J. N. Prout

IOWA

GEOLOGICAL SURVEY

VOLUME XX

ANNUAL REPORT, 1909

WITH

ACCOMPANYING PAPERS

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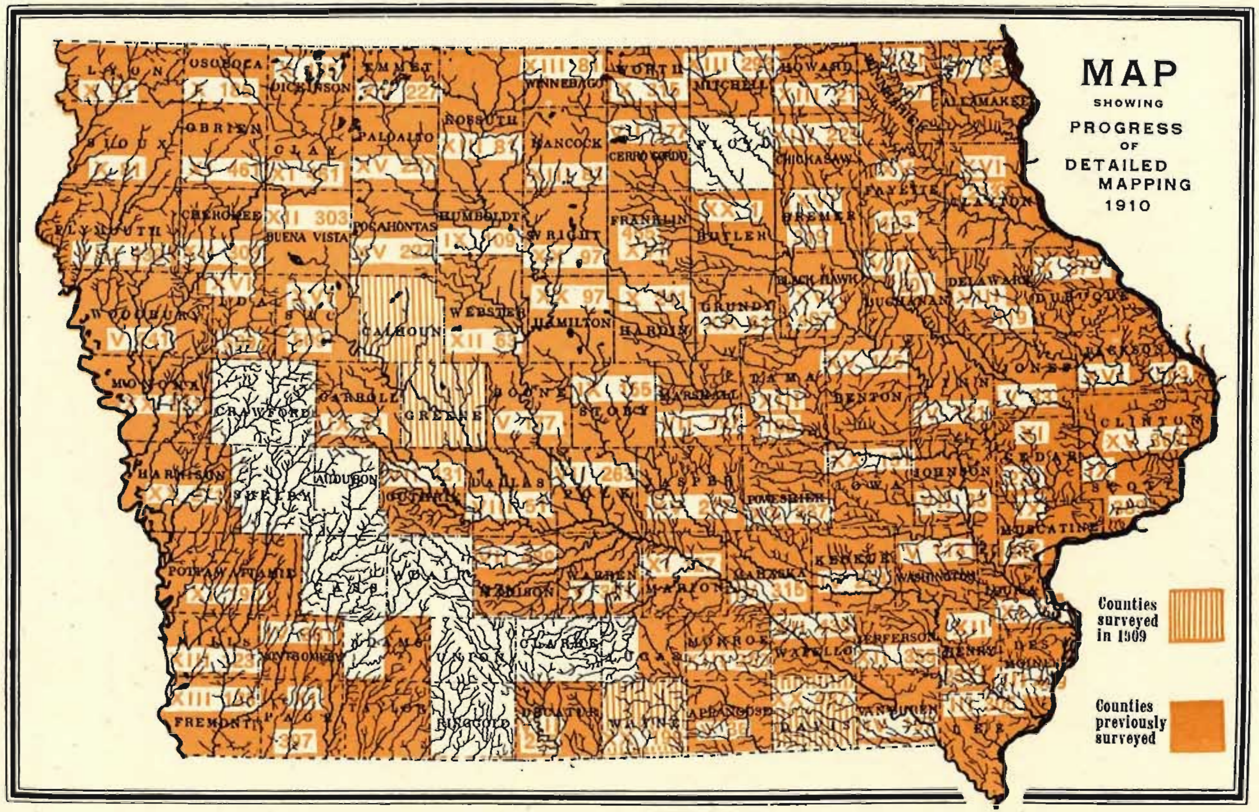
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1910
Counties surveyed in 1909
Counties previously surveyed

EIGHTEENTH ANNUAL

Report of the State Geologist

IOWA GEOLOGICAL SURVEY,

DES MOINES, December 31, 1909.

To Governor B. F. Carroll and Members of the Geological Board:

GENTLEMEN:—I have the honor to report that during the year 1909 the Iowa Geological Survey has continued its investigations relative to the geological structure, geological history and geological resources of the state. Essentially the same plan of organization has been maintained as during the years immediately preceding, and the problems attacked have been much the same. The studies of the coal and peat resources of Iowa, bringing our information down to date, were practically finished in 1908, but additional data needed to make the report more complete were collected during the current year. Mr. J. H. Lees collected samples for analysis from a number of selected typical fields within the state and the samples were analyzed, in accordance with the methods adopted by the United States Geological Survey, by Mr. A. W. Hixson. All the information relating to coal and peat, collected to date, is embodied in the seventeenth annual report, volume xix, now in print and almost ready for distribution.

Papers relating to the geology of Iowa have been given to the public during the year through other channels than the regular annual volumes. In the Bulletin of Iowa State Institutions under the Board of Control, October, 1909, Mr. J. H. Lees presents a timely discussion of *The Water Problem in Iowa*; Mr. B. Shimek has published papers on *The Aftonian Deposits of Western Iowa* in *Science* and in the Bulletin of the Geological Society of America; and the Director of the Survey, in the Bulletin of the Geological Society, has reviewed *The Present Phase of the Pleistocene Problem in Iowa* and in a second paper has described some of the large extinct mammals whose remains are found in deposits of the first interglacial stage in the western part of the state, under the title *An Aftonian Mammalian Fauna.* This remarkable interglacial fauna is not altogether new to science. The individual species, and to some extent the fauna as a whole, have for some time been known to students of paleontology. It has also been known that some of the species were at one or more times inhabitants of Iowa. But, so far as concerns Iowa, it was not known that the few discovered forms, which heretofore have been represented by isolated finds, were contemporaneous; and outside of Iowa, in territory ranging from Texas to western Nebraska, the exact age of the beds in which the remains of this assemblage of extinct mammals were found, was not definitely fixed. The fauna as a whole is markedly different from that familiar to the pioneer settlers of this state, very different from that known to the pioneers in any part of America. True horses were represented by at least two species, both quite distinct from our domestic species; there were three species of elephant, one of imperial size, and there were two mastodons, making in all five great proboscidians; there was at least one species of camel, an extinct bison, a gigantic stag, and two ponderous, awkward, clumsy ground sloths. The smallest of the three elephants seems to be identical with the hairy elephant or northern mammoth of Europe and Asia; it inhabited regions of moderately rigorous climate; it furnishes to this unique fauna a distinctively boreal element. The two great sloths, on the other hand, contribute an element distinctively South American. As found in Iowa, the age of the fauna is definite and clear. The beds in which the remains occur belong to the Aftonian stage; these animals lived, and the beds in which their remains were buried were laid down, in an interval of comparatively mild climate between the first and second stages of Pleistocene glaciation.

The office work during the year has been of the usual character. The Des Moines office has been in charge of the Assistant State Geologist, Mr. Lees, and the Secretary, Miss Newman, and here the greater part of the work has been done. Great numbers of letters written by persons seeking information concerning our geological resources have been answered; many have personally called at the office to look up desired data, and they have been accommodated; volume xviii, and copies of the preceding volumes so far as they are available, have been distributed in accordance with the rules approved by the Geological Board; the several papers making up volume xix have been edited and prepared for the printer, the necessary maps and illustrations were selected and their engraving directed and supervised, the proof of the volume was read and re-read in the office,—taken all together, the direction of the publication of the annual report has been much the heaviest of the tasks falling to the members of the corps employed at the Des Moines office. Much material, supposed by the finders to have commercial value, has been determined and reported on by the officers of the Survey.

The regular field work of the year has been somewhat diversified, as will appear from the following summary:

Mr. James H. Lees visited Adams, Appanoose, Boone, Jasper, Lucas, Mahaska, Monroe, Taylor, Van Buren, Wapello and other coal-producing counties to gather information concerning the history of coal mining in these typical and important fields, and to collect a number of samples from most of the areas named for analyses. With the exception of the few weeks required for this work Mr. Lees has spent practically his entire time in the office in work connected with the preparation and publication of the annual report.

Dr. S. W. Beyer, assisted by W. F. Coover, continued the field study of the distribution and quality of the materials available for road making, at the same time collecting data relative to the deposits of sand and gravel which may be found to have additional value in connection with the rapidly growing use of cement as a structural material. In the laboratory tests of the sands and gravels used in making concrete Dr. Beyer has had the assistance of C. E. Scott.

Professor M. F. Arey completed the work in Davis county and made the geological survey of Wayne.

Professor B. Shimek, who spent the previous season in Harrison and Monona counties, found himself confronted with a number of unexpected problems of great interest, and their proper investigation necessitated the extension of the field work into a number of the adjoining counties. The new lines of inquiry have taken all the time he could spare for work in the field during the past season. The problems of the loess, the problems of the prairie and the problems of the formations and faunas of the first interglacial stage are the problems that, by a long period of observation and study, he is eminently fitted to solve.

Professor T. H. Macbride has given such time as he could spare from other pressing duties to the survey of Calhoun and Greene counties.

Mr. J. E. Carman spent the working season in an investigation of the drift deposits lying outside the marginal moraine in Buena Vista, Clay, Dickinson, O'Brien, Osceola and Sac counties. The Pleistocene problems presented by this region are numerous, and additional study will be required for their satisfactory solution.

Professor George F. Kay took up the study of the water powers possible along the streams of Iowa, and during the season his work covered about half of the state. Another season in the field will make it possible for him to present a report on a subject that, in point of commercial importance, stands next to the subject of fuel supplies.

Professor W. H. Norton has kept up the work of collecting data relating to the deep wells and underground waters of Iowa, a work that he has carried on with marked success practically since the organization of the present survey. The publication of a volume on this subject, setting forth all obtainable information, is among the plans for the near future.

The field work of the Director during 1909 was limited chiefly to more or less extended field conferences with the other members of the corps.

During the year the Iowa Survey has continued its co-operation with the United States Geological Survey in the making of topographic maps of areas selected by the Director of the Iowa Survey, and on the same terms as were agreed upon for the seasons 1907 and 1908. The work for 1909 was prosecuted in the Knoxville and Pella quadrangles.

The Survey has maintained the usual exchanges, both domestic and foreign. In this way a library of increasing value is being accumulated. The list of exchanges is constantly increasing and as a consequence, in addition to the increased scope of the library the publications of the Survey are becoming more widely distributed and more generally known.

In addition to the current numbers of the publications which are enumerated in preceding reports, new exchanges have been received as follows:

Alabama Geological Survey.
Florida Geological Survey.
Georgia Geological Survey.
Louisiana Geological Survey.
Mississippi Geological Survey.
Missouri Geological Survey, 3d series.
Nebraska Geological Survey.
American Mining Congress.
British Columbia Department of Mines.
British Guiana Geological Survey.
California Academy of Sciences.
Canada Department of Mines.
Field Museum, Geological Series.
Journal of Geology.
Lloyd Library.
University of Idaho Agricultural Experiment Station.
Pennsylvania Department of Forestry.
American Coal Journal.
Industrial World.
Mine and Quarry.
Northwest Mining News.

