massive; the fissility is apparently a function of weathering; small cherty concretions present	6
3.	Sandstone, grayish-blue friable; shaly below	2
2.	Limestone, impure, grayish-buff, uneven to earthy fracture; compact and heavy-bedded	4
1.	Limestone, gray-buff, compact, almost lithographic in character	5

The base of the above section is the water level in the river. The "coral reef" with its associated fauna bisects No. 1, and occurs at a level nearly twenty-five feet lower than at the type section near Bloomington. The sections are removed from each other about two miles in a northwest-southeast direction, presumably coincident with the line of strike. The average dip would be therefore about twelve feet per mile and only demonstrates the presence of a local undulation. The beds exposed north of the flood plain are for all practical purposes a duplication of those exposed on the south side.

North of Hannom's mill the Lower Carboniferous rocks pass from view, being concealed by the Pleistocene deposits until

Soper's mill is reached. Here, as stated in the discussion of drainage, the river flows in a new channel, having been diverted by the last ice-sheet and obliged to cut directly through a hill. The Saint Louis limestone appears in both sides of the gorge, and about twenty-five feet of earthy buff limestone, with considerable chert interspersed throughout, is exposed. The section is very much obscured by talus and drift, but the following is a fair approximation.

		FEET.
4.	Drift, pale yellow, bluish below, unoxidized and unleached	10
3.	Limestone, rubbly, with occasional heavy ledges.	10
2	Limestone, cherty, concretionary, cavernous; some of the larger caverns coated with calcite crystals, which consist of complicated combinations of the scalenohedron and rhombohedron, and smaller quartz decorated caverns	5
1	Limestone, gray buff, compact; heavy, but irregularly bedded; some of the layers two feet in thickness	10

The strata in the above section cannot be correlated with the preceding sections with absolute certainty. Diligent search was not rewarded by even a trace of an organism. The arenaceous beds were not noted at this point. Aside from this the dominant characteristics are so nearly identical with those observed in the preceding quarries, that these beds doubtless may be referred to the same formation with a high degree of certainty.

North of this point no further exposures are known along the Skunk. Similar outcrops, on a smaller scale, appear along Bear creek for some two miles up stream, when the Saint Louis disappears beneath the coal measures.

Although Squaw creek has cut to practically the same level as the Skunk, and the restraining bluffs have, at several points, the appearance of being rock-supported, no exposures are known to exist. Onion creek, however, breaks into the flood plain of the Squaw from the west, through a rock-bound gorge. The Saint Louis is visible at numerous points on section 32, in Franklin township, and attains a maximum of

twenty feet above the water level in the creek. The beds are less constant here than are their equivalents on the Skunk.

On ascending Onion creek from the flood plain of the Squaw, the first important exposure appears on the left bank, where the following sequence may be observed.

SECTION V, NEAR THE MOUTH OF ONION CREEK.

		FEET.
7.	Drift, very bowldery	2
6.	Limestone, impure, very much shattered and weathered	1½
5.	Limestone, heavy-bedded, forming a projecting ledge	1½
4.	Limestone, shaly, and containing numerous remains of a Fenestelloid Bryozoan (Fenestella zone)	1
3.	Limestone, yellowish-buff to gray buff; close textured, and bedding planes not apparent; the upper 15-inch layer more indurated than the lower portion; non-fossiliferous throughout	7
2.	Sandstone, gray to yellowish-gray, calcareous and shaly; but slightly indurated and irregularly bedded	4
1.	Limestone, buff, thinly and unevenly bedded; exposed	2

Organic remains here, as elsewhere, are very scarce. Aside from the Bryozoan, a Syringoporoid coral appears in the limestone layers, and seems to be common to nearly all of the limestone exposed in the region.

About 100 yards up stream from section 5 the following beds, on the opposite side of the creek, may be viewed:

		FEET.
6.	Drift, as in the preceding; only one drift sheet can be identified in any of the exposures of the area	5
5.	Limestone, much weathered and shattered	2½
4.	Limestone, buff, compact to earthy; heavy-bedded; the lower layer approximates two feet	5½
3.	Limestone, cherty, concretionary and cavernous, and containing much iron in the form of limonite and pyrites; forms a projecting ledge in the quarry face	1½
1.	Sandstone, argillaceous, fissile; becoming shaly below, exposed	3

The base of the section is about two feet above the water in the creek. The beds are, apparently, absolutely devoid of organic remains. The creek impinges against the bank at

this point, and the softer layers below, by undermining, aid in maintaining an escarpment. See figure 21.

FIG. 21. Representative section of Saint Louis limestone, as it appears along Onion creek.

One hundred and fifty yards southward the beds exposed to view indicate that shore conditions with variable currents prevailed while the deposits were being put down. Bryozoan remains are very sparsely distributed in the limestone layers. The section shows:

		FEET.
6.	Drift, almost entirely removed	0–2
5.	Limestone, rubbly, thinly-bedded and much weathered, stratification planes almost entirely eliminated; beds graduate upward into a residual clay	4
4.	Limestone, impure, yellowish-buff to gray-buff, compact to earthy; heavy-bedded	7
3.	Limestone, finely arenaceous and marly; contains beautifully preserved mud cracks and ripple marks	2
2.	Sandstone, white to bluish-gray, friable; obliquely laminated and fissile; readily undermined by the creek during seasons of high water	1½
1.	Limestone, concretionary; contains much limonitic iron; exposed above the water level	2

Near the center of section 32, where the creek changes from a west to east course and flows almost due north, about ten feet of the older rocks appear. A fossiliferous band occurs here, and is probably the equivalent of the fossil-bearing zone described in the Bloomington section.

The Brachiopodal remains are confined to a layer scarcely a foot in thickness, while the corals and Bryozoa have a wider range. All of the organic remains are in a bad state of preservation, and cannot be specifically determined. Of the Brachiopods, representatives of Productus, Spirifer and Athyris prevail. In the drift a fragment of sandstone, bearing casts of *Inoceramus—sp?* and a portion of a keeled Ammonite, very similar to *A. (Placenticeras) placenta* DeKay, were found. The lowest beds in the Onion creek area outcrop here, and dip at a low angle both to the north and to the west. In the latter direction they soon pass from view beneath the heterogeneous materials of the drift.

The Lower Carboniferous deposits are reached at many points in Franklin, Washington, Milford, and Grant townships and apparently are not overlain by coal measures; but outside of the area described, they are not known to appear at the surface.

PENNSYLVANIAN SERIES.

THE DES MOINES STAGE.

So far as now known the coal measures are present over seven-eighths of the area of the county. The Saint Louis floor is fully as irregular as the present surface, and is responsible, in a large measure, for the great variability in the thickness and the anomalous distribution of the beds belonging to this stage. The outcrops of the Saint Louis have elevations of 950, 940 and 975 feet A. T. for Onion creek, Hannom's and Soper's mills respectively. While well sections show that the same formation is reached at 880 feet A. T. at the college, 900 A. T. at Story City, and 774, 800 and 700 feet A. T. for Nevada, Maxwell and Collins respectively. The general

inclination of the coal measure basement is to the east and tilts slightly to the south.

While so widely distributed, outcrops of the Des Moines are very rare, and are wholly confined to a narrow zone which extends from Story City and Roland in a southeasterly direction across the county by way of Nevada and Maxwell. This band forms a distinct ridge in the indurated rocks, and exposures occur wherever the more important streams cross it.

About one mile southeast of Story City alternating bands of sandstone and shale appear a few feet above the water level in the river. Clay-ironstones are noted in the stream, and the flood plain is much constricted at this point, being scarcely more than one hundred yards in width. Eastward, in section 18, near the mouth of Long Dick creek, a fissile, highly carbonaceous shale, coaly in places, rests upon a gray-blue fire clay, the top of the clay being almost coincident with low water level. In certain places a highly ferruginous shale appears above the coaly layers. The iron appears in the form of limonite concretions, and where exposed assumes a deep red-brown. The maximum exposure does not exceed four feet. The water in the almost isolated ponds which represent the river during seasons of low water, continues murky for some distance down stream, but the coal measures are not visible below the junction of the above mentioned creek.

Near Roland, at Swenson Brothers' coal pit, several feet of clay shales over sandstone are exposed along Bear creek; while at Nevada, at the McHose clay pit on the West Indian creek, eighteen feet of shales are exposed, and at Maxwell, fifteen feet of argillaceous deposits may be viewed. The above outcrops represent the maximum exposures of the Des Moines in the county. Data collected from wells and shafts give more information concerning the distribution, thickness and nature of the Upper Carboniferous deposits.

The Larson well, on the northeast quarter of section 5, in Lafayette township, penetrated twenty-five feet of sandstone and shale; and the Tilden well, in section 17, in Franklin

township, revealed twenty feet of the same material. Both wells passed through thin seams of coal. The following is the driller's record of the well put down for the C. & N.-W. Ry. Co. at Story City.

		FEET.	INCHES.
18.	Soil and yellow clay	12	
17.	Clay, blue	22	
16.	Quicksand, fine, white, with a little water		6
15.	Clay, blue	51	6
14.	Quicksand, with water	1	
13.	Earthy material, hard, black		6
12.	Fire clay	3	
11.	Sandstone, very hard, white	2	6
10.	Fire clay	1	
9.	Sandstone, with seams of clay, one to two inches in thickness, intercallated	9	
8	Chert		6
7.	Sandstone, ferruginous; magnetized the drill	1	6
6.	Fire clay	4	
5.	Chert and fire clay in alternating layers, varying from five to fifteen inches each	8	
4.	Sandstone and chert	1	2
3.	Sandstone, with much water	12	
2.	Chert, transitional	5	
1.	Chert and clay, as before	22	

Pyritiferous bands and layers of coal from one to four inches in thickness were reported to be associated with the fire clays. The section is scarcely susceptible of more than a tentative interpretation on account of the doubtful nomenclature used. The drift attains a thickness of eighty-seven feet, but it is impossible to delimit the coal measures. The great abundance of chert reported may, perhaps, be a case of "mistaken identity" and is confusing. Clay-ironstone would be more in harmony with the fire clay and coal with which it was said to have been associated. In any case, the Des Moines is certainly present, and is represented by the usual alternating sandstones and shales with carbonaceous layers.

A well at Summit exhibits the following sequence; the record being furnished by Mr. W. S. Johnson.

WELL SECTION AT SUMMIT.

NO.	DESCRIPTION.	FEET.	INCHES.
25.	Soil	3	
24.	Clay, yellow	20	
23.	Clay, blue	5	
22.	Sand, bluish	1	
21.	Sea-mud	46	
20	Sand, yellow	20	
19.	Hard rock	1	
18.	Clay, sandy	3	
17.	Coal		4
16.	Fire clay	1	
15	Coal		5
14.	Fire clay, bluish	11	
13	Coal		5
12.	Fire clay	7	
11.	Coal, good	2	
10.	Slate, dark blue	4	
9.	Slate rock, hard	3	
8	Slate, blue	8	
7.	Coal	4	6
6	Fire clay	3	
5	Rock	1	6
4.	Fire clay	18	
3.	Coal	1	
2	Fire clay	38	
1.	Shale, black	5	

An interesting feature of the above section may be noted in the Pleistocene deposits. Number 21 is designated "sea-mud" by the drillers, and probably represents the loess—a fact which will be elaborated in the proper place. The lower 112 feet are clearly referable to the Upper Carboniferous, and consist essentially of clays and clay shales alternating with arenaceous layers and thin seams of coal. The shale which forms the roof to the principal seam of coal at number 7, contains numerous specimens of *Lingula mytiloides* of Meek and Worthen.

The Nevada well shows 166 feet of shale, which represents the entire thickness of the coal measures at that point.

At Maxwell, a well located near the clay pit of the Maxwell Brick and Tile works, passes through the following layers, as reported by Charles McHose, proprietor of the works.

		FEET.	INCHES.
40.	Soil	6	
39.	Sand rock	2	
38.	Soapstone	2	
37.	Sand rock, gray	2	
36.	Soapstone, gray	2	
35.	Potter's clay, red	2	
34.	Potter's clay, gray	2	
33.	Sandstone, gray, blue	5	
32.	Soapstone	2	
31.	Slate, dark	4	
30.	Coal		6
29.	Sandstone	11	
28.	Sand rock	2	6
27	Soapstone	5	
26.	Slate, decomposed, black	11	6
25.	Slate, bowldery below	7	
24.	Coal		8
23.	Fire clay	1	
22.	Slate, various shades of gray	13	
21.	Soapstone and fine grit	6	
20.	Fire clay	2	
19.	Soapstone	4	
18.	Slate	16	
17.	Black-jack, impure coal		6
16.	Fire clay	2	
15.	Soapstone	4	4
14	Sandstone		6
13.	Coal, rotten		3
12.	Soapstone, pure	3	3
11.	Sandstone, soft	2	
10.	Soapstone	2	2
9.	Slate, black		7
8.	Fire clay	1	
7.	Soapstone	5	7
6.	Slate, black	4	3
5.	Slate, shelly	9	4
4.	Soapstone	1	
3.	Shale, gray	1	8
2.	Fire clay		3
1.	Shale, gray		6

Arenaceous beds and grits are more in evidence here than they are in the Summit and Nevada sections. The mouth of the well is located on the bottom of a small ravine which enters Indian creek from the east. Add to the beds penetrated by the drill the shales exposed at the pit, which lie above the mouth of the well, and a total of more than 160 feet of coal measures are present in this portion of the county.

In Collins township, section 34, a shaft sunk on the bottom land along Wolf creek, penetrated seventy feet of glacial debris, and more than seventy feet referable to the Des Moines.