The publications of the Iowa state departments are also received in exchange for the reports of the Survey.

Herewith I take pleasure in submitting the following papers with the recommendation that they be published with all needed illustrations as part of volume xx:

Mineral Production in Iowa in 1909, by Dr. S. W. Beyer.
Geology of Hamilton and Wright Counties, by Thomas H. Macbride.
Geology of Grundy County, by Melvin F. Arey.
Geology of Iowa County, by Stephen W. Stookey.
Geology of Butler County, by Melvin F. Arey.
Geology of Harrison and Monona Counties, by B. Shimek.
Geology of Davis County, by Melvin F. Arey.
Geology of Wayne County, by Melvin F. Arey.
Geology of Poweshiek County, by S. W. Stookey.

Respectfully submitted,

SAMUEL CALVIN.

GEOLOGY OF BUTLER COUNTY

BY

MELVIN F. AREY

GEOLOGY OF BUTLER COUNTY

BY MELVIN F. AREY.

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GEOLOGY OF BUTLER COUNTY

INTRODUCTION

LOCATION AND AREA.

Butler county, once a part of Bremer and Buchanan counties, was organized in 1851. It was named in honor of General William O. Butler, an officer of the Mexican war and a Vice-Presidential candidate in 1848. It is in the third tier of counties from the Minnesota line and is fourth in order from the Mississippi river. Bremer and Black Hawk counties are on its eastern border. It has Grundy county on the south, Franklin on the west and Floyd on the north. Its approximate area is 576 square miles, divided equally among sixteen civil townships each of which is exactly conterminous with a corresponding congressional township. There is no large city within its bounds, but it has nine thrifty communities with populations ranging from 400 to 1,500 inhabitants. Allison and Bristow are upon upland plains apart from any perennial streams but the other towns are located in the valleys of the principal watercourses. The leading and almost universal occupation of the people is agriculture. Valley and upland alike everywhere respond bountifully to the labors of the husbandman.

PREVIOUS GEOLOGICAL WORK.

Beyond the interest always attaching to a region rich in promise to the future tillers of the soil, there was very little in Butler county to attract the attention of the earlier geologists whose time and purpose did not admit of consideration of details of minor importance.

Mention is made by White in the first volume of his Geology of Iowa, 1870, of "certain important exposures of the Kinderhook formation in the eastern part of Franklin and the western part of Butler counties," without specifying the localities or characteristics of the rocks. Since little or no quarrying had been done in the Lime Creek shales at that time and the natural exposures were slight and the weathered rock gave little clew to its identity, it is not surprising that the area of these shales was assigned by him to the Kinderhook stage, and that on his map of the state the eastern limit of the Mississippian series was drawn even beyond the eastern border of the Lime Creek shales, thus covering more than one-third of the area of the county. As a matter of fact the area of the Kinderhook stage is confined to Washington township and small fractions of Madison and Monroe townships immediately adjacent to it, while all the rest of the territory previously assigned to the Kinderhook must be regarded as belonging to the Devonian.

McGee in his Pleistocene History of Northeastern Iowa makes brief allusions to the topography of Butler county in common with neighboring counties having similar surface features. Recent writers seem to have added nothing, except incidentally, to the meager record of the above named writers.

PHYSIOGRAPHY

Topography

The present surface of Butler county is the resultant of various agencies, both constructive and destructive, that have been incessantly in operation ever since the land emerged from the waters that covered it during the accumulation of the material of the Devonian and the Carboniferous rocks that form the basis upon which the later agencies have been doing their work.

PREGLACIAL.

The destructive agencies corraded, cut and gouged out the rock surface through the long interval preceding the glacial period, in places meeting with stubborn resistance from rock that, being indurated, not only withstood the wear and tear of running waters, but that in some cases, at least, was little affected by the acids of the atmosphere and waters. Elsewhere the surface readily gave way to the assaults of the various attacking forces. Thus it was widely channeled in some places, sharply trenched in others, or made uneven with ridges, mounds and knobs over broad mesas into which were sunk depressions of varied form and character. During this interval little constructive work was done; at least, little if any, appears to-day. In fact, few of the erosive effects of that time are anywhere apparent unmodified by the forces that later everywhere wrought so effectually as to obscure almost, or quite, completely, all that had been accomplished previously.

To-day preglacial erosive effects are chiefly to be noted in the general topographic forms of upland and lowland, in the occasional rock outcroppings where the drift material chances to be thin, or in the observance of the depth at which rock occurs in well drillings in different localities, allowance having been made for the varying elevations of the surface where the wells are put down. Nevertheless, there are several instances in the county where preglacial erosion seems to have escaped complete obliteration by the drift deposits.

In the southwestern part of Washington township Beaver creek valley bears little evidence of modification by the drift. It is narrow, with high bluff-sides, especially upon the north, the sloping surfaces of which are made up of the talus from the breaking down of the Kinderhook limestone, numerous pieces of which appear scattered over the lower two-thirds of the bank, and a sinuous line of which can still be detected in place one-third of the distance from the top of the slope. The bed of the stream is very near to the rock. The comparatively slight aggrading that has been done as well as the formation of the talus has been accomplished in recent times. Little that is distinctly the result of the glacial epoch is manifest here.

A north and south valley, with occasional outcroppings of limestone along its middle slopes, cuts the central part of Fremont and Butler townships. This, too, is the product of preglacial stream activity which was much more vigorous than that which can be ascribed to the ordinarily insignificant rivulet that to-day quietly courses over the drift material that partially fills this ancient valley. Had the drift sheets in this part of the county been as heavy as they are in most other localities, here would have been a buried channel discoverable only from the greater depth at which rock would have been reached along its course by the well driller, and the comparatively near approach of rock to the surface elsewhere in its neighborhood.

For a few miles in the immediate neighborhood of Greene the east border of the upland is marked by an abrupt slope to the level of the river plain. Midway of this declivity numerous outcroppings of limestone are seen; they occur at advantageous points in which quarries have been operated, and they readily supply the local demands for building stone in the northern part of the county. Evidently the river at some time here skirted a rocky escarpment as many modern rivers do, but withdrew towards its present channel so long ago that a perfect talus slope has been formed, and the valley has been aggraded to a thickness of thirty feet or more.

In Pittsford township, a mile or more west of Bristow, Otter creek and a small tributary occupy for several miles a deep valley. As is indicated by the face of the quarries that have been opened up along the west side of the valley, the rock has been cut to the depth of twenty-five feet or more, above which the mantle of rock waste rises by less abrupt slope for forty or fifty feet more. The present gradient of the stream bed is evidently very nearly the same as that of the ancient stream, and, as it is quite high, it is manifest that the rock cut runs out quite rapidly. It is very likely, however, that the upper end of this valley was entirely filled with drift material, but the waters of the melting ice sheet, converging at the lower part of it, and rapidly gaining velocity in descending to the level of the plain of the West Fork, swept it clear of all glacial debris. As the glacial waters subsided and normal conditions of water supply obtained again, the irregular deposits of till made new lines of drainage necessary. The Coldwater, a manifestly young stream running at right angles to the course of the preglacial stream some five or six miles north of the open valley, has cut off the territory that made a large stream possible, and the diminutive creek that has succeeded the older one in its lower course, has wrought comparatively little change in all the years that have intervened.

KANSAN AREA.

With a few notable exceptions, most of which have been mentioned under the previous caption, the general surface of Butler county is that of a great drift plain crossed from the northwest and west by three wide alluvial plains, through which its principal streams flow with easy gradient and consequently with slight erosional effects. The slopes bordering these plains rarely rise abruptly; indeed, in many places it is difficult to determine just where the bounding lines run, so gently do the declivities of the till come down to the alluvial plains. The well behaved streams are content to confine their meanders to the alluvial plains, rarely venturing to trespass upon the slopes of till. A notable and almost sole instance of departure from the rule is at Jerusalem hill, near the point where the West Fork of the Cedar crosses the line between sections 4 and 9, Beaver township. The West Fork here has worked its way well into the till, making a raw, precipitous bank some twenty-five feet high.

New Hartford Recessional Moraine.

Between the West Fork and Beaver creek there are three localities which attract the attention of the most indifferent observer. The largest and most interesting of these constitutes the entire upland region between the above named streams, extending a little north of west from beyond the eastern border of the county in Beaver township to section 9, Albion township, where its distinctive features give way to the ordinary topographic forms of this portion of the county.

Here, apart from the generally recognized Kansan drift area of the state, is a jumble of hills and ridges with their included valleys, not the work of extensive erosion, but rather of deposition, a moraine of Kansan till. Most of the hills are covered with Iowan loess of varying thickness. But, chiefly in section 30, Beaver township, a spur marking the southernmost extension of the moraine, is not only without loess, but has been swept bare of all finer material, leaving a surface of coarse sand, gravel, cobble stones and bowlders, as unproductive as the abandoned hill farms of New England and strikingly suggestive of them in structure and appearance. Here, in marked contrast with the commodious and comfortable farm houses of the neighboring plains and prairies, may be found the original log house of the earlier settler, eloquent of the severe and unremunerative struggle with the hard conditions of this, fortunately small, area where nature seems to have been extremely chary in her allotment of favorable resources. It affords a fine opportunity for the application of the principles of forestry, the best use that can be made of it. Indeed it is becoming more or less wooded, especially upon the south and east sides. It rises with somewhat rounded but steep slopes eighty feet above the adjacent plain of the Beaver. On the north between it and the neighboring hills lies a characteristic morainic valley in which once rested a small body of water, but which has been obliterated, mainly by the filling of its basin with debris washed in from the surrounding slopes.

At the west end of the moraine the hills are relatively low, of lenticular form and somewhat thinly covered with loess. The hilly area rapidly broadens eastward and soon reaches its maximum expression in height and breadth.

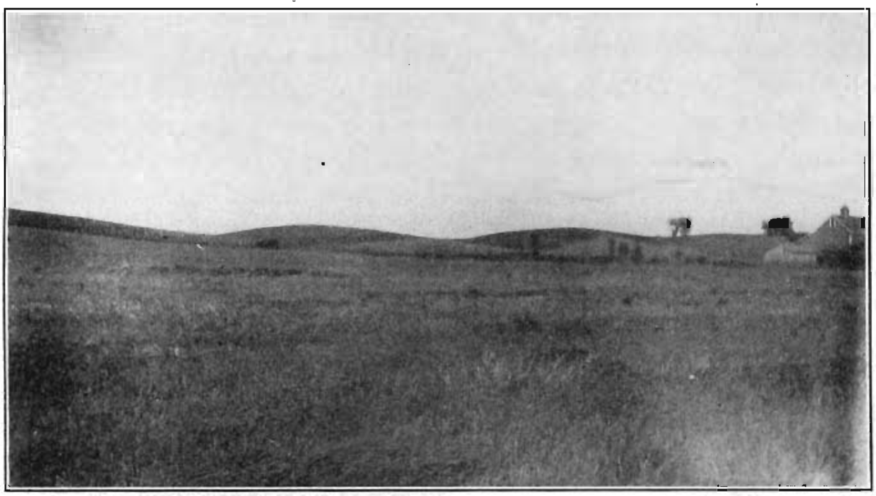

Figure 1. New Hartford hills near eastern end as seen from near center of section 26, Beaver township.