SUMMARY.

So far as now known, the coal measures underlie the entire eastern two-thirds of the county, and occupy the whole of Palestine and Lafayette, and considerable areas in Washing and Franklin townships. From Soper's mill south, the Skunk river has doubtless entirely removed the coal-bearing beds over at least the area mapped as flood plain, and, perhaps, in addition, the terrace areas as well.

The beds referable to the Des Moines are overwhelmingly argillaceous. Fire clays, clay shales and shales of various compositions and textures greatly predominate. Arenaceous beds and carbonaceous seams form an integral, but minor part of the section. The beds probably attain their maximum thickness in the south central portion of the county where they exceed perhaps 200 feet.

THE PLEISTOCENE SERIES.

Beds referable to the Pleistocene period almost completely mantle the county, and consist of bowldery gravels, sands, silts and clays, usually commingled in a most complicated manner, and forming a heterogeneous deposit known as the "drift." Only the more important drainage lines have completely cut through the drift, and these at but few points. Hence the physical features find their expression wholly in the Pleistocene deposits. Not only is the present landscape

dependent upon this superficial mantle, but the latter is the chief source of the wealth of the community as well.

While to the layman an attempt to classify and arrange the constituent elements in this confused mass of rock debris would appear to be a profitless and hopeless task, a careful examination shows that it is possible to correlate certain of the beds and bring some order out of chaos. The Pleistocene deposits in Story county show the presence of at least two drift sheets, which demonstrates that the region must have been subjected to an equal number of ice invasions. The till sheets are separated by, and overlain by, deposits characteristic of interglacial and post-glacial times. In many well sections gravel and sand in considerable amount, containing pebbles foreign to the locality, are found resting upon the indurated rocks underlying the lower till sheet and suggesting the possibility of a still earlier ice invasion.

KANSAN DRIFT.

Deposits referable to the Kansan stage were produced by the Keewatin glacier, which, at its maximum extension, crossed the Missouri river into Kansas, a fact which suggested the name of this sheet of drift. The Kansan ice sheet undoubtedly planed and scored the entire region, and the till formed by it appears to be equally widespread, save that over certain insignificant patches it has been removed by erosive agents subsequent to its deposition. Although so generally distributed, it is even more obscured by the later deposits than are the indurated rocks, and our knowledge of its characteristics, thickness and distribution have been gained almost wholly from artificial exposures and sections. The only natural outcrops known to the writer occur about Hannom's mill and Bloomington along the Skunk, and in the vicinity of Maxwell along road cuts and ravines. In all of these cases the exposures are very insignificant, and never exceed a few feet. At Bloomington, the ferretto zone of the Kansan is very sparingly exhibited near the base of the bluff. At the quar-

ries, about two feet of very compact bowlder clay rests directly upon the Saint Louis, and is referred to this stage. Of the individual bowlders, the greenstones predominate. Near Hannom's mill, the ferretto is more in evidence. Along a small creek entering the Skunk from the north, several feet of till, oxidized to a deep brick-red and thoroughly leached, is exposed. Greenstones are abundant, and the granitic pebbles and bowlders are in an advanced stage of decay. In the Maxwell area the ferretto appears some twenty feet up from the base of the V-shaped draws and ravines; it is generally overlain by the loess, and contains the characteristic bowlders. In no case is the unoxidized portion open to inspection. At all other points where the stratified rocks are exposed, the Kansan appears to have been entirely removed, or else it is wholly concealed by talus slopes of the younger deposits. From the extreme paucity of natural exposures, even where the country rocks are laid bare, it is obvious that either the Kansan till sheet in this area was never comparable in thickness with equivalent deposits in other regions, or else the younger ice sheet dealt with it very harshly. To gain a more correct idea of the importance of this till sheet, well sections must be examined.

LARSON WELL, NE. QR. OF SEC. 5, LAFAYETTE TOWNSHIP.

		FEET.
10.	Soil and yellow clay	10
9.	Clay, blue	5
8.	Quicksand	5
7.	Clay, blue and yellow mixed	5
6.	Quicksand	1
5.	Clay, blue	77
4.	Sandstone, gravel, water-bearing	50
3.	Sandstone	6
2.	Chert	2
1.	Shale, blue. Shale, black Coal..... Fire clay... Shale, black	15
	Total	176

Interpretation.

Number.	NAME OF FORMATION.	Thickness—feet.	Depth—feet.
9–10	Wisconsin	15	15
8	Loess (?)	5	20
5–7	Kansan	83	103
4	Aftonian (?)	50	153
1–3	Coal measures	23	176

The heavy deposit of sand and gravel, number 4, is somewhat anomalous, and may signify a preglacial channel. The mouth of the well is not far distant from Keigley's branch, and the top of the gravels is about the level of the water in Skunk river. The Kansan, as interpreted in the above section, shows the ferretto zone slightly developed and a heavy deposit of blue till. Number 8, which is reported as quicksand by the drillers, may be loess.

TILDEN WELL, NE. QR. OF SEC. 12, FRANKLIN TOWNSHIP.

		FEET.
5.	Soil and yellow clay	45
4.	Sand and clay	10
3.	Clay, blue	63
2.	Slate	12
1.	Sand, with coal and water	8
	Total	138

This well obviously entered the coal measures after passing through 40 feet of Wisconsin, 10 of loess, and 63 of Kansan.

In the college well, at Ames, no material can be referred to the Kansan with certainty, although the loess is underlain by fine sand and ten feet of coarse gravel conglomerate. In Palestine township detailed records are not obtainable. The drift is upwards of 100 feet in thickness, which, after deducting the Wisconsin and making some allowance for the loess, which is known to exist in the township, reduces the Kansan to much below its normal thickness for central Iowa. Excepting in probable preglacial channels, the Kansan rarely

exceeds fifty feet in thickness in the western half of the county, and the ferretto zone is not obvious enough to attract the attention of well drillers, save in rare instances.

In the eastern portion of the county glacial deposits attain a much greater thickness. As nearly as can be determined from the well records the drift varies from 100 to 300 feet in Collins and New Albany townships, and from 150 to more than 300 feet in Sherman and Lincoln townships. While it is possible to obtain approximately the total thickness of the Pleistocene deposits, it is impossible, with the data at hand, to differentiate them into the various drift sheets and interglacial beds.

BUCHANAN GRAVELS (?).

In College park, at Ames, certain coarse, much weathered gravels appear along the roadway which winds around the base of the bluffs skirting Clear creek (figure 22). These gravels consist, chiefly, of well worn bowlders of granite,

FIG. 22. Buchanan gravels? College Park, Ames, Iowa.

greenstone, chert, and a few ironstones. Limestones are represented only by the cherts. The granites and all of the coarser-textured rocks are in an advanced state of decay, and many of these appear in the side of the road cut, broken directly across, instead of being removed from, their matrices. The entire deposit is deeply iron-stained, and bears the unmistakable marks of age. It is clearly overlain by the Wisconsin till, and what appears to be modified loess lies above it. Gravels occupying a similar stratigraphic position have been noted along Squaw creek at several points, and all are provisionally referred to the Buchanan stage.

THE LOESS.

The Iowan till is not known to be present within the confines of the county, but the loess, which is supposed to be genetically related to the Iowan, has been recognized recently at several points, and is believed to cover a considerable portion of the area. This most paradoxical of deposits is unconformable with the Kansan below and with the later drift above. It grades upward from fine sand and sandy silt to silt and clayey silt, and carries much lime throughout. In the upper portion lime concretions known as loess-kindchen and loess-mannchen are commonly present, and in some places root-casts, and even wood fragments, are not uncommon. Molluscan shells are usually present, and oftentimes occur in great numbers.

The loess is exposed at numerous points along the flanks of the deeper cuts in Indian Creek and Collins townships. Over a very small area in the extreme southeast corner of Collins township the loess has never been covered by the later drift, and hence forms the surface soil. There are occasional exposures in Franklin and Washington townships along the tributaries of Skunk river and Squaw creek.

Inferentially, from a consideration of well sections, spring lines and topographic features, the loess covers a much larger area. The best exposures are located on sections 5 and 34, in Washington township. That on section 34 exhibits nearly

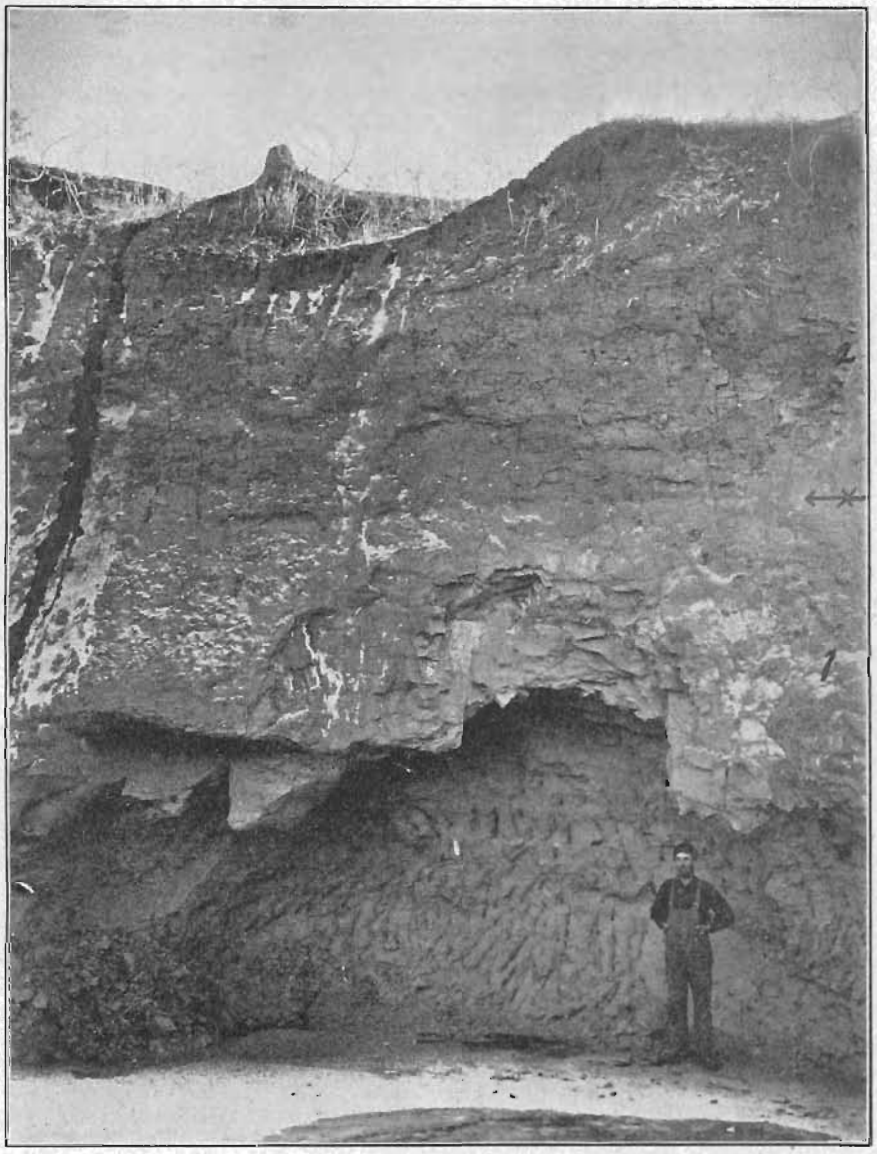


FIG. 23. Clay pit of the Kelly tile works; 1, represents the loess, and 2, the Wisconsin drift.

twenty feet of silt, silicious below, underlain by a gravelly bowlder clay, and covered by from five to twenty-five feet of Wisconsin till. The silt is distinctly jointed above and stained a faint yellow-brown along the joint planes. It grades downward into a massive, structureless, pale blue, clayey silt, which contains an abundance of root-casts, wood fragments, and black, carbonaceous spots, and emits a distinct swamp-like odor. The entire deposit is highly calcareous and carries a rich gastropodous fauna. The majority of species represented are strictly terrestrial in their habits. The following species were identified by Prof. B. Shimek.

1. *Zonitoides shimekii* (Pils) P. & J.
2. *Sphyradium edentulum alticola* (Ingers) P. & G.
3. *Pupa muscorum* L.
4. *Bifidaria pentodon* (Say) Sterbi.
5. *Vertigo ovata* Say.
6. *Conulus fulvus* (Mull).
7. *Polygyra multilineata* (Say) P. & J.
8. *Pyramidula striatella* (Anth) P. & J.
9. *Vallonia costata* (Mull) Sterbi.
10. *Succinea lineata* Binn.
11. *Succinea avara* Say.
12. *Limnea humilis* Say (?).

Loess concretions are relatively scarce and are diminutive in size. The deposit shows no signs of oxidation or leaching where the drift covering is thick, but where the covering is so far reduced as to afford imperfect protection from the weathering agents both leaching and oxidation may be noted; and here alone are lime concretions to be found. It is obvious that little or no alteration took place prior to the deposition of the overlying drift.

The outcrop in section 5 is an almost exact duplicate of the section just described. The drift mantle is thinner, and from two to five feet of the loess has been stained to a yellowish-buff. Loess concretions are more in evidence, thus attesting the greater progress made in leaching. Here, again, the

upper portion is distinctly jointed, while lower, the deposit is apparently structureless. The jointing is due, no doubt, to the pressure exerted by the Wisconsin ice. Gastropod shells abound throughout.

WISCONSIN DRIFT.

Many of the larger, and essentially all of the minor physical, features are impressed in the Wisconsin drift sheet. This drift is represented, chiefly, by a bowldery clay which has suffered little change since its deposition, either physically, chemically or mechanically. The till contains numerous patches and lenses of sand and gravel, in whose deposition running waters was obviously an active agent. These sand and gravel deposits oftentimes form conspicuous surface features and appear as knobs and kames. Bowlders are numerous and, in many instances, attain an enormous size. Barring the younger volcanics they include nearly all of the rock species known to lithology. Gray and red granites predominate, but there is a liberal sprinkling of limestone blocks, and the gneissic and basic rocks are well represented. All of the erratics* are remarkably fresh, and many show one or more planed or faceted surfaces. Of the smaller bowlders and pebbles clay-ironstone and fragments of calcareous and cherty rocks are very abundant. The deposit is not only rich in lime pebbles and bowlders, but it contains an abundance of lime concretions; and the clayey matrix, even at the surface, effervesces freely when treated with dilute hydrochloric acid.

The topographic features of the Wisconsin are remarkably immature. Ponds, undrained basins and incipient drainage lines are the rule, and afford corroborative testimony as to the extreme youthfulness of the deposits.

The Wisconsin till attains a thickness of from twenty to eighty feet over the general upland, but it probably consider-

*A bowlder of native copper was found on the farm of Wm. Arrasmith, about two and one-half miles north of Ames. The mass was much abraded and flattened, and bore evidence of rough usage in general. It weighed four pounds. Bowlders of the copper conglomerate are not uncommon and make it reasonably sure that the Des Moines lobe of the Laurentian glacier came by way of the Lake Superior copper region.

ably exceeds 100 feet in the morainal regions. The upper portion of the till, varying from three to thirty feet, is stained a pale yellow through incipient oxidation of the iron constituent, and the color grades downward into a gray-blue. Faceted pebbles and bowlders increase in commonness downwards. Wood fragments and earthy bands, presumably indicative of old soils, are often encountered at or near the base of this till sheet.

The eastern margin of the Wisconsin drift is marked by the Altamont moraine, the inner border of which crosses the extreme southeast corner of the county and continues northward nearly parallel to the Marshall-Story county line. The main body of the moraine lies in Marshall county.

In Story county the Wisconsin is clearly separable into an earlier and later stage, with the Gary moraine as the dividing line. The time interval between the stages, measured in terms of oxidation and leaching, and topographic development, was certainly greater than the time which has elapsed since the retreat of the ice from the county. Outside of the Gary moraine, well sections show that the yellow till attains a thickness of from fifteen to forty feet over areas which have suffered little loss through erosion, and have received no gain from deposition. Over similarly circumstanced areas inside of the moraine, the slightly altered zone rarely exceeds from five to ten feet. The streams which have established themselves on the earlier drift have cut vertically from thirty to seventy or even eighty feet, and have made some progress toward the formation of valleys. On the later drift, stream trenching is inconsiderable, and, if Hamilton county be included, a glance at the map is sufficient to show the great disparity in the development of the drainage lines in the two areas.

As has been mentioned earlier in this report, the retreat of the Wisconsin ice from the region was interrupted by numerous halts, marked by a succession of recessional moraines. One of these, in addition to the Gary, is believed to possess

sufficient individuality to deserve a name—the Walnut creek moraine.

Contemporaneous with the heaping up of glacial debris at the end of the ice were certain streams issuing from the melting ice. These surcharged streams were competent to carry coarse sand, gravel, and even bowlders of small size, which were redeposited over the flood plains of the then existent streams in their lower courses. These gravel beds and bars have been removed in part since the retreat of the ice, and broad benches or terraces are the result. A system of terraces has its beginning at the Walnut creek moraine, and thus establishes more firmly the reality of the ice-halt at that point. Cambridge, on Skunk river, and Maxwell, on Indian creek, are built on terraces belonging to this system and attaining heights of twenty-five and twenty feet above the flood plains of the respective streams. Terraces continue northward on East Indian creek to the three forks in sections thirteen and fourteen in Nevada township, where they have a height of twenty-five feet above the flood plain and are composed of very coarse materials; much coarser than at Maxwell. The equivalent terrace was not recognized on the west fork of the Indian.

Along the Skunk the Walnut creek terrace may be traced northward to the creek of the same name, where it is superseded by a younger terrace, the contemporary of the Gary moraine. The gravel train produced by the Gary, reaches its maximum development, both areal and in vertical section, in the vicinity of Ames along both the Skunk river and Squaw creek. At Soper's mills the Gary rises twenty feet above the flood plain; at Ames, it rises thirty feet, after which it grades down gradually to ten feet in southern Grant township, and finally merges into the Walnut creek bench. Figure 24 shows the cross-section and gradient of the terraces in comparison with the cross-section and gradient of the present stream.

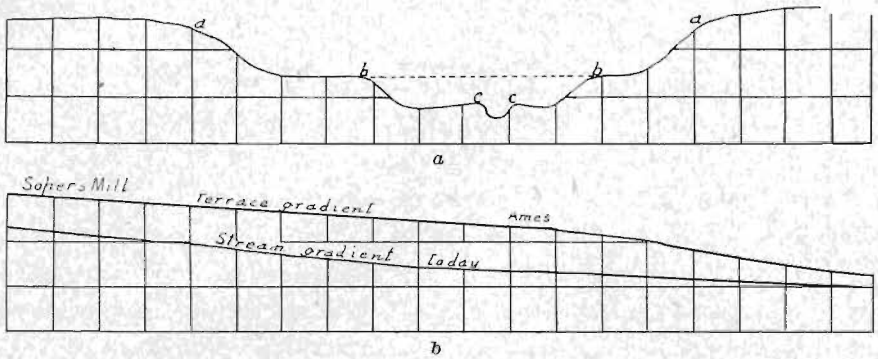


FIG. 24. *a*, Cross-section of Skunk river. The space below the broken line, bb, represents the amount of material removed since the retreat of the Wisconsin ice.
b, Stream and terrace gradients compared.

Development of the Skunk River System.—The towns of Ames and Cambridge are built on gravel bars located at the confluences of Squaw and Ballard creeks, respectively, with the Skunk river. Records of wells put down at these points show a series of sands and gravels separated by heavy beds of clays and silts. At Ames the basal gravels are reached at a depth of from fifty to eighty feet below the bottom of the present stream. The creamery well at Cambridge, which is located upon the Walnut creek gravel train, shows:

		FEET.
5.	Loam and yellow clay	10
4.	Sand and gravel	10
3.	Clay, blue	25
2.	Sand, fine	10
1.	Gravel, coarse	10
	Total	65

Borings at other points tell the same story. The country rock under the area mapped out by the terrace and flood plain lies from fifty to one hundred feet lower than in the walls of the valley.

The flood-plain terrace deposits average two miles in width south of Ames. The low ridges which bound these deposits rise gradually away from the river, so that the real depression possesses a much greater width. North of Ames the scene soon changes. At Hannom's mill the valley cross-section is

RANGE XXIV WEST.

TOWNSHIP LXXXIV NORTH.

TOPOGRAPHICAL MAP

OF

A PORTION OF

FRANKLIN TOWNSHIP

STORY COUNTY IOWA

1898

SURVEYED AND DRAWN BY

FRED N. LEWIS DEPARTMENT OF CIV.-ENG.

AND

IRA A. WILLIAMS DEPARTMENT OF GEOLOGY

IOWA STATE COLLEGE

AMES IOWA

HORIZONTAL SCALE — MILES

0 1/4 1/2 3/4 1

Contour interval 10 feet.

GILBERT

BOONE CO. STORY CO.

SQUAW CREEK

NORTH WESTERN R. R.

CHICAGO AND

SKUNK RIVER

© 210 (Rock)

© 206 (Rock)

© 270 (Rock)

LEGEND

- Contours showing elevation above sea level.
- Contours showing depression.
- Streams and ponds.
- County lines.
- Roads, school houses and section lines.
- Railroads.
- Marshes
- Towns.
- Quarries.
- Well

GEOLOGICAL SECTIONS

VERTICAL SCALE FEET

A

8	Drift (Wisconsin)
7	Weathered limestone.
6	Cherty limestone.
5	Arenaceous limestone.
4	Fine grained limestone.
3	Lithographic limestone.
2	Fossiliferous limestone.
1	Lithographic limestone.

B

9	Drift (Wisconsin).
8	Drift (Kansan).
7	Weathered limestone.
6	Cherty limestone.
5	Arenaceous limestone.
4	Fine grained limestone.
3	Lithographic limestone.
2	Fossiliferous limestone.
1	Lithographic limestone.

C

4	Soil.
3	Drift (Wisconsin).
2	Drift (unoxidized).
1	Gravel (Buchanan?).

This map shows the topography typical for the Wisconsin drift; also the marked constriction in the flood plain of Skunk river, which marks the probable point of divergence of the present stream from its pre-Wisconsin channel. The sections at the lower left-hand corner show the sequence of strata which outcrops at A, B and C, on the map.

reduced to less than one-third of its dimensions a mile below. The stream is not only rock-walled, but rock-bottomed. The broad, depressed U-shaped valleys, indications of old age, have been replaced by the narrow U to the V-shaped gorges which are only retained during the early stages in the development of a stream. The river occupies no well-marked depression wider than the flood plain.

In the valley of the Squaw the old age characters are still retained. The creek meanders through a notable depression, much wider than indicated by the flood plain and terrace deposits, and wholly comparable with the depression below Ames. Artificial sections demonstrate that the indurated rocks lie much lower in the valley than under the general upland. Alternating clays and gravels, similar to those penetrated at Ames and Cambridge, are encountered. Briefly told, it would appear almost a certainty:

First.—That the lower course of the Skunk river proper is very old, certainly older than the Wisconsin, and probably preglacial. Above Hannom's mill the stream is much younger. Here its history is somewhat contradictory. In places well sections located in or

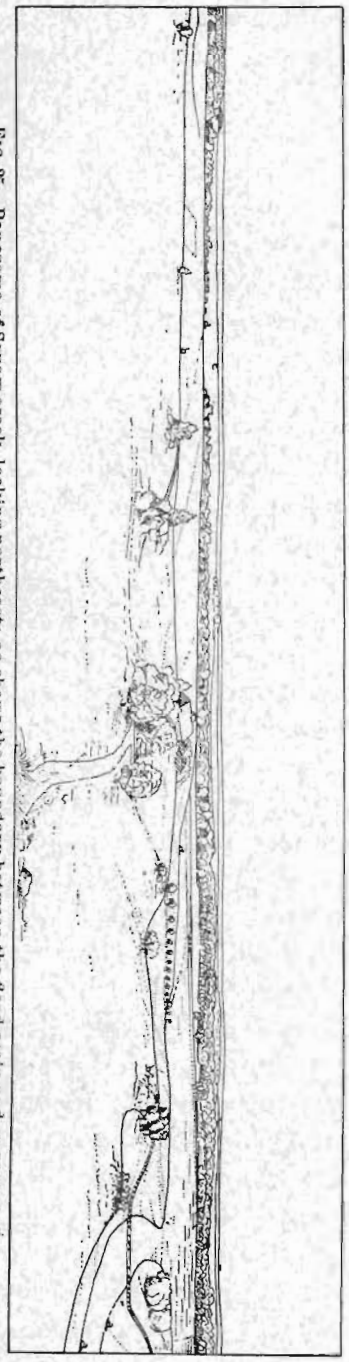


FIG. 25. Panorama of Squaw creek, looking northeast; aa shows the boundary between the flood plain and terrace, and bb separates the terrace and upland.

near the flood plain penetrate deeply buried silts and gravels At other places, at Hannom's and Soper's mills, its youthfulness is unquestionable. Suffice it to say that the Skunk has, perhaps, in this section, sought out and partially resurrected one of the important tributaries of the preglacial system.

Second.—That the river which was capable of cutting a gorge more than 100 feet in depth, and at least two miles in width, was immensely greater than its insignificant descendants, and, if the preglacial climate was not materially different from that of to-day, the progenitor of the Skunk drained a much larger area than the present stream.

Third.—That near Ames the principal channel pursued a northwest-southeast course, which was filled in, in large measure, with glacial debris, and has been only partially reopened by Squaw creek. The precise point of departure from the old course cannot be located definitely. From the great embayment below Hannom's mill a depression continues in a northwesterly direction, and becomes tangent with the valley of the modern Squaw near the Boone-Story county line. The general surface features and stream trend would lead one to suspect this to be an opportune point. The well data at hand fully accords with this view, but is scarcely sufficient to demonstrate it beyond a doubt. That the rock surface as a whole is rapidly depressed to the southwest and reaches its minimum elevation in the Squaw valley proper there can be little question. This arrangement would be in strict accordance with the almost universal northwest-southeast pre-Wisconsin drainage systems of the state.

Fourth.—It has been stated in previous reports* that the Des Moines river, above the city of Des Moines, flows in a post-Wisconsin channel, while its lower course occupies a much older valley. This fact, taken in connection with the facts derived through the present investigation, suggests very strongly that the last ice invasion despoiled the Skunk of much of its territory, and the Des Moines was the gainer. In

*Geology of Polk county, vol. VII, Geology of Boone county, vol. V.