The elevations and depressions assume a confusing variety in form, size and relation to each other. There are extended ridges, elongated, rounded and irregular hills, narrow, deep valleys, wide, long valleys and short, flat bottomed valleys, having the appearance of having been the beds of small ponds that later found a ready outlet for their waters. The road on the line between the townships of Albion and Beaver passes through a

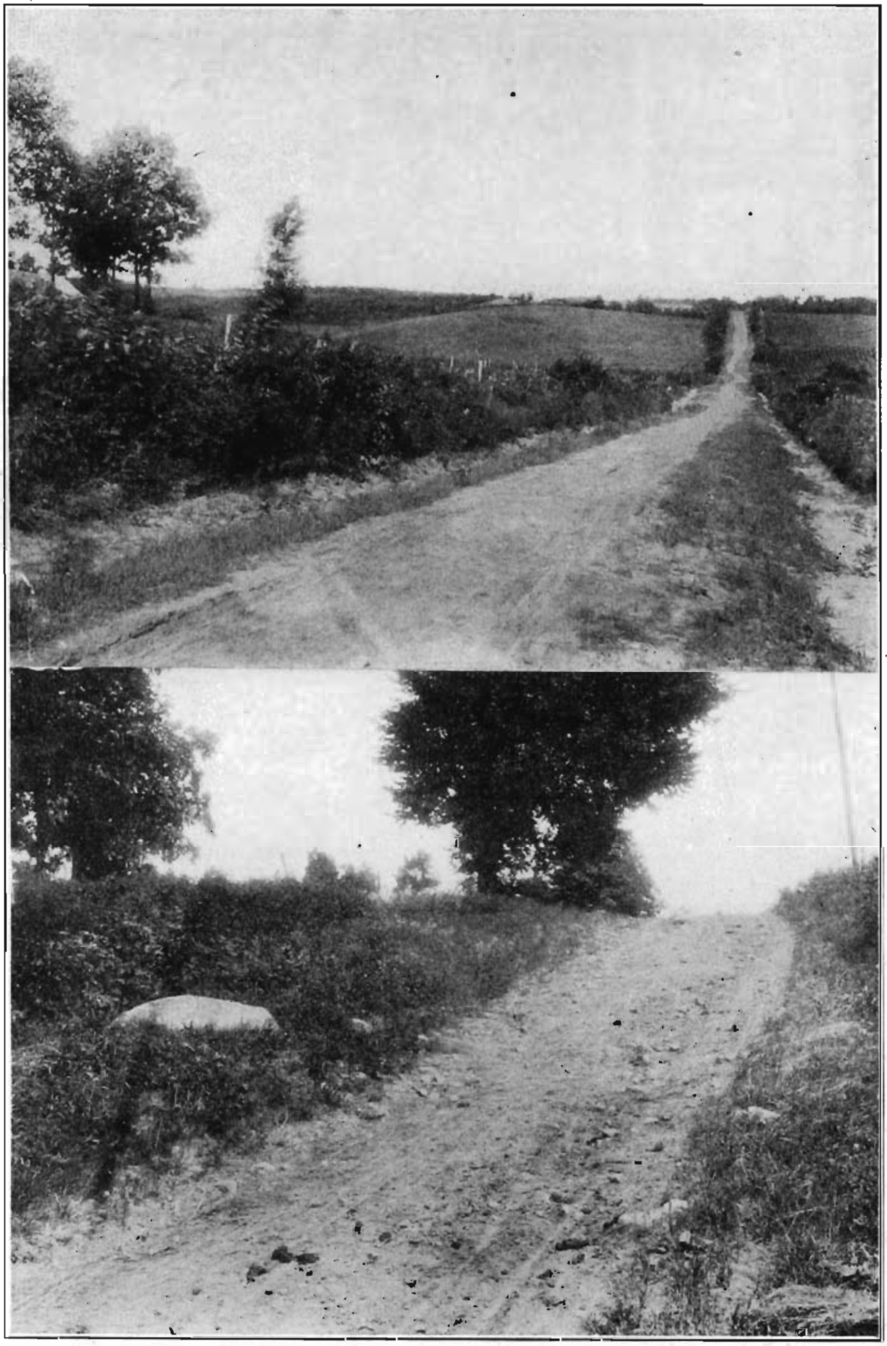

Plate VII. Upper view—Loess-Kansan topography due to what seems to be a modified recessional moraine of the Kansan stage. In the southeast quarter of section 19 and the northeast quarter of section 30, Beaver township.

Lower view—Stony road in the northwest quarter of section 25, Albion township. Some of the hills and knobs of what seems to be a recessional moraine of Kansan age are covered with deep loess; some, as in the view here shown, are bare and stony.

illustration
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pg 12

very characteristic portion of the moraine. For two and a half miles it crosses a series of hills, some of which are very steep sided and narrow, others with gentle grade and lower summits. The whole western half or two-thirds of this moraine was originally heavily wooded and much of it is so still, but the eastern end is to-day well tilled everywhere, being much less rugged and intractable.

The entire congeries of elevations is covered with loess, usually yellowish in color, of varying thickness, except the portion already described, a portion that must for some reason have been bare of vegetation and thus gave a full sweep to the winds which not only left none of their burden on it, but carried away whatever of finely triturated material may have originally belonged to it. It is not clear why this spur should be thus exceptional, but as the ice retreated northward, lying as it does well out from the principal mass, it may have been exposed for some time before the rest and the fierce winds which blew off from the glacier, as must have been the case at times, at least, may have completely denuded it of everything within their power of transportation, so that later on when vegetation found the rest of the moraine an inviting field, this was then, even more than now, too forbidding to encourage any growth whatever.

Here, as elsewhere, usually the loess is moulded upon the hills, though it is heavier on the upper part and varies greatly in different portions of the moraine. The maximum depth observed is in a cut on the road between section 19, Beaver township, and section 24, Albion township, a little north of the point where the road running through the middle of section 19, turns to the east. Here some twelve feet of loess is exposed, the lower part of which is gray in color and abounds in vertical ferruginous pipes of concentric layers which often readily separate. The average diameter of these cylinders is about one and a quarter inches.

The underlying Kansan till was observed but rarely, but in the road a few rods east of the east line of section 26, Beaver township, a cut shows seven feet of Kansan till, most of which consists of well oxidized clay freely mingled with greenstone pebbles, some of which are glaciated, and granitic cobbles easily crumbling. About a foot of the clay at the base of the cut is firmer and darker in color. Above the till are seven feet of loess, the upper foot of which is dark with vegetable mold. The Kansan appears also in the roadside in the central part of section 30, Beaver township.

Kansan bowlders are not uncommon in this neighborhood. Usually bowlders are few and these are generally concealed, but in sections 23 and 24 and in a few other localities in Beaver

Figure 2. Bowlder in section 26, Beaver township.

township, Iowan bowlders of considerable size lie in the lower levels as if the Iowan ice sheet pushed up between the less formidable hills of the eastern end without leaving much other trace of its presence there. In figure 2 is shown a large bowlder of unusual appearance that is to be seen by the roadside near the center of section 26. The surface is thickly embossed with dark, somewhat cruciform masses an inch above the surface sometimes, as if the ground-mass, hard as it is, had weathered out. The mineral constituents of the bowlder have not been determined.

The few well sections of which reliable data could be secured show not only that the entire mass above the stream level is of glacial origin, but that in places, at least, the rock beneath these hills lies at a lower level than in the stream valleys adjacent.

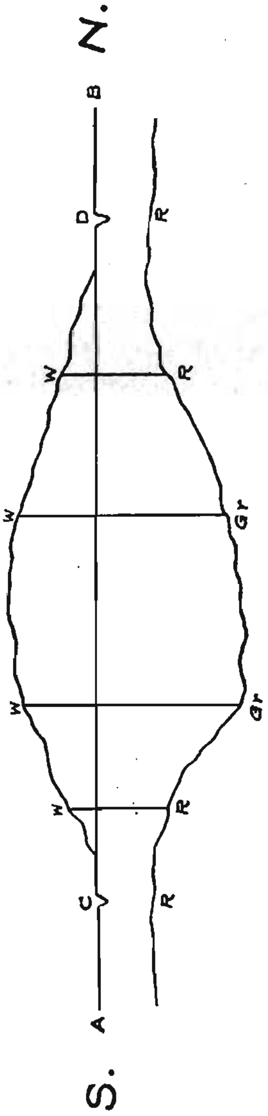

Figure 3. A diagrammatic section through sections 27, 22, 15 and 10, Beaver township, showing by the wells that the rock beneath the hills is at a lower level than that beneath the creek valleys. A B, level of the creek valleys; C, Beaver creek; D, West Fork; W, location of wells; R, rock; Gr, gravel beneath blue clay and probably just above rock.

Near the center of section 27, Beaver township, on the border between the valley and the moraine a drilled well is 101 feet deep, ending in rock, but its depth in rock could not be ascertained.

In the northwest quarter of section 27, on a hill seventy feet above the level of the alluvial plain a well is 190 feet deep, ending in gravel, probably Aftonian, beneath blue clay.

In the northwest quarter of section 22, a drilled well is 180 feet deep, ending in gravel beneath blue clay.

In section 15 on the north margin of the moraine a well is 122 feet deep, the last ten feet being in limestone.

The maximum height of these hills does not exceed ninety feet. Many of them, however, reach the height of eighty feet. The maximum width is more than three miles. They gradually lose their characteristic features as they pass into Black Hawk county, making way within three miles for the junction of the valley of Beaver creek with that of the Cedar river. They soon reappear on the south side of the Beaver, not however in strict alignment, but as an overlap starting farther south, and, though at first having very nearly the same trend, below the junction of the two streams just mentioned a more decidedly southeasterly course is taken and an average height of eighty feet is soon reached, bounding the Cedar valley on the south and constituting "The Bluffs" both east and west of Cedar Falls. Between Cedar Falls and Waterloo they reach their maximum expression where their morainic nature is fairly well developed in places.

Paha.

Beginning in section 16, Monroe township, and extending in a northwesterly direction into section 5, Washington township, there is an assemblage of hills tamer in aspect than those of the New Hartford moraine. Had this group continued far enough to the east it would have overlapped the New Hartford range on the south, bearing the same relation to it as do the Cedar river bluffs at its eastern end. The hills of Monroe and Washington townships are beautiful, elongated, smoothly rounded elevations, capable of tillage to their summits, loess covered and, of course, superficially free from bowlders, in this respect in marked contrast with much of the surrounding country. They do not lie in line one with another but run by at the extremity *en echelon,* tnough in some cases so closely as to make a continuous ridge irregular in line both vertically and horizontally. The more typical central hills are steep sided. The included valleys as a rule are narrow. The north and south road between the two townships crosses over four or five ridges in close succession, the highest of which are forty or fifty feet above the adjacent valleys. Cuts in this road show beneath several feet of loess a coarse dark red sand containing pebbles of greenstone and crumbling granites. No further data as to their interior make-up was secured. Good water is obtained from hillside wells at a depth of thirty-five to forty-five feet.

West of Kesley, occupying chiefly portions of sections 26, 27 and 35, Madison township, is a cluster of heavily wooded hills, known as Bear Grove. There is little opportunity to learn the character of these hills beyond the fact that their surface is composed mostly of loess. In form they are more nearly round than are the hills a mile south of them and from which they are separated by a creek which joins the Beaver a dozen miles to the south and east. These two groups of hills and a third in Grundy county, some four or five miles south of the first named, belong to the pahoid type and are the farthest west of any known to the writer. Much discussion has been had as to the nature and origin of paha. One of the more recent occurs in the report on Bremer county.*

IOWAN AREA.

With the exception already named the surface of the county is made up of Iowan drift plains and the alluvial plains of the larger streams. In three townships of the northern tier, Fremont, Dayton and Coldwater, the drift is thin for the most part and the surfaces are determined to some extent by the underlying rock, but the drift gains in thickness to the southward, and the ordinary undulatory surface of the Iowan is manifest.

Near the center of Coldwater township, solitary and unique among the elevations of the county, stands Mt. Nebo, an ellipsoidal hill with the same trend as the pahoid hills north of

*Norton: Iowa Geol. Surv., Vol. XVI, pp. 377-382.

Aplington and the morainic hills north of New Hartford, but differing from both in the absence of loess. Superficially, at least, it is composed of gravel, but no means of ascertaining the nature of its core was presented. The topography of that part of its immediate neighborhood which is in alignment with its trend, especially to the southeast, seems to have been influenced somewhat by the same cause that produced it, but not to such an extent as to make inapplicable the term solitary as used above.

In Benezette township the drift material is much thicker, but the surface is unusually flat, there being just enough inclination to enable the excess of rainfall to find its way to Coldwater creek without anywhere cutting the sod. There is little that is exceptional or worthy of special note elsewhere in the Iowan drift area. Southeast of Clarksville, running across sections 29, 30, 31 and 32, Shell Rock township, is a series of eight ridges and intervening troughs of remarkable uniformity in trend, size and form. Their trend is nearly east and west. The three northward ones are gravelly to the tops. The others seem to be composed of Iowan drift material. Iowan bowlders are prominent in the depressions. The general effect here is that of decided ruggedness as compared with the surrounding country.

In the four northeast sections of Ripley township and sections 6 and 7 of Jefferson, the undulations assume unusual proportions culminating in the south part of sections 1 and 2 of Ripley and section 7 of Jefferson. In sections 11 and 12 they circle about in such a way as to form a huge irregular amphitheater forming a landscape of great beauty and attractiveness.

In the east and south of Pittsford township and in portions of Madison and Washington townships exposures, or the near approach to the surface, of the older formations modify the general effect of the drift to some extent, though many excellent examples of Iowan drift topography are to be seen in these townships.

The most characteristic expression of the Iowan is to be seen in West Point, Jackson, Jefferson and Shell Rock townships along the central part of the highland between the Shell Rock and the West Fork of the Cedar river. Throughout this region everywhere is a maze of gentle swells and sags, rising here and giving way there, now persistent in long sinuous ridges and again quickly dissolving into others, but in almost imperceptible curvatures and changes of direction, never really obstructing drainage but providing for it in unexpected ways. In places bowlders are surprisingly abundant while elsewhere they are wholly wanting or found only in the sags. Sometimes they are invariably small or of moderate size, sometimes they are of truly giant proportions. Pilot rock in the west half of section 23, West Point township, has a girth of ninety-nine feet and a maximum height of twelve and one-half feet.

ALTITUDES.

A table of altitudes so far as these could be secured is appended. It will be noted that they are mostly for localities that are in the alluvial plains. The greatest elevations in the county are probably Mt. Nebo, chiefly in section 20, Coldwater township, and the hills of Bear Grove west of Kesley, but no figures are at hand to confirm the report. The highest hills about New Hartford have an elevation above the creek valley of about ninety feet. It is safe to say that the difference between the highest and lowest points in the county is about 180 feet.

LOCALITY.	ALTITUDE.	AUTHORITY.
Allison	1044	C. G. W. Ry.
Aplington	968	I. C. R. R.
Austinville	1006	I. C. R. R.
Bristow	1030	C. G. W. Ry.
Clarksville	924	C., R. I. & P. Ry.
Dumont	977	C. G. W. Ry.
Greene	955	C., R. I. & P. Ry.
New Hartford	895	I. C. R. R.
Packard	953	C., R. I. & P. Ry.
Parkersburg	951	I. C. R. R.
Shell Rock	921	C., R. I. & P. Ry.
Sinclair	921	I. C. R. R.

Drainage

Situated as it is within the Iowan drift area, the dendritic type of drainage is notably absent in Butler county, yet it can scarcely be said that it is not fairly well drained. It is wholly within the basin of the Cedar river, its three principal streams flowing into that river within four miles of its eastern border in Black Hawk county, though the Shell Rock and the West Fork of the Cedar mingle their waters just before their common junction with that stream. Good drainage may be accounted for in part from the fact that its large streams divide its territory so equally that no large area is so distant from them but that its surface waters can be readily cared for by the multitudinous sags, intervales and wet weather streams that scarcely interfere with tillage. In the north tier of townships underground drainage is usually good through the jointed and much shattered limestone that immediately underlies the thin mantle rock.

THE SHELL ROCK RIVER.

The Shell Rock river, which rises just over the state line in Minnesota, pursues a uniform southeast course to its junction with the West Fork of the Cedar. About twenty miles of its course is in Butler county, which it enters just a little northwest of Greene and leaves a mile and a half southeast of Shell Rock. In common with its companion streams, most of its course is over a broad plain of aggraded material into which it has cut a channel of modest depth, and as it has a low gradient, its current is usually mild, and little aggressive work is done even at times of high water. At Clarksville and Shell Rock low limestone ridges run athwart its way, so that the country rock appears in its bed. At Greene and Shell Rock warrant is found for the construction of servicable mill dams. Its only noteworthy tributary from the east throughout its course is Flood creek, which rises near the northwest corner of Floyd county, and flows at an average distance of less than four miles from the Shell Rock and in strict parallelism with it till it has traversed about three miles of Butler county, when it suddenly turns at nearly a right angle and soon loses itself in the more abundant waters of the Shell Rock, which by an equally sharp turn has come half way to meet it.

Coldwater creek enters the northwest corner of the county, taking for six miles an east course, then a southeast course, till it reaches the alluvial plain of the Shell Rock, after which it follows down that plain for four or five miles before it merges its waters with the main stream at the point where it turns towards the advancing waters of Flood creek. In its upper course, at least, it is a youthful stream and drains territory that in preglacial times paid tribute to a stream that today persists only in its lower course as a tributary of Otter creek. It occupies a narrow, well defined channel cut into the level plain of Benezette township. The tilled fields come down to the very water's edge at first, though a narrow flood plain harboring a fringe of natural timber appears lower down. Its course in Coldwater township was determined no doubt in preglacial times. A small prairie creek enters the Shell Rock west of Clarksville.

THE WEST FORK OF THE CEDAR.

Entering the county four miles north of the center of its west line, the West Fork of the Cedar river traverses the entire

Figure 4. View on the West Fork on the line between sections 10 and 11, Beaver township, showing the shallow bed of the stream.

county, a distance of twenty-seven miles in a direct line, crossing its east line in section 12, Beaver township. A single tributary enters it from the north in each of the three townships of Madison, Ripley and Beaver. The second and third are scarcely more than the average prairie creek, the name of the third, Dry Run, being suggestive of its intermittent character. The first, Otter creek, is entirely unassuming for the first six or seven miles of its course, when in section 14, Pittsford township, it quickly finds its way to the level of the old valley already mentioned under the topic, Preglacial Topography, where, skirted upon the west by an escarpment made by a series of quarries in the Devonian limestone and upon the east by high but moderately gentle slopes, it acquires an interest and importance quite beyond any ability its meager waters of today can command.

Hartgrave and Mayne creeks are considerable streams joining the West Fork on the south, the one near the southwest corner of section 35, Pittsford township, and the other near the center of section 7, Ripley township. Both perform an important part in the drainage of Franklin county, but much less is done for Butler county owing to the promptness with which they reach their master stream. Hartgrave creek has the broad alluvial valley underlain with many feet of oxidized gravels so characteristic of most of the streams of this county. Mayne creek has one or two small streams joining it in Madison township. Its valley for the most part is relatively narrow.

BEAVER CREEK.

Beaver creek, the third of the tributaries of the Cedar in this county, flows across the county in a nearly direct line, entering it in the southwest corner of section 31, Washington township, and leaving it in the northeast corner of section 36, Beaver township. In eastern Washington, in Monroe and in western Albion townships its course is between two and three miles from the south border of the county. Elsewhere its flood plain takes in nearly all of the county south of its course. Once well within the county limits it enters a deeply eroded valley which is narrow and with little alluvium, but which within less than two miles begins to widen and quickly assumes the more prevalent characteristics of the Butler county streams. The South Beaver comes in at Parkersburg, while two miles farther east a smaller branch enters from the northwest and yet another in section 23, Washington township. Each of these tributaries is of the usual type of prairie streams with little that is distinctive or noteworthy, even in detail.

By means of the streams mentioned above the drainage of the county is accomplished quietly but very efficiently nevertheless. With the exceptions that have been named these streams are remarkably uniform in having wide, flat valleys, moderate meanders, shallow beds, barely reaching below the alluvium, and few branches located principally near the north and west borders of the county. True swamps are practically unknown. A few ponds occur in Fremont, Dayton, Madison, Albion and Beaver townships. They are small and most, if not all of them, will disappear with the better drainage that attends upon the complete settlement and general cultivation of the land. Seepage springs are failing in like manner. A few perennial springs may be found especially along the old eroded valleys in eastern Pittsford and southern Washington townships.