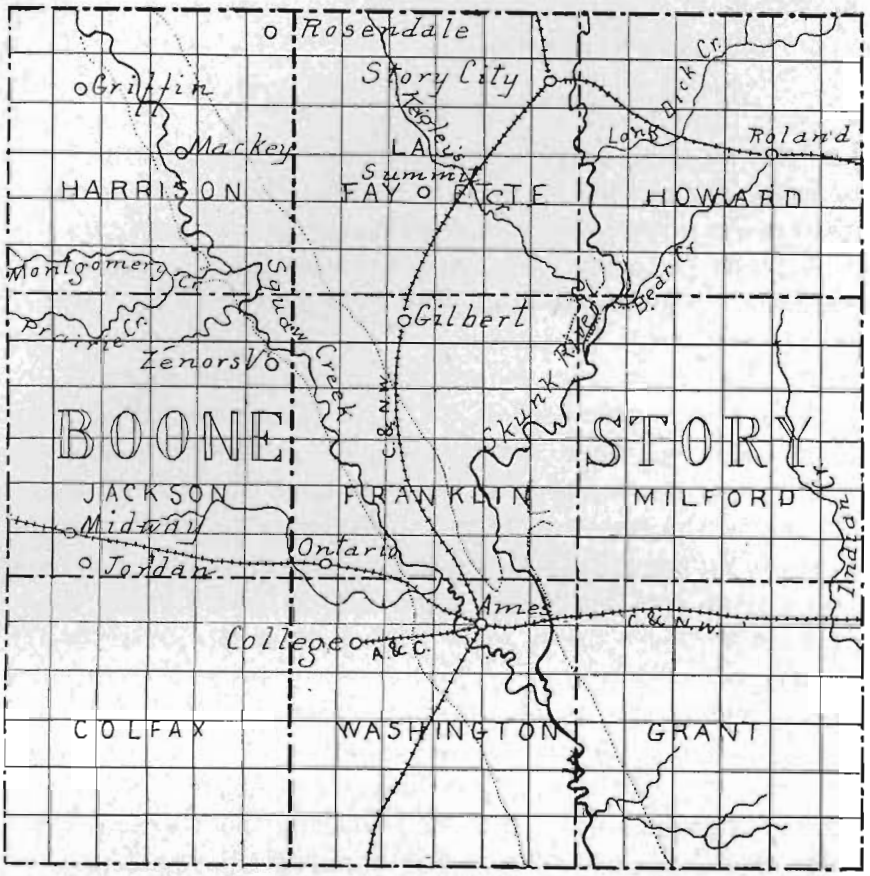


FIG. 26. Map showing the probable course of Skunk river in pre-Wisconsin times.

fact, it appears highly probable that the headwaters of the present Des Moines found their way to the Mississippi formerly through the Skunk. Or, in other words, the Skunk was literally "beheaded" by the Wisconsin ice. One tributary of Squaw creek extends within a mile of the Des Moines river to-day, at Stratford, in Hamilton county.

Aside from Squaw creek the tributaries of the Skunk can be dismissed with slight mention. Indian creek, in its lower course, has a well developed valley which is terraced, and at Maxwell is underlain with alternating clays and gravels similar to those of the Skunk and is, perhaps, the only tributary

represented in the early history of the system, all of the others being post-Wisconsin.

REMAINS OF THE MAMMOTH.

"Sometime during the summer of 1894 an interesting find was made on the farm of Dr. H. M. Templeton, in Washington township. The discovery was made by the occupant of the farm, while engaged in digging a well. The well was being sunk in one of the numerous depressions which are a frequent surface mark in this section of the county. This depression formerly contained a few feet of water, and it still receives surface drainage in times of heavy rainfall. The center of this basin, which comprised two or three acres, was but a few feet below the level of the outer rim. The soil was composed of the washings from the surrounding land and the remains of marsh vegetation characteristic of similar surface conditions on the Wisconsin drift. When the digging had proceeded to the depth of four or five feet, a deposit of bone fragments was discovered. This included the bodies of four or five dorsal vertebræ, a portion of the upper extremity of one rib, a short section from the lower end of the tibia and the lower extremity of the left femur, besides a number of fragments rather difficult to assign to their exact location in the skeleton. The masses would very nearly fill a half-bushel measure. There were none of the long bones complete, and none of the pieces would give a very correct notion of the entire length of any of these portions of the skeleton. The parts giving the best idea of proportion are the vertebræ, the head of a rib, in quite good state of preservation, and the lower extremity of the femur. The vertebræ show both anterior and posterior articular surfaces in a perfect state of preservation. The transverse and vertical measurements of these surfaces are nearly exactly the same; four and one-half inches. The antero-posterior diameter, or the vertebral body, is exceedingly short, considering the immensity of the other measurements. The length is but two and one-half inches.

This must have given the creature a back grotesquely short in comparison with its gigantic size. The articular facets on the inner surface of the head of the rib, measures three and one-half inches. The excavations at the anterior and posterior extremities of the vertebral bodies almost blend into one another. The part giving the most correct notion of the enormous size of the animal is the remains of the thigh-bone. The fragment represents a section from the lower end of the bone, just long enough to show the femoral trochlea and the two condyles. These are almost perfect, with the exception that a small fragment has been broken away from the external posterior part of the external condyle. The internal condyle is in a perfect state of preservation. The extreme length of the articular surface extending from the lower border to the external condyle to the upper margin of the trochler surface, on which the patella glides, is sixteen inches. The transverse measurement through the center of the condyles is eight inches. This mass is from eight to ten times the size of the corresponding part of an average sized horse.

All the parts are quite firm, and in such state of preservation that they have not in the least been affected by exposure since their removal from the ground. The conditions were such as to lead to the conclusion that the bones could never have been buried to a greater depth than that at which they were discovered. The superincumbent covering must have been increasing in thickness, rather than diminishing, on account of the process of gradual filling now going on in these shallow prairie basins. A number of trial excavations were made in different parts of the depression, without unearthing any additional portions of the skeleton."*

A perfectly preserved molar tooth of *Elephas primigenius* was found by a C. & N.-W. Ry. employee, at Polk City, during the present summer. The tooth occurred in the gravels which occur at that place and are evidently late Wisconsin in age.

*The above description was written by Prof. M. Stalker, of Ames, Iowa.

These finds are interesting in that it makes it reasonably certain that these huge Proboscidians roamed over Story county during late Wisconsin, or even during post-glacial, times.

POST-WISCONSIN DEPOSITS.

Aside from the terrace gravels whose deposition was contemporaneous with the retreat of the Wisconsin ice, and the alluvium accumulated since the retreat, both of which have been discussed sufficiently, certain arenaceous to silty gray-brown deposits, remarkably homogeneous and devoid of pebbles and bowlders, border some of the larger streams and are, perhaps, worthy of special mention. These highly siliceous deposits flank the Skunk and the Squaw, are noticeably present along the lower course of Indian creek, but are most in evidence along the eastern margin of the Skunk river valley below Bloomington. The deposits attain a maximum thickness of from three to five feet on the brow of the bluffs, thin rapidly inland and are scarcely recognizable more than a mile from the bluff scarp. These deposits are responsible for the heavy, sandy roads along so many of the streams in the Mississippi valley, and are shunned alike by the teamster and the bicyclist. They are often known locally as "White Oak soils," because that very well known and desirable species of oak finds in them a congenial host. The deposits are thoroughly oxidixed and leached, and appear to be wholly devoid of structural or bedding planes. The coarsest materials which enter into their composition are found nearest the flood plain, and the size of grain diminishes gradually as the deposit feathers out away from the river. The source of the materials and the transporting agent are not difficult to apprehend. The process of accumulation is going on to-day. The wind, sweeping across the broad flood plain, gathers up such material as can be transported and moves it toward the restraining bluffs. Perhaps only the very finest materials are given continuous passage for any considerable distance. But

through successive short excursions the coarser silt-particles and even fine sand grains eventually reach the brow of the bluff and are deposited in the reverse order of their fineness*.

The position of these deposits is determined essentially by the surface contours. The wind crossing the valley impinging against the hill flanks is deflected upward, and, coming in contact with the still air above, loses velocity, and being unable to carry its load further, deposits it over the brow of the hill. In this location its position is reasonably secure, though the entire assemblage of deposits possesses the proclivities of the sand dune and may progress bodily inland.

This process of wind transport and accumulation of materials may readily be witnessed. During early spring and late autumn, when large tracts of bottom land are unprotected by vegetation, dust storms are common, and often during a single "blow," a measurable deposit is accumulated. If this be true now, how much greater must have been the efficiency of the winds which blew across the wide flats before vegetation had time to reclaim the valleys so recently vacated by the Wisconsin ice?

The prevailing winds for central Iowa during spring and fall are from the west, and hence the greater accumulation of æolian deposits on the eastern flanks of the streams.

These deposits are worthy of more than passing notice, when viewed analytically, on account of their striking similarity, in many respects, to the loess. Structurally, texturally, and in composition and distribution, there is a remarkable resemblance. Both are essentially devoid of stratification planes, possess a uniform, open texture, are highly siliceous,

*A most luminous and helpful discussion of wind erosion, transport and deposition, will be found in Professor Udden's Memoir, entitled "The Mechanical Composition of Wind Deposits," published by the Lutheran Augustana Book Concern, of Rock Island, Ill., 1893. The subjoined table gives the approximate maximum distances over which quartz fragments of different dimensions may be lifted, by moderately strong winds, in single leaps:

Gravel (diam. from 8 to 1 mm), a few feet.
Coarse and medium sand (diam. 1 to ¼), several rods.
Fine sand (diam. ¼ to ⅛ mm.), less than a mile.
Very fine sand (diam. ⅛ to 1-16 mm.), a few miles.
Coarse dust (1-16 to 1-32 mm.), 200 miles.
Medium dust (1-32 to 1-64 mm.), 1,000 miles.
Fine dust (1-64 mm. and less), around the globe.

being composed chiefly of silt and fine sand, and appear to be genetically related to the chief water courses, along which they attain their maximum development. True, the loess is usually highly calcareous, but this may readily be referred to a difference in the condition of the materials drawn upon, and be wholly independent of the process of accumulation. It is now pretty generally conceded that the loess is genetically related to the Iowan drift, perhaps the overwash from that sheet. It is also well known that the Iowan carried the largest and freshest bowlders of any sheet, and it is reasonable to suppose that the finer materials were equally fresh at the time they were deposited. This is evidenced by the Iowan drift itself, the surface only showing any signs of weathering. The mud flats were doubtless much more important then than now and if atmospheric circulation was equally as vigorous as at the present time, wind erosion and deposition would be much more widespread and important, and the rate of accumulation might be so much accelerated that oxidation and leaching of the rock meal would be imperfect or almost wholly wanting. The loess deposits which have been protected by the Wisconsin drift lend credence to this view. The exposures near Kelly and Ames are not only unoxidized and unleached, but still retain their original blue color, which is so characteristic of unaltered secondary deposits. These deposits also emphasize the extremely short time interval between the deposition of the loess and the Wisconsin advance. The loess, where unprotected, is a straw to gray-brown throughout, and the lime concretions sufficiently attest that incipient leaching has begun. In places where the deposit has neither lost by erosion nor gained by deposition, the leached zone varies from two to four feet in thickness and is identical with the wind accumulations along the streams of to-day. The loess, in all probability, originated through the rapid accumulation of perfectly fresh materials from the extensive mud flats and overwash plains, which formed an apron to the Iowan till sheet, while the latter represent the much slower assembling

IOWA GEOLOGICAL SURVEY

MAP OF THE SUPERFICIAL DEPOSITS OF STORY COUNTY, IOWA.

BY

S. W. BEYER

1899.

R XXIV W · R XXIII W · R XXII W · R XXI W

T 85 N · T 84 N · T 83 N · T 82 N

LAFAYETTE · HOWARD · WARREN · LINCOLN

FRANKLIN · MILFORD · RICHLAND · SHERMAN

WASHINGTON · GRANT · NEVADA · ALBANY

PALESTINE · UNION · INDIAN CREEK · COLLINS

STORY CITY · Roland · McCallsburg · Zearing · Summit · Gilbert Station · Bloomington · Ontario · AMES · NEVADA · Colo · Kelley · Iowa Center · Cambridge · Huxley · Slater · Sheldahl · Elwell · Maxwell · Collins

Scale 1/125000

1 ½ 0 1 2 3 4 5 Miles

1 ½ 0 1 2 3 4 5 Kilometers

LEGEND

ALLUVIUM	
WISCONSIN DRIFT	
ALTAMONT MORAINE	A
GARY MORAINE	G
KAMES	
IOWAN LOESS OVERLYING KANSAN DRIFT	

IOWA LITHO. CO.

DRAWN BY F. C. TATE

of the leached and oxidized materials from the alluvial plains of to-day.

While the processes which obtained during the deposition of the two sets of deposits cannot be demonstrated to have been identical, their inherent resemblances and environments are certainly very striking. Aside from the comparisons already made they are very closely related faunally. Professor Shimek* has shown that with a few unimportant exceptions the loess Mollusks were all air-breathers whose habitat must have been very similar to that which prevails in the Iowa-Nebraska region of to-day.

Unconformities and Deformations.—Outside of the county in areas where the Des Moines and Saint Louis occur together, and the contact plane can be observed, the former is seen to overlie the latter unconformably. In Story county the glacial debris effectually conceals the contact zone between the two formations, and yet the uneven surface presented by the basement of the coal measures, as already sufficiently elaborated, makes it reasonably certain that the Des Moines occupies erosion hollows in the Saint Louis.

There is everywhere a profound unconformity between the Pleistocene and the older deposits, and a break of minor importance separates the two drift sheets known to be present in the county.

While the epeirogenic movements of the area have been several times repeated on a scale sufficiently large to be recorded in recurrent series of deposits, differential uplifts are more elusive in a drift-buried country, and only one can be definitely recognized in the geological structure of the county.

The Skunk River Anticlinal.—Prof. W. J. McGee, in his "Pleistocene History of Northeastern Iowa,"† records a series of more or less parallel flexures in the strata of Iowa. The general trend of these deformations is northwest-

* The exhaustive memoirs which embody the results of this keen, conscientious observer and conservative writer may be found in the recent volumes of the Iowa Academy of Sciences.

† Eleventh Annual Report, U. S. Geological Survey, p. 336 et seq.

southeast, and as a rule their amplitudes are so slight that "their presence is only detected by a comparison of altitudes at different points, by anomalies in outcrop, or by the topographic configuration determined by them." Among the salient flexures an anticlinal is mapped whose axis is approximately coincident with the Skunk river, and McGee has denominated it the Skunk River anticlinal. Its recognition was based largely upon inferences from geologic outcrops, and its establishment was scarcely beyond the pale of hypothesis. The College well record, when taken in conjunction with the well records from Boone and Nevada, establish the existence of such a convex flexure beyond the peradventure of a doubt. (See plate iv.) The average difference in elevation of equivalent strata between the College and Boone is about 300 feet. If the dip is assumed to be constant between the two points, this would give a gradient of 25 feet per mile. Between the college and Nevada the average fall of equivalent strata is about 150 feet, or 15 feet per mile. The strike is presumably northwest-southeast, and is essentially parallel to the supposed direction of the anticlinal axis. Hence, the average dip would be about 35 and 21 feet per mile for the southwest and northeast limbs of the fold, respectively.

ECONOMIC PRODUCTS.

Coal.

As has been previously stated, Story lies wholly within the Iowa coal field. Although seemingly as favorably situated as other counties, which surpass it in production, the county does not rank as one of the great coal counties of the state. In 1898 only one mine was in active operation. The output for 1897 scarcely exceeded 12,000 short tons, the greatest for any year in the history of the county. Desultory attempts have been made to develop the coal resources of the county near McCallsburg, in Warren township, and in Collins township, near the Polk county line, and some prospecting has been

done at other points. At present the only mine in operation is located at Summit, in Lafayette township.

Summit.—North Star Coal & Mining Co. During the fall of 1892 and the spring of 1893 a shaft was sunk on land owned by W. S. Johnson, Sw. qr. of Sec. 21, Lafayette township. Operations have continued with slight interruption since. The vein worked is about 135 feet from the surface. The sequence of strata penetrated in sinking the shaft, as given by W. S. Johnson, is as follows:

Number.	DESCRIPTION.	Thickness —feet.	Depth - feet.
19	Soil	3	3
18	Clay, yellow, gravelly	20	23
17	Clay, blue	5	28
16	Sand, bluish	1	29
15	Sea-mud (loess, probably)	40	69
14	Sand and gravel (till, perhaps)	26	95
13	Hard rock	1	96
12	Clay, sandy	3	99
11	Coal "blossom"	½	99½
10	Fire clay	1	100½
9	Coal	⅓	100⅚
8	Fire clay, bluish	11	111⅚
7	Coal	⅙	112
6	Fire clay	7½	119½
5	Coal, good	2	121½
4	Fire clay, bluish	4	125½
3	Shale, hard	3	128½
2	Shale, blue	6	134½
1	Coal, excellent	4½	139
	Fire clay, exposed	3	142

At least five coal horizons were penetrated, only one of which was thought to be of commercial importance. At least one vein is known to exist below the one worked. The mouth of the shaft is located on the north slope of the Gary moraine, about 1,050 feet above sea level. The mine is equipped with modern top-works, a steam fan, and the "room and pillar" plan is pursued in mining the coal. Owing to the nature of the underlying strata some trouble is experienced from "creep," and even with the most approved methods of working, under existing conditions, it is scarcely possible to win

more than 60 per cent of the total coal. The vein runs fairly even, thickening towards the basins and thinning towards the "rolls." The maximum variation in elevation does not exceed ten feet. The roof is rather weak and treacherous, and renders careful mining imperative to avoid accidents. The coal is of excellent quality, comparing favorably with the best product of central Iowa. The mine supplies a large local trade, but it, nevertheless, ships a considerable percentage of its output. A spur of the C. & N.-W. Ry. has been extended to the shaft, so that the coal may be loaded on the cars without rehandling.

The coal developed at Summit is apparently an eastward extension of the Squaw creek basin. This is evident from the general stratigraphic similarity of the coal horizons in the two areas. The veins mined in both localities have practically the same elevation. This basin is divided by Skunk river, but the coal reappears in the vicinity of McCallsburg, where some prospecting has been done. At this point a vein of coal, three feet in thickness, is said to have been found, and mining operations, in a crude way, were carried on during short intervals for several winters. A seam of cannel coal was at one time reported, but upon examination the find proved to be a highly carbonaceous shale associated with the coal seam. The Mormon Ridge coal, in Marshall county, appears to mark the eastern terminus of this basin, and the territory lying between this point and the Squaw creek fields, in Boone county, will undoubtedly yield a fair return to systematic prospecting.

Collins.—Well drillers report coal at numerous and widely distributed points over the southeastern quarter of the county. While this is generally known almost no systematic prospecting has been done, and only in a single instance has any serious attempt been made to develop the bed. On the farm of Silas McQuiston, located on the Ne. qr. of the Sw. ¼ of Sec. 34, in Collins township, a shaft was sunk some years since, and operated during the winter season. The entire

output found a ready sale at the mine, but was never great enough to supply the local demand. The mouth of the shaft is located on the bottom land along Wolf creek, and the strata penetrated are essentially as follows:

		FEET.
5.	Drift	70
4.	Coal measure shales and clays	60
3.	Coal	2
2.	Fire clay and shale	7
1.	Coal	3½
	Total	142½

The coal has a good reputation among the consumers. The vein was reported to run fairly uniform in thickness, but the roof, as in the case of all Story county coal, was of rather uncertain character. The mine was last operated, some two years ago, by Marshall & Crow, of Boone county. Prospect holes have been put down, both east and south of the above mine, and demonstrate that the coal continues some distance in those directions.

The outlook for the development of the coal industry in Story county, while not brilliant, is certainly not wholly discouraging. Practically no systematic prospecting has, as yet, been done. Numerous well records show the presence of one or more coal seams throughout most of the coal measure area. It is scarcely probable that so wide an area, showing the presence of coal horizons, will not, sooner or later, be found to include veins of commercial importance. The most hopeful areas would appear to be in the line of the Squaw creek-Summit basin and in the vicinity of Collins. An intelligent and judicious use of the core drill in these areas may be reasonably expected to earn a moderate reward.

Clay.

Story county is supplied with an adequate quantity of clay for furnishing brick for all structural purposes, for paving the streets of its towns, and making the draintile necessary for

properly draining its immature surface. The younger drift covers practically the entire county, and when unmodified, yields no clays suitable for either brick or tile. The alluvial deposits, which attain considerable importance along Skunk river and its greater affluents, and the wind accumulations along the bluffs which border these streams, afford unlimited quantities of material suitable for handmade brick capable of meeting all requirements for the less imposing structures. The larger streams have removed the younger drift at numerous points, and have greatly reduced its thickness at many others, so that the clays and shales of the older terrains have been rendered available. In Washington, Indian Creek and Collins townships, important deposits of loess are easily accessible, while at Story City, Roland, Nevada, and Maxwell, from ten to twenty feet of Carboniferous clays and shales are exposed. The coal measure shales are at present being developed only at the last three places mentioned.

COAL MEASURE CLAYS.

Nevada.—Several factories have been operated somewhat intermittently, in the vicinity of Nevada, during the past fifteen years. Of these, Lyman & Company operated continuously for more than a dozen years. Draintile and structural brick were the chief manufactured products. The works were located along West Indian creek, immediately north of the C. & N.-W. right of way. The raw material was obtained from the east bank of the creek.

The Paul Nelson Tile works were in operation a number of years at this place. The plant is situated near the railway station, and the raw material used was obtained south of the railway track near the Lyman pit. While neither of the above plants are entirely dismantled, neither was in active operation during the current year. In 1897, the S. M. McHose Brick and Tile plant was established on the West Indian creek, just south of the Ames-Nevada wagon road. Here nearly twenty feet of clays and shales are available with com-

paratively little stripping. In the following section, all save the drift and the arenaceous layer is utilized.

		FEET.
7.	Drift, bowldery, calcareous	5
6.	Shale, blue, variegated; containing much ferruginous staining along the joint planes and known as "calico clay"	12
5.	Sandstone, gray	½
4.	Clay, gray blue, jointed; containing some concretionary matter	3
3.	Shale, carbonaceous	½
2.	Fire clay	2
1.	Shale, jointed, highly ferruginous; exposed	2

The plant is equipped with dry-pan, pugger and Hoosier Brick and Tile mill. Ample drying sheds are provided, and both air and steam are used. Three days are required to dry the brick by steam, while two days proves sufficient for tile. Four round, down-draft kilns, of 48,000 brick capacity each, are used in burning. Ordinary brick is burned in seven days. For common brick and tile one part of alluvium or hillside wash is added to two parts of the clay shales. The loam heightens the color and facilitates the burning, though it weakens the product. Common structural brick and drain-tile, the latter varying from three to twelve inches in diameter, constitute the chief product. Fire brick and pavers have been produced in small amounts. The paving brick examined were "end cut" and the lamination exhibited in cross-section was very pronounced. The product vitrifies very well, and the lamination could be, in large measure, prevented by more careful mixing and tempering, or it could be rendered less pronounced by side-cutting the brick. However, the plant can scarcely be said to be fully installed as yet, and the intelligence and good judgment displayed in its equipment are certainly very commendable.

Roland.—In the southern part of town is located the Swenson & Co. Brick and Tile works, which have been in operation for nearly a quarter of a century. The plant has been under the present management since 1886, though until the past

year the firm name was Swenson Bros. The clay is obtained from the bank of Bear creek. Seven or eight feet of shales of good quality are exposed, black below, and light grey to a variegated yellow above. Underlying the material used is ten or twelve inches of dark blue to black clay, containing iron pyrites; while overlying the deposit is a foot of sand and gravel, followed by a foot of black loam. The loam and some sand is mixed with the shales in treating them to deepen the color and render the ware more easily worked. The Potts disintegrator and Brewer machine are used. The ware is air dried and burned in a round, down-draft kiln. Tile, ranging from three to ten inches in diameter, form the chief product, though of late years a considerable number of common brick have been manufactured.

Maxwell.—The Charles E. McHose Brick and Tile works are located about a mile east of town, on the Chicago, Milwaukee and St. Paul railway. The plant is equipped with a Potts disintegrator and the Ideal brick and tile machine, made at Decatur, Ill. Drying is done chiefly through natural heat, though aided somewhat by exhaust steam. One down-draft kiln of 30,000 capacity is employed in burning. The time required is eighty hours. Draintile from threes to eights inclusive, and side-cut common, and end-cut paving, brick constitute the manufactured product. The milling and tempering of the raw material is very imperfect, and the small kiln capacity, which leads to forced burning and too rapid cooling, are responsible for the great loss suffered through checking of the ware and for the poor quality of the manufactured product.

The pit is located about one-half mile south of the works. About fifteen feet of Carboniferous shales are available, and very little stripping is required. The section is as follows:

		FEET.
4.	Drift, weathered above, but calcareous below	6
3.	Shale, gray; slightly arenaceous	8

2. Shale, variegated, much iron-stained along the joint and bedding planes; a limonitic, concretionary layer occurs about two feet from the base; iron concretions are common throughout..... 7
1. Sandstone, exposed..... .....

The shales are of good quality and an enormous quantity is in sight. Number 3 is difficult to burn when used alone, but when mixed with number 2 yields more readily, and takes on a more desirable color for structural purposes.

The coal measure shales have been developed intermittently at other points during the last decade. Several firms have operated from time to time in the vicinity of Story City, but none were in operation during the current year.

PLEISTOCENE CLAYS.

Ames.—Clay working has been practiced in the vicinity of Ames for almost a third of a century. The plants were located along Clear creek, a branch of the Squaw, about three miles west of the railway crossing at Ames. Many of the brick used in the construction of the main college building, and the rough brick used in several of the later buildings, were made in these yards. Here a heavy bed of loess occurs and has been utilized for soft-mud brick. At the pit the following beds are exposed to view.

	FEET.
2. Drift, yellow; upper portion modified into soil.....	5–10
1. Loess, the upper portion oxidized a yellowish-buff in color, two to five feet; lower portion a gray blue, exposed, five to eight feet	12

Gastropod Mollusks, as mentioned in an earlier paragraph in this paper, abound throughout the loess. Lime concretions are somewhat abundant in the slightly oxidized zone, and when worked in with the raw material have a deleterious effect on the manufactured product.

Cameron & Lyon operate the works at present. Some brick and draintile of the smaller sizes constitute the sole manufactured product.

Kelley.—The Kelley Tile works, J. M. Stark, proprietor, were established in 1887. The plant is located just east of the railroad station, though the raw material is secured from a pit along Walnut creek, about two miles east of town. Common brick and the more common sizes of draintile are the chief products. A smooth-roller, Penfield crusher, and a Hoosier brick and tile machine constitute the machinery used. Round, down-draft kilns are used, and the siliceous clay withstands much heat. There is considerable lime, in a finely divided state, in the raw material, and to prevent air slacking it is necessary to heat to high enough temperature to vitrify slightly the product, and, perhaps, to fix the lime completely in the form of the silicate. The raw material here, as at Ames, is the loess. Considerable stripping is made necessary in order that the deposit may be worked. The loess is blue gray, jointed above, and grades downward into a massive, structureless deposit, which is finally terminated by a gravelly layer of an earlier drift sheet. The deposit is highly siliceous and fossiliferous throughout.