STRATIGRAPHY

General Relations of Strata

The natural exposures of indurated rock in Butler county are confined to the northeast and southwest thirds of its area. The Middle Devonian alone is represented in the former and the Upper Devonian and the Kinderhook of the Lower Carboniferous in the latter area, while the Pleistocene is represented almost everywhere. No certain evidence of pre-Kansan glacial deposits is known, but the Kansan is very generally distributed, though it is pretty effectually hidden by the Iowan, despite the scantiness of the latter, since post-Iowan erosion has wrought very slight changes, due not only to the comparatively recent deposition of the Iowan drift, but quite as much to the little difference between the maximum and minimum altitudes over the greater part of the county and the consequent absence of high gradients. In the New Hartford hills and other localities where high, steep slopes prevail, thick deposits of loess, with its well known resistance to vertical erosion, provide an adequate protection to the underlying Kansan.

No deep wells have been sunk in this county, and so nothing is known experimentally of the older underlying formations, but the deep wells of Waverly, Waterloo and Ackley, not far from its borders, as well as logical inference from well known general geological principles give every reason to believe that the preceding formations in the geological column occur in order at normal distances from the surface.

SYNOPTICAL TABLE OF FORMATIONS.

The following table gives a graphic exhibit of the sequence of the strata as recognized within the territory under consideration, named in accordance with the latest geological section adopted and used in the publications of the Iowa Geological Survey.

GROUP	SYSTEM	SERIES	STAGE	FORMATION
Cenozoic	Quaternary	Recent		Alluvial Aeolian
		Pleistocene	Iowan	Loess Drift
			Kansan	Buchanan gravels Drift
				Residual material
Paleozoic	Carboniferous	Mississippian	Kinderhook	Limestone Sandstone
	Devonian	Upper Devonian	Lime Creek	Shales Limestone
		Middle Devonian	Cedar Valley	Lithographic limestone, etc.

DEVONIAN SYSTEM

Middle Devonian Series

CEDAR VALLEY STAGE.

Exposures and Sections.

The Devonian rock system is represented over a widespread area, about fifteen-sixteenths of the whole county, eleven-sixteenths of which belong to the Cedar Valley limestone of the Middle Devonian, the remainder to the Lime Creek shales of the Upper Devonian. The terrane that here is outspread is unusually broad. The first rock exposures in the northeast corner of the county are to be seen along the midsides of the preglacial valley in Fremont township, especially in section 22. It is a stromatoporoidal limestone. In the northwest quarter of section 3, Butler township, some quarrying has been done in one of these outcrops. Here the lithographic character of the stone is apparent. Weathered specimens are of a chalky white appearance, but the conchoidal fractured surfaces are drab, though along joint planes they are yellowish with iron stains. The rock is characteristically brittle, is smooth, compact, fine grained and rings under the hammer. The Stromatoporas are usually of the sheet-like type. A few of the small spherical ones were seen. A single fish tooth was picked up here.

A quarry from which considerable stone has been taken is in the south half of section 35, Butler township, just east of the Great Western railroad track. Little of geological interest is presented, however. The stone is a thin bedded dolomitic limestone, firm textured, finely granular, or crystalline, from buff to drab in color and non-fossiliferous and very uniform in vertical section, excepting that in the fourth foot from the base pockets and seams of crystals appear.

In the southeast quarter of section 11, Shell Rock township, a quarry gives the largest section to be found in this part of the county, though it has been too much modified by the weathering agents to be considered fully representative.

		Feet.	Inches.
6.	Limestone, gray, non-fossiliferous, first four feet somewhat firm, the rest thin bedded and shattered, dolomitic	7	
5.	Thin bedded limestone containing *Atrypa reticularis*, a spirifer, a small gastropod and a small branching coral	4	
4.	Massive limestone with a soft yellow matrix having in it numerous small hard nodules, making a very irregular weathered surface. A single *Atrypa reticularis*, a gastropod and small branching corals were found in it	3	4
3.	Limestone, at times massive, elsewhere with bedding planes, of uncertain hardness and color due to weathering	2	
2.	Soft gray limestone, with numerous small yellow spots, breaking into irregular blocks that obscure the bedding planes, weathering so as to allow No. 3 to overhang	1	3
1.	Drab, compact, hard, brittle limestone, lithographic in inferior degree	1	6

In the road between sections 14 and 15, same township, an outcrop of limestone of manifest lithographic character is the last rock exposure in the county towards the south and east.

The only other opportunity of observing the Cedar Valley limestone in the south half of the county is in the west half of section 9, Jefferson township. It is an artificial exposure made through the drift evidently for quarrying purposes. The following section was secured with difficulty as the mantle of waste by washing has covered much of the rock, no work having been done here for a long time apparently.

		Feet.	Inches.
6.	Iowan drift	5	
5.	Weathered Kansan till	6	
4.	A soft, yellow stone which has lost its lithographic character entirely, glacially smoothed and striated	1	6
3.	A gray, hard, somewhat coarse grained limestone...		11
2.	A drab, irregularly jointed limestone	1	11
1.	A very good grade of lithographic limestone irregularly layered		9

At another point six feet of blue Kansan till was observed, but the nine feet of material above it was so overgrown with vegetation and had been so mixed by washing previously, that its true nature could not be determined with assurance. The slopes about the quarry indicate that a sink hole may have suggested the practicability of securing stone here, though no sinkholes were noted elsewhere in this vicinity.

A quarry in the center of section 35, Dayton township, furnishes the following section:

		FEET.	INCHES.
10.	Thin bedded yellow limestone, becoming thinner and more shattered toward the top	4	6
9.	Clay parting with a two-inch band of ferruginous limestone, more or less persistent, just above the middle		11
8.	Yellow limestone joining No. 7 with a comb-like suture, in three parts: (a) 2 inches, very nodular; (b) 5 inches showing on the weathered edge many fine laminæ; (c) more homogeneous, yellow, soft. This is the yellow, modified lithographic stone found just above the typical lithographic in so many places	1	
7.	Two layers, lower, laminated, upper, nodular; both gray, very brittle, much jointed and rusty along joints	1	4
6.	Clay parting		6
5.	Limestone in two layers; the lower, one foot thick, has a powdery white upper surface, beneath which is the gray compact stone which has an uneven surface of fracture, due to an obscure nodular structure	1	9
4.	Clay parting, yellowish brown below, green above		3
3.	Dolomitic limestone in two equal layers, jointed, gray, finely saccharoidal, upper surface rusty	2	3
2.	Greenish clay parting with hard nodules		3
1.	Very good lithographic limestone in two layers, upper four inches thick, lower undetermined		8

Outcroppings were seen in the road between sections 25 and 36, between sections 9 and 16, 8 and 17 and 7 and 18, Dayton township. The stone is quite like that in numbers 3 and 4 of the quarry in section 35. That between sections 8 and 17 affords specimens of papillated Stromatopora, otherwise all the rock in the outcrops readily suggests beds 3 and 4 of the quarry last mentioned.

Several quarries have been worked to a limited extent in the bluffs that mark the western border of the rocky tableland between the valleys of the Shell Rock and Flood creek just below Greene, from one of which the following section has been taken.

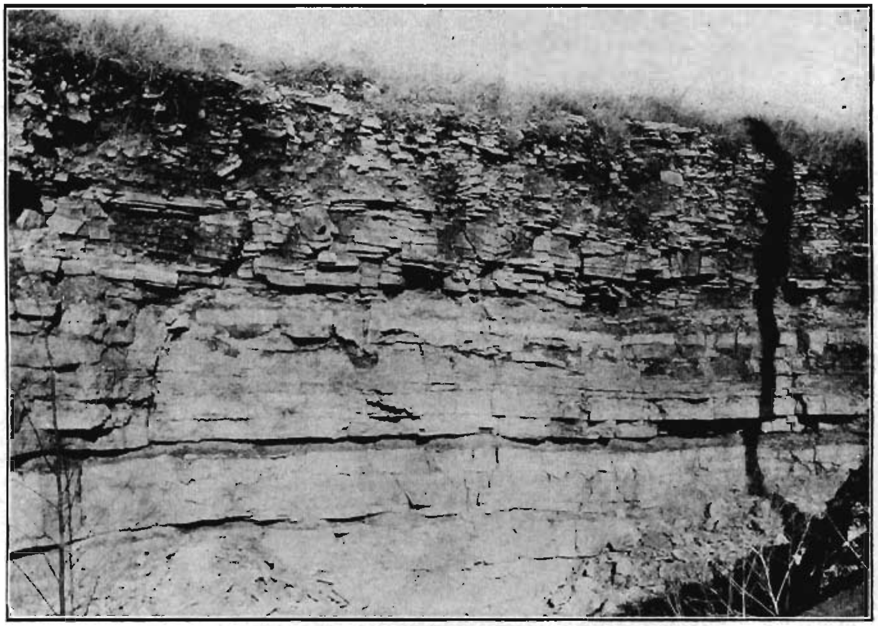

Figure 5. Schrader quarry, section 35, Dayton township, showing the flaggy, lithographic facies of the Cedar Valley stage.

		FEET.	INCHES.
8.	Limestone, the upper nine inches of which is nodular, heterogeneous, gray; the lower part is gray on fracture, yellow along joints, stromatoporoidal, smooth, firm, compact	3	5
7.	Shaly layer		7
6.	Yellow limestone in three imperfect layers; of same horizon as No. 8 in section 35	2	
5.	Thin layered, shaly limestone		10½
4.	Very brittle, nodular, gray limestone, yellow along joints	2	4
3.	Much like No. 4		10½
2.	Clay parting		10
1.	Drab, sugary limestone, dolomitic, (No. 3 of section 35)	2	2

On the west side of the river, near the southwest limit of the city, a quarry has been worked quite extensively. A section here gives the following:

		FEET.	INCHES.
14.	A many layered and fragmental limestone with a small undetermined brachiopod in the upper layers, lower beds white where weathered, but gray on fracture, and somewhat granular	4	8
	Clay parting		2
13.	Lithographic limestone, many layered, much jointed, lower layers light gray, upper drab, a nodular band in the lower part of the upper third	3	7
12.	A shelf holding quarry debris conceals the stone of this number	3	
11.	A buff limestone, the lower part very soft and earthy, the upper firmer, but many layered	4	
10.	Dolomitic limestone in three layers, (a) the lower not everywhere distinct, soft, brownish yellow, breaking into lenticular pieces, 4 inches, (b) drab, granular, breaking vertically into large conchoidal flakes, 8 inches, (c) freely spotted with small patches of calcite crystals, 5 inches	1	5
9.	A firm, compact limestone of smooth fracture, irregularly laminated, upper surface wavy		8
8.	Clay parting		1
7.	A gray to drab limestone weathering to a creamy yellow, tending to divide in irregular layers, jointed	1	5
6.	Clay parting		1
5.	A gray, fine grained limestone with powdery surface and numerous rusty spots, in three layers, middle layer inclined to buff. (No. 5 of quarry in section 15)		9
4.	Thin shales in clay		7
3.	A gray limestone in two layers joined by a toothed suture, upper layer finely granular, lower hard, brittle, but of irregular fracture on account of its nodular structure	1	8
2.	A shaly clay parting		2
1.	A very good grade of lithographic limestone in two layers, 6 and 10 inches	1	4

Near the northeast limits of Greene a quarry exposure gives beds almost wholly of the lithographic and white limestone types.

An exposure in the northeast quarter of section 14, Coldwater township, gives the following section:

	Feet.	Inches.
3. An indistinctly layered limestone creamy where exposed, but drab on fracture, and much streaked and spotted with calcite and iron stain...........	2	8
2. A drab lithographic limestone.....................		9
1. A drab nodular limestone, stromatoporoidal at top, weathering oddly on account of its structure......	2	5

For a quarter of a mile along the line of sections 11 and 14 a band of rock borders the upland terrace along the valley of Coldwater creek. In the northwest quarter of section 26, Coldwater township, is an outcrop of soft, yellow, earthy limestone similar to that in sections 11 and 14 and also very like that in number 11 of the West Greene quarry.

Numerous outcrops occur in sections 10, 15, 25 and 36, Coldwater, and sections 28, 29, 30, 31, 32 and 33, Dayton township. The rock is somewhat different in the different localities, some being stromatoporoidal, some of the white limestone type and again of the more strictly lithographic phase, evidently correlating with the rock of the outcrops and of the upper beds of the quarries east of the river.

In section 1, Benezette township, lithographic limestone occurs. Two loose pieces, unlike the rock of any other part of this region, were highly fossiliferous, being made up largely of crinoid stems, dendroidal Stromatoporas and brachiopods, in this respect suggesting an outcrop in Union township, Black Hawk county.

A belt from eight to sixteen miles wide along the northwest and southeast diagonal of the county is entirely free from natural outcrops of rocks. The old pit quarry in section 9, Jefferson township, exposes the only rock seen in place within this extensive area. The only occurrence at the surface of the Cedar Valley limestone west of this belt is within the east third of Pittsford township. The same horizons are here displayed as in the quarries east of this diagonal and the absence of fossils is even more marked than in the rock of the northeastern part of the county. For correlating the beds in Pittsford township therefore, dependence must be placed entirely upon their lithological character. Fortunately this is quite uniformly sustained in some of the beds, the lithographic stone being quite exceptional in this particular.

An outcrop on the west side of section 34, Pittsford township, has been quarried into, to some extent for a local supply. A nearby barn is built of stone evidently taken from this place. The rock is of the so-called white limestone phase, originally heavy bedded, but by weathering many irregular layers have been developed and numerous small veins of calcite appear. Calcite crystals also fill the few molds of *Atrypa reticularis* that occur. This brachiopod and a small branching stromatoporoid make the sum total of organic remains definitely manifest in the rock in this locality. Across the road near the remains of an old lime kiln considerable quarrying had been done superficially, but the mantle rock in washing had made any satisfactory observation impossible.

Along the west side of Otter creek in sections 23 and 26 and along a branch of this creek in section 11, considerable quarrying has been done. Two sections from this locality are given:

HEWITT'S QUARRY.

		FEET.	INCHES.
14.	Thin bedded limestone, the lowest 2 inches a dark drab, the rest yellowish and much iron-stained, a little granular, but often showing a firm, smooth surface with conchoidal fracture	5	6
13.	Clay parting with lenticular masses of limestone as if the matrix of stone had broken down, the more resistant portion only remaining		10
12.	Dolomitic limestone in five layers, the two lower with a toothed suture, saccharoidal, yellowish brown	2	
11.	An interesting bed varying in thickness, the beds below bending down where No. 11 is thick and up where it is thin or entirely wanting	0-2	
10.	Clay parting		2
9.	Bed of about four layers, upper stromatoporoidal	1	10
8.	Clay parting		3
7.	Lithographic limestone, several layers in places but only two usually	1	5
6.	Clay parting		2
5.	Limestone, drab, splintery on fractured surfaces, in two layers with toothed suture, 8 and 4 inches	1	
4.	Clay parting		3
3.	Lithographic limestone	1	2
2.	A dolomitic limestone, showing several layers with some constancy, grayish, brittle, splintery, saccharoidal and having patches of calcite	4	8

1. Several irregular layers varying from an earthy, granular dolomite above to a more compact stone with glints of calcite and dendrites along delicate cracks, all somewhat iron stained	2	

At a point a little northeast of this quarry, rock below No. 1 is exposed for five and one-half feet. It is soft, yellowish or whitish, earthy, in layers about three inches thick.

The variableness in thickness of No. 11 is quite remarkable, both in linear extent and in uniformity of occurrence, seven of these alternations being found within ten rods, and is very noticeable everywhere in the escarpment along the creek. It seems to have been due to a slight deformation of the beds immediately underlying it, which produced a series of slight anticlines and synclines and thus formed an undulatory surface which the next deposit of sediment filled to an even line, with one or two slight exceptions, where the upper beds partake a little of the unevenness. At one point crushing is quite manifest, an accompaniment of the movement that took place at the time of the deformation.

S. S. JACKSON'S QUARRY, SECTION 11.

	FEET.	INCHES.
11. Many feet of sloping drift, 2 or 3 feet of which, resting immediately upon No. 10, is exposed, a sandy loam		
10. Very thin bedded limestone	1	2
9. Clay parting		2
8. Reddish brown limestone	1	
7. Clay parting		2
6. Thin bedded yellowish limestone. The first two layers are jointed rarely and so yield large flags serviceable in walks and the like	2	7
5. Yellowish brown limestone, earthy and containing numerous patches of calcite as well as crystal lined cavities	1	
4. A drab lithographic limestone in several beds with thin clay partings, the lowest bed in several layers, the upper in two, the uppermost more or less disintegrated. Below the middle of this stratum there is a nodular layer due perhaps to an obscure stromatoporoidal structure; about	7	
3. A yellowish brown, granular dolomite in three nearly equal layers	3	2

2. A yellowish gray dolomitic limestone with calcitic patches, the lower two-thirds having numerous yellow lined cavities of variable form, the size varying from a small fraction of an inch to an inch or more in diameter. At first soft, it soon hardens on exposure and makes a durable building stone.	2	2
1. A gray dolomitic limestone, called sandstone by quarrymen; quite firm. A good quarry stone..........	1	5

The above mentioned sections and outcrops include nearly all the exposures of the Cedar Valley limestone in the county. In the northern half of the county it has an east and west extent of nearly twenty miles and a total vertical extent that is accessible not much exceeding thirty feet. The fossils that occur are largely of a stromatoporoidal character, including mostly those of the lamellar type, though a few are spheroidal or cylindrical. A few specimens of *Atrypa reticularis* and other brachiopods were seen. They are found only in the upper beds and as the lithological characters of the lower beds are more variable than those of the upper, conclusions can be drawn in most instances only from the superposition of the beds. As the lithographic beds are very generally distributed and certain dolomitic beds maintain quite a constant relation to them, even though they exhibit variations in thickness and other physical features, it seems unlikely that the conclusion that the vertical range of the exposures of the Cedar Valley limestone in Butler county scarcely exceeds thirty feet is incorrect.

Upper Devonian Series

LIME CREEK SHALES.

Owen Beds.

Acquaintance with the Lime Creek shales has been gained principally from the typical locality at the Hackberry Grove clay banks and neighboring exposures mostly in Cerro Gordo county. The area of this stage of the Devonian has been clearly defined only in the above named county by Calvin* and in Franklin county by Williams.† From the reports of both these writers it was evident that the Lime Creek shales extended somewhat into the northwestern portion of Butler county. Quite unexpectedly, however, it has been found that a lobe of this stage

*Iowa Geol. Surv., Vol. VII, Geol. Map, facing p. 192, and pp. 161-170.
†Iowa Geol. Surv., Vol. XVI, Geol. Map, facing p. 506, also pp. 477-481.

extends southeasterly across the county and well into Grundy county, as is evidenced by well sections, though no surface exposures are found within three miles of the south border of Butler county.

EXPOSURES AND SECTIONS.

In the road on the county line along the southwest quarter of section 6, Pittsford township, there is an exposure of a yellow calcareous rock packed with fragments of fossils so worn and weathered as to be unidentifiable, but free by the roadside were casts of small *Atrypa reticularis* Linn., also specimens of *A. aspera* var. *hystrix* Hall var., *Stropheodonta arcuata* Hall, a small unidentified brachiopod and a gastropod not recognized.

Mr. Wm. Sprole speaks of encountering a blue soapstone in sinking a well on his place near the schoolhouse in the northeast quarter of section 19, Benezette township. This undoubtedly is the blue clay of the Hackberry shales.

Just west of the bridge across Hartgrave creek, along the south line of section 29, Pittsford township, yellow calcareous shales appear in which were found *Atrypa reticularis, Atrypa aspera* var. *hystrix, Spirifer whitneyi* Hall, *Strophonella reversa* Hall and a small cyathophylloid coral. This is believed to be the same horizon as No. 3 in Calvin's section at Hackberry Grove.* At the top of the hill in the field on the north side of the road is a rocky ridge where quarrying has been done. The excavation is quite superficial and the exposed layers show little variation. The rock originally was heavy bedded, apparently, but has weathered into irregular layers and masses white, drab, gray and yellow, often made up entirely of corals, largely *Pachyphyllum woodmani* White, and less commonly an Acervularia. *Stromatoporella incrustans* H. & W., is also abundant and of considerable thickness as well as superficial extent. The two Atrypas found in the shales of the hillside and two or three other brachiopoda were noted, while the rock was sometimes made up almost wholly of fragments of their shells cemented together. This is the horizon of No. 4 in the Hackberry Grove section and therefore represents the Owen beds. This exposure may be referred to as Wickham's quarry.

*Calvin: Iowa Geological Survey, Vol. VII, p. 162.

In the southeast quarter of section 6, Madison township, a low ridge running northwest and southeast has along its eastern slope near the top an outcrop of rock of the same horizon as that at Wickham's quarry. Several similar ridges and outcroppings may be noted south of this. At one place just above the limestone is a yellow shale with numerous limestone masses in it and also with cup corals and Cladoporas. This overlying shale was noted nowhere else in connection with the outcrops of this horizon.