Maxwell.—Prince Shope owns and operates a small plant near Indian creek. Hillside wash and alluvium are wrought into mud brick.

Numerous other small factories have operated during brief seasons and then were abandoned. Handmade brick were the more common product.

Scarcely more than $6,000 worth of clay goods, manufactured in Story county, were sold during 1897. The entire output was consumed at home, and in not a single department was the output sufficient to supply the local demand. From the beginning of the tile industry the production has never been equal to home consumption, and the deficit has been supplied by neighboring counties no better equipped, so far as the natural resources for tile making is concerned, but, perhaps, more resourceful in using what they had. Only a minor portion of the common brick used were made within the county, and no attempts have been made to produce dry-

pressed and fancy brick. A few pavers and fire brick have been manufactured, sufficient, merely, to demonstrate the possibilities along that line. The Pleistocene deposits afford an abundance of material suitable for structural and dry-pressed brick, and draintile, while the coal measures offer, in addition, material suitable for the vitrified pavers and more refractory fire brick.

Building Stone.

Story county is poorly supplied with stone suitable for structural purposes. The Saint Louis limestone affords a limited quantity of stone adapted to foundation work and use in the rougher grades of masonry. The rock is, as a rule, highly absorbent and does not stand frost well. Its earthy-buff to gray-buff color gives it a dull, somber appearance, which increases rapidly on exposure on account of the readiness with which it takes up foreign matter. Some quarrying has been done at nearly every one of the outcrops in the county, though in no instance does the annual output of any single quarry exceed a few dozen cords of rough stone. The ledges developed are practically the same at all points. The section exposed north of Hannom's mill may be considered a fair average, and is as follows:

		FEET.
6.	Till, pale yellow; unoxidized and unleached.....	0-6
5.	Till, oxidized to a deep, reddish-brown and thoroughly leached; much weathered limestone and many decayed granite bowlders, and numerous, tolerably fresh greenstones present.....	1-3
4.	Limestone, residual; reduced to an iron-stained, cavernous chert	1
3.	Limestone, arenaceous; where unaltered, a bluish-gray, but weathering stains it a yellowish-brown; not thoroughly indurated, though when unweathered presents a massive appearance	5
2.	Sandstone, bluish-gray, shaly; presents a fissile character after being exposed to the weather, and forms a marked re-entrant in the quarry face.....	3
1.	Limestone, impure, buff to earthy-yellow, gray buff when unweathered; heavy bedded, compact; lithographic in part, chief quarry stone, exposed.....	8

At the Bloomington quarries more of No. 1 is exposed.

Well borings and other artificial excavations seem to indicate that no other quarry rock may be looked for in the region. The drift, especially in the morainal regions, affords great numbers of bowlders suitable for nearly all purposes to which stone can be put. They range in size from the cobble to great blocks, large enough and of suitable quality for monuments. In the early history of the county bowlder land was very much shunned by the pioneer settlers, and any attempt to render it arable was sure to prove a heroic test of the Christian fortitude of the would-be tiller. Splendid granites were piled up in fence corners and along roadways. In recent years the bowlders are being rapidly transformed into shapely blocks which appear in the foundations of substantial structures. It is found that these rough masses of stone yield readily to skillful treatment, and when tastefully arranged in a wall the effect is most pleasing and the structure is almost imperishable. In a measure, then, the Pleistocene bowlders make good the deficiency of structural materials in the older terrains.

Soils.

Agriculture is the chief industry of Story county, and the wealth of the community depends upon the fertility of the soil. The county possesses no barren or untractable land. A considerable percentage of its surface has not yet been brought under cultivation, but this is not a matter of any inherent property of the soil, but is wholly due to outside environment. As has been previously stated, the surface is immature. Nature has not had sufficient time to establish perfect drainage systems, and many undrained basins of small area persist. By the introduction of tile drains man is simply abridging natural processes, and at no distant day it may be confidently expected that no land will lie idle on account of improper aeriation and drainage.

The soils of the county resolve themselves readily into three groups, viz: alluvial, terrace and upland. The first are

coincident with the flood plains of the larger streams, and comprise an area of about twenty square miles. The alluvium, when mixed with organic matter, forms a rich, black loam, and is one of the most tractable and productive soils in the area. Its low level, however, renders it liable to inundation during seasons of high water, and hence subjects the farmer to occasional losses.

The terrace soils are limited to Skunk river and its greater affluents, and comprise the smallest area of any of the types mentioned. They are uniformly underlain with gravel, and hence do not retain water well through seasons of extended drouth. On the face of the terraces where the gravels outcrop seeping springs are formed. Ordinarily small grain does well on the terrace soil, but underdraining is rather too rigorous to ensure a good crop of corn unless the season be unusually wet.

The upland type comprises by far the greater portion of the county. It is essentially a modified Wisconsin till, stained a gray black with humus, and varies from six inches to three or four feet in thickness. In the numerous basins it is heavily charged with humus and assumes a jet black color. When properly drained and aeriated, the upland type compares favorably with the bottom land in productiveness, and is not subject to periodic inundation. To show that the productiveness of the Wisconsin drift soil depends largely upon ventilation and drainage the subjoined table has been compiled. This table also shows, in a general way, the relative value of the principal drift-sheets as producers. Corn has been selected because it is believed to respond more readily to soil treatment along the lines outlined above, is the most generally grown of any of the cereals, and requires the entire season in which to mature, for which reasons it ought to give a more correct measure of the real productiveness of the soil. Story county may be considered typical for the Wisconsin drift, Grundy for the Iowan and Poweshiek for the loess-covered Kansan. The first is characterized by a surface very

imperfectly drained and but little stream dissected. In the second the surface is monotonously even, but the drainage is fairly complete though the water escapes slowly, while the last represents a perfectly drained area. In the first period selected tile-draining was in its infancy and but little drain-tile had been laid in any of the counties. In the last trio of years selected artificial drainage has been extended greatly in Story county, and to this cause more than to any other is the greatly increased yield per acre ascribed.

Yield of Corn, in Bushels, Per Acre *

COUNTY.	CORN YIELD PER ACRE FOR—				CORN YIELD PER ACRE FOR—				Av. gain—per cent.
	1885	1886	1887	AV.	1895	1896	1897	AV.	
Story	30	15	20	21⅔	47	37	31	38⅓	77
Grundy	37	30	25	30⅔	41	50	33	41⅓	31
Poweshiek	30	20	40	30	41	42	30	37⅔	26

Road Materials.

Along the larger streams the terrace gravels afford an abundance of material suitable for road macadam. The railroads have developed these gravels at Maxwell along Indian creek, and west of Ames along Squaw creek. About ten feet of gravel is available at each place, and comparatively little stripping is required. Away from the streams, in the morainal regions, numerous gravel knobs and kame-like aggregations furnish great quantities of material suitable for road making. At other points in the county ballast is scarce, and the roads in the country and the streets in the towns are uniformly bad in wet weather and almost impassable in the Spring of the year.

Building Sand.

Sand in every way suitable for building purposes and for plaster is found in nearly all of the stream channels, and in the gravel terraces and the sand and gravel knobs so much in evidence in the morainal regions of the Wisconsin. The

*The statistics are taken from the Iowa Agricultural Reports.

FIG. 27. The Gary terrace at Soper's mill, showing course bowlder gravel overlying undisturbed Wisconsin till.

extensive sand flats along the Skunk furnish unlimited quantities of sand adapted to the rougher grades of masonry, while the finer grades of sand are often obtained in pockets in the morainal and terrace accumulations.

Potable Waters.

Until recent years, within the region under discussion, water of good quality and adequate in quantity for domestic purposes was derived from shallow drift wells. Such wells varied from ten to rarely more than fifty feet in depth. During later years the increased supply demanded by stockmen, and the series of dry years, caused the shallow wells to be abandoned, as they proved inadequate to meet the greater demands placed upon them under such trying conditions. Accordingly, deeper wells have been put down throughout the county. The chief sources of water appear to be the sands and gravels at the base of the Wisconsin drift or of the entire Pleistocene series, the interstratified sands and silts in the

valleys of the Skunk river, Squaw and Indian creeks, and certain arenaceous layers in the Lower Carboniferous series. Several pretty well defined artesian areas belong to the first group. Of these, Keigley's branch, Zearing and Dye's branch constitute the most noteworthy artesian basins in the order of their importance. "Watkins' well" is the strongest well in the Keigley's branch basin, and may be considered typical of the area. The sequence of strata passed through is as follows:

		FEET.
5.	Soil	3
4.	Clay, yellow	17
3.	Clay, blue	35
2.	Gravel and sand, water bearing	7
1.	Blue clay, penetrated	

It is reported that the drill dropped nine feet on reaching the gravel, and that water carrying gravel with it, spouted out with great violence. Bowlders of several pounds weight were thrown out. A sample of the water was analyzed by the U. S. Geological Survey in 1885, and the result is herewith appended:

Total Solids, 0.471 Grams Per Liter.

SOLIDS FOUND.		Per cent of total.	PROBABLE COMBINATION.	
SiO_2	0.0250	5.31	SiO_2	0.0250
Fe_2O_3	0.0060	1.28	Fe_2O_3	0.0060
Ca	0.0796	16.90	$Ca\,CO_3$	0.1990
Mg	0.0356	7.56	$Mg\,CO_3$	0.1246
Na	0.0501	10.64	$Na\,CO_3$	0.1155
CO_3		58.12		
Total		99.81		0.4701

SO_2	None
Cl	Trace
K	Trace
$C\,O_2$	0.3920
$C\,O_3$	0.2738

Total CO_2 in one liter, determined by R. B. Riggs, deducting the CO_2 required in the third column, leaves 0.1912 grams

for the bicarbonate. The water contains much suspended sediment.

Temperature ..... 48° Fahr.
Rate of flow ..... 28,000 gallons per hour.

There are numerous other flowing wells in this vicinity, but all of small flow. In the majority of instances the temperature is 2° or 3° higher than in the case of Watkin's well, and about 5° higher than in ordinary shallow wells in the same locality, which shows a temperature of about 45° to 46° Fahr.

In the Zearing basin all of the wells are located on the bottom land along Minerva creek, within a radius of a mile from the town of Zearing. All are of small capacity and vary from sixty to ninety feet in depth.

Along Dye's branch several flowing wells have been developed. The water-bearing stratum is reached at from eighty to 120 feet below the surface, the depth depending upon the position of the mouth of the well. The water is of good quality, but, as in the case of the preceding basins, it carries considerable ferruginous matter, as evidenced by the taste, and by the brownish rust which coats all vessels in which the water has been allowed to stand.

Several other flowing wells are known at widely separated points in the county, but in every case they are of small capacity and possess little of general interest. One fact, perhaps, worthy of repetition is that, in all cases so far as investigated, the water in flowing wells run from 3° to 5° warmer than the water in the non-flowing wells in the same localities. The temperature for the latter accords very closely with the mean annual temperature of the region while the waters which supply the former, have, perhaps, received some increment of heat by coursing through strata below the plane of variation.

Ames, Cambridge, Iowa Center and Maxwell draw their water from the alternating sands and silts of the Skunk river and Indian creek. The supply is abundant and the quality satisfactory. The railways which cross these streams secure

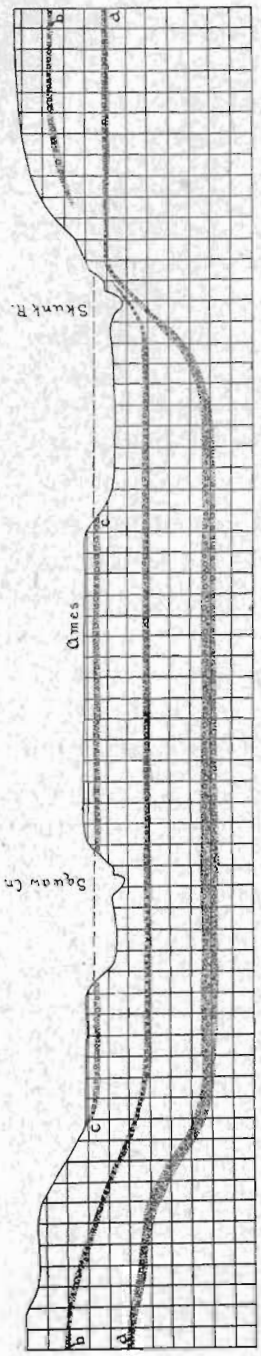


FIG. 28. Cross-section of Squaw creek and Skunk river valley at Ames, showing the gravel terrains at aa, bb and cc, all of which are water-bearing.

their water supply from the same source as the towns.

In the eastern half of the county numerous wells obtain their supply from the arenaceous beds or the limestones of the Carboniferous. The majority of these wells vary from 200 to 400 feet in depth. The water is uniformly good, but the supply is very variable. In two instances, at Nevada and Ames, the deeper strata have been explored. The former obtains a satisfactory supply from arenaceous layers in the upper Silurian, while the latter draws chiefly from the Jordan sandstone of the Saint Croix. In the latter instance, the reservoir lies more than 1,100 feet below sea level, but hydrostatic pressure brings the water within thirty feet of the surface, or 970 feet above tide. Hence the head is nearly 2,000 feet, and exerts a pressure of about 850 pounds per square inch. The supply is sufficient to sustain a continuous flow of about 8,000 gallons per hour, reducing the water level to about 250 feet below the surface. The dimensions of the well may be observed, drawn to scale in plate iii. Complete sanitary and mineral analyses of the water were made by Prof. J. B. Weems of the department of agricultural chemistry of Iowa State college, and are given below:

Sanitary Analysis.