In the southwest quarter of section 15, some quarrying had been done in a limestone, somewhat thin bedded, similar to that in the exposures just named. About eight feet of rock is exposed. It is yellowish brown where weathered, but drab on fresh fractured surfaces. The layers show little difference except that the upper are quite fossiliferous, a cyathophylloid coral predominating. A Cladopora is quite common also. Along the road south in section 21 and east in sections 26 and 27, several outcrops were seen.

On the east side of section 35, Mr. Thomas Faint has quarried stone for a large barn, the walls of which abound in fossils, among which may be mentioned *Stromatoporella incrustans, Alveolites rockfordensis* H. & W., *Pachyphyllum woodmani, Spirifer whitneyi, Naticopsis gigantea,* one or two smaller gastropods, a Cladopora and fragments of the stems of a crinoid. The layers are quite irregular and a satisfactory section is impossible, but the following is approximately correct.

	FEET.	INCHES.
4. A less rifted, more granular and compact limestone than was noted in the outcrops elsewhere in Madison township, but containing numerous fossils such as have already been enumerated..........	2-3	
3. Limestone, much broken, rusty along joints, but gray on fracture, having numerous calcitic pockets	5	
2. A dolomitic layer, compact, minutely crystalline, drab, conchoidal on fracture....................		4
1. Two very fossiliferous layers not well seen in place for quarry debris. *Atrypa reticularis, Strophonella reversa*, two or three Spirifers, a minute branching Stromatopora, perhaps, etc., occur. Each...		4

This section belong to the Owen beds, undoubtedly, and at least a portion of it is referable to the horizon of No. 4 of the Hackberry Grove section. The rock is of fairly good quality for building purposes and in some layers differs quite materially from that seen elsewhere, but the testimony of the fossils settles all doubts as to the place of these beds in the geological column.

In the southwest quarter of section 9, Albion township, appear the most southeasterly outcrops of indurated rock to be found in the county. One is near the road along the west line of the section, the other is in a pasture an eighth of a mile or so to the east. The rock, which is a brown, finely crystalline dolomite, is fragmental and yields very many casts of *Atrypa reticularis*. No other fossils were seen. The rock as well as the fossil casts give strong evidence that this outcrop, too, belongs to the Owen beds.

The only other exposures of the Lime Creek shales noted are by the roadsides a half mile north of Aplington. Near the west line of the section in the roadside ditch about four feet of shales may be seen. The lower and greater portion is a light gray argillaceous shale, slightly ferruginous and indurated in places. Immediately above this is a thin brown layer overtopped by a darker band. Common dark soil rests upon this band. No fossils were seen. An eighth of a mile east, a north and south road cuts the hillside, leaving eight or ten feet of bank upon the east side. In the lower five or six feet of this bank the rock is brown, breaks freely into irregular blocks never more than four or five inches thick and shows no well defined layers. In the upper two feet the rock is light gray, thin layered and sparingly fossiliferous. Casts of *Atrypa reticularis* are most numerous, a few of which are of moderate size. The majority, however, are small, some being extremely so. The rarer individuals of *A. aspera* are also much reduced in size. The rest of the bank is made up of a bed of gravel overlain with a sandy loam. Here too, was found a single specimen regarded by Calvin as *Bellerophon pelops* Hall, or a form very closely related to it. "The only reason for entertaining any doubts is that Hall's specimens of the species came from the old Upper Helderberg, Corniferous, or as it is now called, the Onondago limestone, while yours comes from the Upper Devonian. There are other cases of the same kind, however, forms characteristic of the Corniferous of New York occurring in the Lime Creek shales of Iowa."—Calvin.

In the fossiliferous beds of the Lime Creek shales the sturdy *Atrypa reticularis* is notably prevalent. *A. aspera* var. *hystrix,* though never as abundant, is nearly as universal in its occurrence. But in the southern borders of this stage of the Devonian even their hardiness and readiness of adaptation yield to the changing conditions indicated by the increased dolomitic and argillaceous character of the rocks, and variably undersized specimens predominate.

CARBONIFEROUS SYSTEM

Mississippian Series

KINDERHOOK STAGE.

Numerous outcrops of the Kinderhook stage are noted by Williams* as occurring in the eastern sections of Geneva and Osceola townships in Franklin county. These townships border upon Madison and Washington townships, Butler county. The northernmost of these outcrops is described as "a nodular, fossiliferous limestone in the road on the east edge of section 13, Geneva township." This is within a mile and a half of an exposure of the Lime Creek shales in section 17, Madison township, Butler county, from which fact it might be inferred that the rock observed by Williams is not far from the base of the Kinderhook.

Exposures and Sections.

The northernmost exposure of the Kinderhook observed in Butler is in the road between sections 7 and 8, Washington township, where a light gray shale containing calcareous nodules, topped with a thin layer of chert, appears. Near the middle of the east line of section 17, a small quarry on land belonging to Mr. H. K. Brower gives a section of eight or nine feet in the Kinderhook as follows:

*I. A. Williams: Iowa Geological Survey, Vol. XVI, pp. 487-488.

	FEET.	INCHES.
3. A yellowish shale with thin calcareous layers and a poorly developed layer of chert	2-3	
2. Five layers of limestone, similar to No. 1		6
1. A heavy bed of limestone with few joints and a tendency to cleave irregularly along a few imperfect seams	6	

No. 1 varies in color, ranging from a plain light gray to a darker mottled gray and even to a light tan; it varies also in structure, the plain gray being semi-oolitic, but with small rhomboidal crystals of calcite freely disseminated through it. The mottled gray is a fine breccia of brachiopod shell fragments and hollow spines of some Productus, with which are gray crystals of calcite and many spots of a yellow earthy material to which the mottling is due. In both of these, numerous minute tubular or spherical openings are very characteristic as seen under the lens. The tan variety has larger and more abundant crystals in a matrix of extremely minute earthy and shell fragments freely intermingled. Weathered edges of the mottled variety develop thin laminæ, the earthy material dissolving out and the shell fragments presenting a peculiar hackly surface. Identifiable fossils are few. Professor Calvin has recognized *Athyris proutii,* and a spirifer of uncertain relations. Two undetermined species of Productus were found. The lithological character of this rock suggests that in No. 1 of the sections at Alden and at Eagle City, Hardin county* and also faunally as well as lithologically it seems to be of the same horizon as No. 2 in Williams' section at section 10, Geneva township, Franklin county.†

On the west line of section 19, Washington township, the road makes a cut exposing several feet of Kinderhook material, the uppermost foot of which is an arenaceous limestone, not very firm, yellowish gray much streaked with a dark brown. The rest of the cut is a calcareous sand, white, yellow, brown and even red. In it are irregular indurated masses that have withstood the weathering better than the rest. Neighborhood indications are that chert overlies it where it might be found in place. Farther south chert outcrops in the road and in one

*Beyer: Iowa Geological Survey, Vol. X, pp. 268-269.
†Williams: Iowa Geological Survey, Vol. XVI, p. 486.

place along the west line of section 30, a white sugary limestone may be seen beneath the layer of chert. Chert fragments are very plentiful along the hillsides in all of the southwest sections of Washington township. In some places, as near the school house in section 32, they seriously encumber the fields.

At several places in sections 31, 32 and 28, Beaver creek has removed the talus from the bordering slopes and exposed the rocks of the Kinderhook for a considerable height. The most extensive section of the Kinderhook in the county is at the junction of a small tributary from the south with the Beaver in section 31, as follows:

	Feet.	Inches.
7. A thin bedded yellow to drab limestone with bands and nodules of chert	3	
6. Brown, sugary, dolomitic limestone with a five-inch band of chert in the lower half	1	10
5. Chert band		5
4. Hard, compact, finely crystalline, gray to yellowish limestone in three well defined layers	4	
3. Soft, somewhat crystalline limestone irregularly layered, but with two distinct chert bands	6	
2. Limestone, in several poorly defined layers and having two chert bands near the middle	8	5
1. Massive sandstone, soft, yellow, rarely jointed	1	6

No fossils were seen here and the rock has no striking characteristics that suggest sections described elsewhere by others. The chert, as has been mentioned above, is a common feature of the Kinderhook in Franklin and this county. Irregular bedding is quite noticeable.

Along the left bank of the Beaver there is an escarpment of soft calcareous sandstone for three hundred rods or more, and ten feet high. Near the top in places a cherty layer appears and near the base thin layers of dolomitic limestone may be seen. The color varies from a light red brown above to a dark brown below. A few rods west of the railroad bridge over the Beaver, just west of Austinville, some quarrying has been done, exposing ten feet of a soft, yellowish brown, calcareous sandstone with a cherty band near the top. These two last mentioned outcrops are to be identified with the basal member of the more extensive section mentioned immediately preceding this.

While the area of the Kinderhook in Butler county is not more than fifty square miles, its expression is unusually varied, each outcrop having an individuality of its own. The dip is nowhere unusual and the vertical range is believed to be moderate. In a few instances correlation with certain sections in Franklin and Hardin counties has been made with a degree of assurance, but the exposures in the southeastern part of the area, which are by far the most extensive vertically, are non-fossiliferous, show merely general similarity lithologically with beds of this stage as described in other localities, and evidence as to order of superposition is only indirect. Nevertheless, while the exact horizon of these beds may be uncertain, it is unquestionably true that their position is not far from the base of the Kinderhook column.

RESIDUAL MATERIAL

As soon as the marine deposits represented in the county had been lifted above the water, weathering became active and the exposed surface was modified, the rock crumbled or became pulverized and often leached, till only the more insoluble portions remained. In some places this leached material, mingled with rock fragments, overlies the rock, having been undisturbed by the moving ice masses of the glacial epoch.

In portions of the southern sections of Washington township where the chips and blocks of chert are so prominent, there is little or no drift, and the mantle rock is a residuum chiefly of preglacial origin. Usually, however, the ice sheet obliterated the ancient residuum as a distinct factor, ultimately leaving in its place a much greater quantity of material consisting of rock flour mingled with this residual matter and fragmental rock of wide range in size and composition. In some of the northern townships this is very apparent, for the country rock appears here and there in the roads and fields rounded and smoothed like miniature *roches moutonnees,* while the thin mantle rock is manifestly till with some organic matter superadded or intermingled.

QUATERNARY SYSTEM

Pleistocene Series

KANSAN STAGE.

Kansan Drift.

No trace of any material older than the Kansan was clearly recognized anywhere in this county. In by far the greater part of the county next to the Paleozoic formations lies a body of till, always distinctly characteristic, but ever varying within certain limits. Wherever there is any considerable thickness, the basal portion consists of a very compact, jointed blue clay with intermingled pebbles and bowlders and with bands, streaks and pockets of sand and gravel. Among the indurated materials the greenstone type predominates. The larger rock fragments are often very distinctly glaciated on one or more sides. From this basal part upward there is a gradual change in the appearance of the till. It is less compact, is yellowish or reddish brown in color, the granitoid fragments are disintegrating and the soluble constituents have been well leached out. Everything indicates exposure to the weathering agents through a very great length of time. This is the Kansan till. The morainic hills north of New Hartford described earlier in this report are composed chiefly of Kansan till mantled with loess, though usually it is concealed beneath the later Iowan.