	Parts per million.
Free ammonia	1.2
Albuminoid ammonia	Trace
Solids	1258.
Nitrogen as nitrites	Trace
Nitrogen as nitrates	Trace
Oxygen absorbed in 15 minutes	.....
Oxygen absorbed in 4 hours	.....

Mineral Analysis.

	Grains per gal.	Parts per million.
Silica (SiO_2)	.174	3.000
Alumina (Al_2O_3)	.406	7.000
Ferric oxid (Fe_2O_3)	.....	.....
Lime (CaO)	2.859	49 300
Magnesia (MgO)	1.409	24.300
Potash (K_2O)	.....	.....
Soda (Na_2O)	30.554	526.900
Chlorin (Cl)	11.821	203.800
Sulfur trioxid (SO_3)	24.923	429.700
Carbon dioxid (CO_2)	6.891	118.800
Water in combination	1 020	17.600
Totals	80 057	1380.300
Less oxygen replaced by chlorin	2.668	46.000
Net total	77 389	1334.300

Probable Combinations.

Silica (SiO_2)	.174	3.000
Alumina (Al_2O_3) ..)		
Ferric oxid (Fe_2O_3))	.406	7.000
Calcium bicarbonate [$CaH_2(CO_3)_2$]	1.259	21.700
Magnesium bicarbonate [$MgH_2(CO_3)_2$]	5.115	88.200
Sodium sulphate (Na_2SO_4)	44.254	763.000
Potassium chlorid (KCl)	.....	.....
Sodium chlorid (NaCl)	19.505	336.300
Sodium acid carbonate ($NaHCO_3$)	2.355	40 600
Calcium carbonate ($CaCO_3$)	4.321	74.500
Magnesium sulphate ($MgSO_4$)	.....	.....
Calcium sulphate ($CaSO_4$)	.....	.....
Total	77 389	1334.300

Temperature Observations on the College Well at Ames, and on the Deep Well in Greenwood Park, Des Moines, Iowa.*—The condition of the earth's interior must always be an interesting question to the student of earth physics, and data which will throw any light upon this obscure problem have, in all times, been sought for eagerly by geologists and physicists alike. The rate at which the temperature increases as the earth's crust is penetrated has been recorded in numerous instances both in Europe and in America. The commonly accepted increment which has found its way into our leading text-books is 1° Fahrenheit for every fifty-three feet descent. The data upon which this unit was based were derived, largely, from mine shafts and well sections located in or near disturbed areas, or areas whose sedimentary rocks contained igneous injections. Later observations, made in regions where the sedimentary series have remained practically horizontal throughout all time and igneous rocks are absent, have tended to lengthen the interval.

Among the most recent and reliable contributions to this subject are those of Prof. William Hallock, of Columbia college, on the deep well at Wheeling, W. Va., and Mr. E. Dunker, of Halle, Germany, on the deep wells at Sperenberg, near Berlin, and Schladabach, near Leipzig. Professor Hallock's results for the Wheeling well give a gradient of 1° F. for every 81.5 feet, down to 3,200, and below this point an increase of 1° F. for every 60 feet was recorded. Mr. Dunker's observations at Sperenberg give a gradient of 1° F. for every 59.2 feet, and at Schladabach the increase is 1° F. for every 65 feet.

The temperature observations conducted under the direction of Prof. A. Agassiz† on the Calumet and Hecla mine, in the Lake Superior copper district, give results somewhat at

*The writer desires to acknowledge his indebtedness to Prof. William Hallock, of Columbia college, for many helpful suggestions. Among the many courtesies extended by the department of Mechanical Engineering of the Iowa State College, special credit is due, for devising an ingenious contrivance for lowering the thermometer and measuring distances, without which the observations could not have been made.

†Am. Jour. Sci. (3), vol. L, p. 503. 1895.

variance with those earlier reported. The plane, 105 feet below the surface, with a temperature of 59° F. was assumed as the level unaffected by seasonal changes. The mine reaches a depth of 4,580 feet and has a temperature of 79° F. at the bottom. This gives a differential of 20°, or an average increase of 1° F. for every 223.7 feet.

The wells upon which the present observations were made are practically full of water and had not been disturbed for more than a month before the temperatures were taken. Professor Hallock's investigations on the Wheeling well, both when the well was dry and when full of water, shows that convection currents are essentially *nil* and may be neglected in ordinary temperature reductions. No corrections are made for convection currents nor for conduction, in the present investigation. A Miller-Casella self-registering, maximum-minimum thermometer* was used. The instrument was lowered and the depths measured by a steel wire which passed around a calibrated drum. In the college well, readings were taken every 100 feet, while in the Greenwood park well the interval between readings was 250 feet. The results are shown in Figure 29, where the temperature gradients are

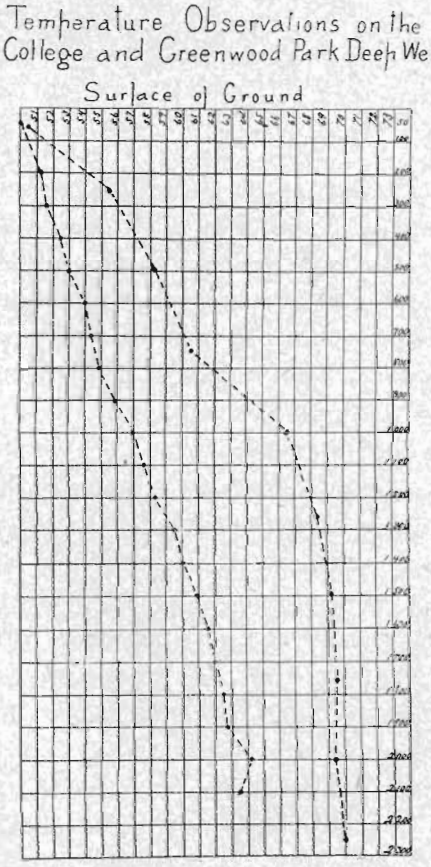


FIG. 29.

*Generously loaned by the U. S. Fish Commission.

drawn to scale. The mean annual temperature at Ames* is 47.2° F., while the temperature at 2,100 feet is 63.4° F., and the mean average gradient is 1° F. for every 129.6 feet. The mean annual temperature at Des Moines† is 48.7° F., and the temperature at 2,250 feet is 70° F., giving an increase of 1° F. for every 105.6 feet. The temperature gradient for the college well is a more or less uniform curve, while that of the Greenwood park well is a parabolic curve. In the latter instance the temperature increment is 1° F. for every 63.4 feet through the first 1,250 feet, while the last 1,000 feet measured shows a total increase of but 1.7° F.

Natural Gas.

Several years since Mr. J. F. Taylor, in sinking a well on his farm, struck a flow of natural gas. The flow was sufficient to furnish the family with heat and light, and was so utilized for several years. The gas pressure is reported to have continued undiminished until the well was filled in some two years ago. The boring was located on the Ne. qr. of the Sw. ¼ of Sec. 26 in Nevada township. The mouth of the well is on the upland, and the gas-bearing stratum was reached at about ninety feet below the surface after two feet of indurated rock had been penetrated. Two test holes were put down in the near neighborhood, and in each instance gas was reached at somewhat lower levels, but under practically identical circumstances as in the case of the first well. The gas reservoir appears to be located in the coal measures, and to be separated by several feet of more or less impervious strata from the drift. This fact is of some interest, for in most of the gas wells reported from the southwestern portion of the state, the reservoirs are located wholly within, or just at the base of, the Pleistocene deposits. The occurrence is strikingly similar to the gas and oil wells in Kansas, which draw their hydro-carbon from the Upper Carboniferous.

*Reduced by J. R. Sage, director of the Iowa Weather and Crop Service.

It has often been prophesied that gas and oil would be found in the Trenton limestone of Iowa, providing a low anticlinal in the formation can be found and explored. Prospecting has been carried on at great expense in Polk and Dallas counties, by parties familiar with the eastern oil fields and said to be backed by eastern capital. The records of the drillings were kept secret, and an air of secrecy surrounded the whole operation. One fact only is known to the public, and that is that nothing ever came of these ventures. In Story county the Trenton limestone has been explored at but a single point. The college well at Ames appears to be ideally located to test the "gas theory" thoroughly for Iowa. The arch of Trenton, hermetically sealed in by the Maquoketa shales, was punctured near its greatest amplitude, and so far as known not a bubble of gas or a drop of oil escaped. Prof. Edward Orton's* prediction, "there is a strong presumption that the Trenton limestone will not prove an oil rock or a gas rock in any new field" still holds unchallenged.

ACKNOWLEDGMENTS.

In the preparation of the above report the writer has received much encouragement from the friendly attitude of the citizens with whom he has come in contact. The representatives of the various industries have been uniformly cordial in their co-operation. The well data for "Watkin's well" and vicinity was, in large part, taken from a thesis prepared by Mr. Frank Leverett and accepted for the baccalaureate degree at the Iowa State College. Mr. W. O. White, of Cambridge, furnished valuable information concerning the wells in the southern half of the county. Any value this report may possess is in no small part due to the friendly advice and helpful criticism of my colleagues of this Survey, and to all who have contributed to it in any way acknowledgments are gladly given.

* Eighth Ann. Rept. U. S. Geol. Surv., p. 662, pt. 2.

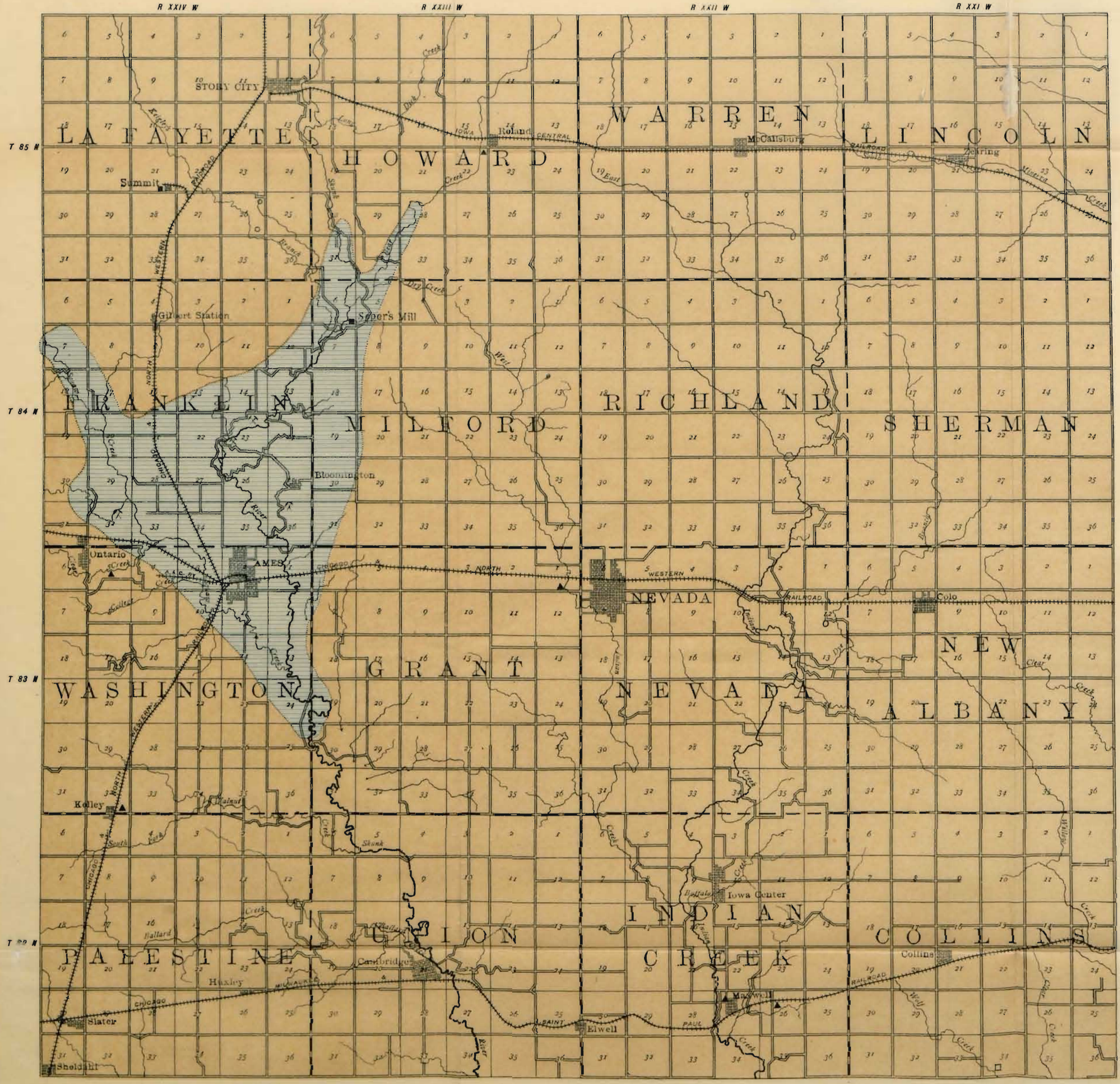
IOWA GEOLOGICAL SURVEY

GEOLOGICAL MAP OF STORY COUNTY, IOWA.

BY

S. W. BEYER

1899.



Scale 1:250,000

1 ½ 0 1 2 3 4 5 Miles

1 ½ 0 1 2 3 4 5 Kilometers

LEGEND

GEOLOGICAL FORMATIONS

DES MOINES (Coal Measures)

SAINT LOUIS

INDUSTRIES

QUARRIES

COAL MINES

COAL MINES ABANDONED

CLAY WORKS

ARTESIAN WELLS

IOWA LITHO. CO. DES MOINES.

DRAWN BY F. C. TATE.

FLORA OF STORY COUNTY.

BY L. H. PAMMEL.

The flora of Story county has been well treated by Bessey*, who made various references to the plants of this vicinity. Later Hitchcock† published an exhaustive list with full notes on distribution. No attempt has heretofore been made to study the plants of this county from an ecological standpoint. For our purpose two typical areas will be considered, one a wooded area in the vicinity of the college, mostly embraced by what is known as the college park; the other, a lowland area in the vicinity of Watkin's well.

COLLEGE PARK.

This area consists of low, thickly wooded hills sloping toward the west, with several gulleys running north. The hills on the opposite side slope toward the southeast, and are almost denuded. Running through this wooded tract is a small stream which contains running water during the early summer months only. Some water remains the entire year in small pools. Perennial springs are few in number; the removal of the timber and tile drainage has largely decreased the amount of water coming from them. The surface soil is a rich humus which rests on a yellow clay sub-soil. The water of the small stream flows into Squaw creek. The flood plain varies greatly in width; it is made up of the usual rich alluvium; and, near the present bed of the river, of considerable sand.

*Bessey, C. E. Contributions to the Flora of Iowa, Biennial Report, Iowa Agrl. College, 90

†Hitchcock, A. S. A catalogue of the Anthophyta and Pteridophyta of Ames, Iowa Contri. from Shaw School of Bot., 7: 477. St. Louis Acad. Sci., 5, No. 3.

Woody Species, Ostrya Group.—It is difficult to designate any one tree as being characteristic of the narrow strip of timber remaining along the course of the streams, but along all the smaller streams in this region, and in the college park, Ostrya is typical for many others. The white oak, *Quercus alba*, and red oak, *Q. rubra*, are common in the entire region. The *Ostrya virginica* is more abundant in numbers than any other tree. Frequently dense copses are found. The black maple, *Acer nigrum*, is a typical tree and is as abundant as the black oak. The basswood, *Tilia americana*, is commen only in places, especially where the soil is highly retentive of moisture, as in the vicinity of springs or on steep banks of the Squaw creek, where it naturally receives the drainage of the bench above. The *Crataegus mollis* is abundant, not only near the base of the hills, but frequently persists in the large open pastures where most other trees have been removed. The hazelnut (*Corylus americana*) is associated with the *Ostrya*, *Quercus* and *Acer*. The *Ulmus americana* encroaches on the upland area, but *U. fulva* is a typical upland species. The *Amelanchier canadensis*, *Crataegus tomentosa*, and *C. punctata* all occur in upland woods. *Fraxinus viridis*, though occurring with the above species, is not exclusively an upland plant.

The *Ampelopsis quinquefolia*, *Menispermum canadense*, *Vitis riparia*, and *Celastrus scandens* represent the climbing plants. *Lonicera glauca* and *Viburnum pubescens* are local and occur only on the steep banks near the streams. *Prunus americana* and *Rubus villosus* are common in some places. *Pyrus coronaria* is common only on the borders of the alluvial flood plains. The *Salix rostrata* near springs associated with *Caltha palustris*. The *Salix nigra* along the stream with *Sambucus canadensis Salix amygdaloides* in similar places.

Herbaceous Plants, *Viola pubescens Group.*—The upland, rich, shaded woods are marked by the common occurrence of several types. The most common of the early plants *Hepatica acutiloba* which forms large mats; the *Dicenera cucullaria*,

Sanguinaria canadensis, *Viola cucullata* and *V. pubescens* in quantity. *Isopyrum biternatum*, *Phlox divaricata*, *Erigeron philadelphicus*, all marked early April and May plants, followed by the *Osmorrhiza brevistylis* and *O. longistylis*, *Thalictrum dioicum*. *Aquilegia canadensis*, in richer and moister places *Erigeron strigosus*. The summer and fall plants are marked by *Cystoptris fragilis*, *Solidago ulmifolia*, *Aster sagittifolius Eupatorium ageratoides*, *E. purpureum*, var. *maculatum*.

Festuca Group.—Economic grasses are not abundant. Blue grass (*Poa pratensis*) occurs in the more open places. The nodding *Fescue* grass (*Festuca nutans*) is the most abundant of all the grasses in early spring. Later a species of Brome grass occurs rather commonly, namely, *Bromus ciliatus*, var. *purgans*. *Brachyelytrum aristatum* blooms about the same time, but is less common. The *Oryzopsis melanocarpa* also occurs in these woods, but it is scarce. It has no tendency to occur in colonies, like so many of our grasses, but occurs in separate bunches. The *Diarrhena americana* occurs more frequently. *Phryma leptostachya*, *Circœa lutetiana* and *Podophyllum peltatum* are abundant. The *Caulophyllum thalictroides* is less common. *Monarda fistulosa* occurs more commonly as a border species. The *Verbesina helianthoides* borders the low grounds. *Thalictrum dioicum* is common in the woods. The dry open woods are covered with *Poa pratensis*, and later in the season *Sporobolus heterolepis*, *Elymus robusta*, *Andropogon nutans*, and *A. provincialis*; all of these, with the exception of blue grass, are indigenous prairie species.

Open Prairie Vegetation.—The praires border on the woods and are marked by several distinct types of plants. The most abundant of the early flowering plants is *Vicia americana*, and we may designate this the *Vicia* group. With this species occur the following early plants: *Phlox pilosa*, *Geranium maculatum*, *Viola palmata* var. *culcullata*, *V. petatifida*, *Litho spermum canescens*, *L. augustifolia*, *Baptisia leucophœa*, *Heuchera americana*, *Fragaria virginiana*, *Oxalis violacea*, *O. corniculata*, *Panicum scribnerianum Carex pennsylvanica* and *Thalictrum*

purpurescens; of the later blooming plants *Eryngium yuccæfolium*, *Silphium laciniatum*, *Liatris pycnostachya*, *L. scariosa*, *Asclepia tuberosa*, *Lepachys pinnata*, *Mollugo verticillati*, are contemporaneous in flower with *Elymus robdsta*. Then come the fall asters, numerous in species, *Aster azureus*, *A. multiflorus*, *A. lævis*.

The *Solidago missouriensis* is the earliest, and one of the most common species, followed by *S. rigida*. The *Solidago speciosa*, a late flowering plant and a most beautiful species. *Cnicus altissimus* var. *discolor* is common everywhere in late season. Of the grasses we find *Andropogon scoparius*, *A. provincialis* and *A. nutans*. Here and there may be found *Gentiana alba* and *G. andrewsii* and, occasionally, *G. puberula*. But a single orchid is common in this section of the state, the *Spiranthes cernua*, which occurs in great abundance on the prairies. *Sporobolus heterolepis* is an abundant and graceful grass everywhere on our prairies.

Stream Vegetation.—The vegetation along the small streams consists largely of blue grass (*Poa pratensis*), and in the lower places *Spartina cynosuroides*. The *Glyceria nervata* is rather common along the streams and in the lower places, also, *Glyceria arundinacea*. *Phleum pratense* is abundantly naturalized. *Veronica anagallis*, *Mimulus ringens*, *Eragrostis reptans*, *Cyperus diandrus*, all hydrophytic plants, are common where the water stands for considerable lengths of time.

The *Anemone pennsylvanica* and *Ranunculus pennsylvanica* are common in low grounds. The former easily typifies low grounds where a large percentage of humus occurs. *Xanthium canadense* is abundant in sandy flood plains of the streams.

Only five woody plants are common to the prairie, namely: *Rosa blanda* var. *arkansana*, *Ceanothus americanus*, *Salix humilis*. The *Amorpha canescens* and *Ceanothus ovatus* on dry hills.

Alluvial Flood Plains.—In the alluvial flood plains occur two types of plants: (1) The mesophytic, which are abundant throughout the flat bottoms, with very few modifications. (2) The hydrophytic, which occur close to the shore lines of

the stream. There is, however, an intermediate type represented by *Cenchrus tribuloides*. These occur on the drift sand, or shore line, between the water and the alluvial banks.

Mesophytic, Walnut Group.—The Black walnut is a typical alluvial species. It is never common beyond the influence of the alluvial drift. Throughout this region the species is a predominating plant in such places. It reproduces itself readily. Occasionally the butternut (*Juglans cinerea*) occurs, but only on the edges where it is seemingly influenced by the drift soil. The Kentucky coffee tree (*Gymnocladus canadensis*) is also an abundant alluvial species. *Fraxinus viridis*, and *F. americana* are local. *Ulmus americana*, *Populus monilifera* are other conspicuous species of this walnut group. The *Celtis occidentalis* occurs near the streams. The *Vitis riparia* is as abundant as it is in upland woods. *Sambucus canadensis* is an abundant species, and in clearings is almost a weedy species. *Pyrus coronaria* as well as *Crataegus mollis* sometimes form large thickets in the alluvial flood plains.

Mesophytic Herbaceous Vegetation.—The dense shade of the trees forms a most favorable place for *Claytonia virginica*, *Phlox divaricata*, *Isopyrum biternatum*, *Viola pubescens*, *Dentaria laciniata* and *Arisaema draconitum*. These are early blooming plants. Somewhat later, *Thelypodium pinnatifidum*, *Ranunculus septentrionalis* and *R. abortivus*. During mid-summer, *Impatiens pallida*, *I. fulva* and *Rumex altissimus*. During late summer and early fall the following species are abundant: *Verbena urticafolia*, *Scrophularia nodosa* var. *marylandica*, *Bidens frondosa*, *Aster salicifolius*, *A. diffusus*, *Helenium autumnale*, *Erichites hieracifolia*, *Solidago canadensis*. *Xanthium canadense* and *Vernonia fasciculata* are weeds in many of the low bottoms.

Hydrophytic Vegetation of the Streams.—The list of strictly hydrophytic plants is not a large one, owing to the fact that many of the streams become dry during midsummer, and these plants can only maintain themselves in the small remaining pools. The most conspicuous of these are *Scirpus*

lacustris, *Veronicr anagallis*, *Nasturtium officinalis*, *Penthorum sedoides*, *Cyperus diandrus*, *Hemicarpha subsquarrosa*, *Ilysanthes gratioloides*. Of the plants of somewhat hydrophytic aptitudes mention should be made of *Mimulus ringens*, *Lobelia cardinalis*, *L. syphilitica*, *Steironema longifolium* and *Lythrum alatum*.

Platanus occidentalis confines itself quite closely to the shore lines of the streams.

WATKIN'S WELL REGION.

Watkin's well region is selected because it offers an interesting field for the study of a large number of marsh plants. The surface soil is a very tenacious black clay, with a subsoil of a yellow tenacious clay which prevents sub-soil drainage, and hence the marshy character of the region. A typical section of this region may be found in the immediate vicinity of Watkin's well, in the midst of the artesian basin. Trees are entirely absent, except along the small streams. Here we find *Ulmus americana*, *Salix longifolia*, *Quercus macrocorpa* and *Q. rubra* Of the shrubs *Rosa blanda* var. *arkansana*, *Amorpha fruticosa*, and *Ceanothus ovatus* on the highest hills. The *Ceanothus americanus* more commonly on the upland prairies.

Hydrophytic Plants.—In the small artificial lake, which is representative of the aquatic vegetation elsewhere in small lakes abounding in this region, the following plants occur: *Ranunculus aquatilis* and *R. multifidus* are abundant in the entire region, especially *R. multifidus* var. *terrestris*. *Ranunculus cymbalaria* is also abundant on the shores of these lakes. It is not known to occur on this side of the artesian basin. *Potamogeton natans* is abundant, as is *Chara fragilis* and *Pontederia cordata*. The *Polygonum amphibium* is abundant in the region. The allied *P. hartwrightii* is also abundant, but it is frequently found in drier situations. *Scirpus lacustris* and *Phragmites communis* both abound, as elsewhere in the state, in standing water. *Glyceria fluitans* and *Phalaris arundinacea* both in water, the latter, however, frequently in drier meadows.

The meadows which border on these lakes are characterized by the abundance of *Thalictrum purpurascens*, *Phlox pilosa*, *Juncvs, tenuis*, *Caltha palustris*, *Cardamine rhomboidea*, *Lathyrus palustris*, *Glyceria nervata*, and *Phalaris arundinacea*.

During midsummer *Lilium canadense*, *Habenaria leucophæa*, *Phlox pilosa*, *Poa pratensis* and *Panicum scribnerianum* are abundant. *Pedicularis lanceolata* is common in the fall, as are *Gerarella purpurea* and *Solidago riddellii*.

Low Hills—Lathyrus, *Zizia*, and *Pimpinella Group*.—Rising from the marshes are low hills. These are drier, and are covered in spring with *Lathyrus venosue*, *Zizia aurea*, *Pimpinella integerrima Poa pratensis*, *Baptisia leucophæa*, and *Pedicularis canadensis*. Later in the season *Lilium philadelphicum*, *Solidago missouriensis* are conspicuous representatives. In the autumn these are replaced by *Solidago rigida*, *Aster lævis*, *A. azureus* and *multiflorus*. These species are typical prairie species, except for the *Lathyrus venosus*, which is not common ordinarily on our prairies.