The Buchanan Gravels.

The melting of the ice was attended with the movement of much of the loose material produced by it which resulted in a sorting process by which the finer portions were swept into the remote estuaries, while the coarser sands and gravels were sooner dropped in sheets, valley trains and lenses over uplands or along the courses of the streams. As these deposits were superficial during the long pre-Iowan interval, they always have an appearance of age, that later deposits of similar character do not possess.

Along the three principal streams of the county extensive valley trains occur, having a depth sometimes of thirty or more feet. The larger tributaries of these streams have similar deposits, though of less extent. The occurrence of the Buchanan gravels, as Calvin has termed them, is not uncommon as one feature of the Kansan stage, but rarely are they more widely diffused or in greater quantities than in Butler county. Every township has its supply, but where the topography is flat as in Benezette, it is not as readily manifest. Wherever the roads cut through the Iowan ridges, the upland phase of these gravels appears, and sometimes it shows beneath the loess of the Kansan hills, though the cuts only now and then extend through the loess. Stratification and cross-bedding are very noticeable in many of these deposits, as in the gravel pits of the railroads at Clarksville and in the Butler pit just north of Greene.

Some of the deposits that already have afforded much material for various purposes are those just named, one owned by T. H. Ahrends in the southeast quarter of section 30, Pittsford township, and deposits in sections 24 and 30 in West Point township. The Ahrends pit has been proven to be eighteen feet deep. The upper part consists of unstratified pebbles with bowlders as much as a foot in diameter, but running down to a mere gravel at seven feet below. Then occurs stratified sand and gravel somewhat ferruginous. Crumbling granites are numerous in the lower part and here, too, are consolidated sand masses of considerable size.

In the West Point pits a well defined layer of pebbles and small bowlders is found just below the thin, dark, sandy soil. The gravel is well stained with the iron oxides and in section 30 it is stratified and the lower five or six feet are cross-bedded.

About half a mile north of Greene there is an extensive deposit owned by Mr. J. W. Butler who has, a few rods north of the pit, a sixty-five foot well wholly in the gravel. This pit is usually worked on two levels separated by an eighteen inch layer of clay, bluish below and grayish above, streaked and spotted with an iron stained sand. Material is taken out to a depth of twelve to fifteen feet below this clayey band. While there is much variability in the deposit, something like the following may be fairly well discerned. The lower part is beautifully cross-bedded,

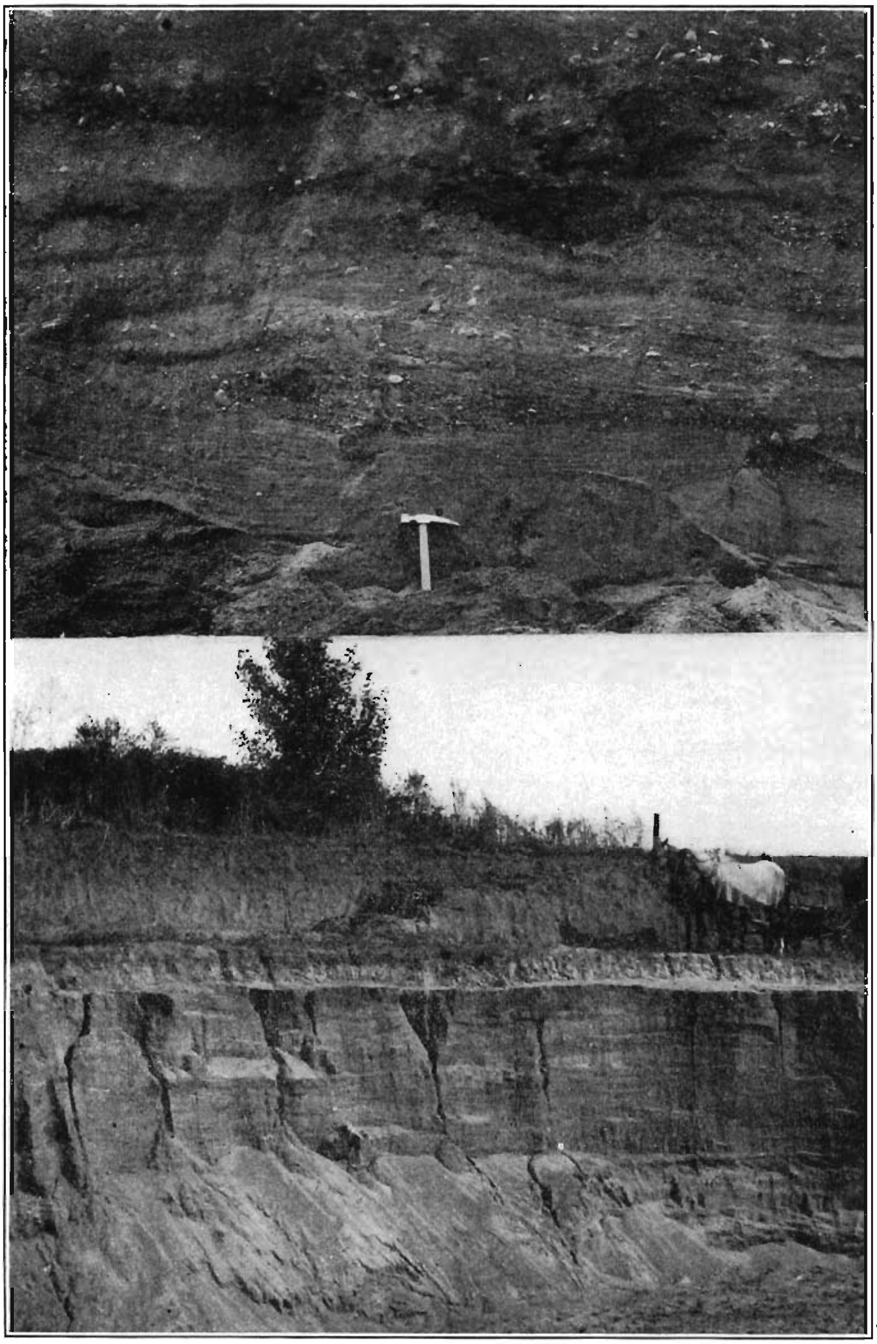

Plate VIII. Upper view—Cross-bedding in gravel pit of Chicago Great Western Railroad at Clarksville.

Lower view—View in Butler gravel pit one-fourth mile north of Greene, showing cross-bedding and the clayey band which makes a convenient platform for excavating the upper portion.

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the shifting beds taking all grades of pitch and direction and often cutting each other very abruptly, many of them being very short, thus indicating rapidly changing currents. The prevailing color is gray with iron-stained beds streaking the lower and also the extreme upper portions. The coarsest gravel, with pebbles averaging one and one-half to two inches in diameter, lies four or five feet from the present bottom of the pit. Also a coarser bed showing little cross bedding makes the uppermost foot or two of this division of the pit. The pebbles are much water worn, and chiefly of the granitoid and greenstone types though occasional pieces of limestone similar in character to the neighboring outcroppings are to be found. Next above the clayey band, which makes a convenient platform from which to work this part, is a foot or two of cross-bedded sand, fine, grayish yellow, with occasional yellowish brown streaks. Next are three feet of a homogeneous, yellowish, compact, sandy, loess-like material topped with a foot or two of sandy soil. Iron pipes occur in the lower beds as well as in the clayey bed below.

A gravel pit extensively used by the Chicago Great Western Railroad just northwest of Clarksville has been excavated to the depth of ten or twelve feet below the soil, which here is about two feet thick. The lower six or eight feet are cross-bedded, the grades running from a coarse sand to a coarse gravel containing pebbles and cobbles from two to five inches in diameter. In addition to pebbles of the usual kind there are iron nodules and numerous limestone fragments. The origin of the latter in the immediate country rock is very probable. The gravels in and about Clarksville are unusually extensive superficially, and lie immediately upon the indurated rocks. The above descriptions are sufficient to indicate the general character of the Buchanan gravels of the county.

IOWAN STAGE

Iowan Drift.

Since in regions where the continental glaciers prevailed the topography is mainly determined by the drift deposits, the discussion of the topography of the county in the previous pages has left little to be said concerning the Iowan drift. It forms the basis of the soil in by far the larger portion of the county, though it is very thin in many places and probably nowhere has it a depth of more than seven or eight feet. In the more level townships little opportunity is afforded for testing its thickness, as the few cuts that have been made are shallow. The solid and oftentimes very large granitic bowlders universally regarded as belonging to the Iowan drift deposit are the commonest and most obvious evidences of its presence, since the soil is such a complete modification of whatever geological material may have constituted the superficial deposit as to offer little satisfaction in determining its age or origin.

From the very conditions of its formation the Iowan drift is usually a very thorough mixture of pulverized and disintegrated rocks of great variety and therefore contains all the constituents of plant food to an unlimited extent, for the comparative recency of its origin has not afforded time in which the soluble constituents could be leached out. For this reason, too, it does not have the deep color that a long period of weathering has given to the more superficial portions of the Kansan. The agricultural possibilities of the soil wherever the Iowan drift is found are therefore unsurpassed.

LOESS.

This material of seeming uniformity of texture and composition and which therefore is often described as homogeneous, is really made up of siliceous, argillaceous and calcareous particles in varying proportions, which range from minute, but distinct granules to an impalpable dust. It is wholly destitute of the coarser elements of the till, yet the variety of minerals in its composition may be as great. To the naked eye it appears as a compact earth, yet it has such porosity as to make it an unusually favorable root home for most forms of vegetation in both wet and dry seasons. In its erosional forms it is as unique as in its other characteristics. Where it covers hillsides, running water cuts in it deep but steep-sided gullies and in cuts and excavations it maintains vertical faces almost as well as do the indurated rocks. It has a kind of vertical cleavage, but usually is without well defined stratification. In color it ranges from an ashen gray to a light yellow. Fossils, chiefly land snails of existing species, are not infrequently present, and there are calcareous concretions, often of more or less fantastic forms, called loess kindchen, together with ferruginous rods and cylinders made of concentric layers as if they had developed around decaying roots. At times the loess seems to grade into a fine sand and again into a sandy clay, though often it has a well defined plane of demarkation beneath it. The upper surface shows somewhat the effect of exposure to the elements but its modifications are mostly due to the changes incident to the production of vegetation through the ages. As a rule, the effect of loess, topographically, is to soften a little the sharper contours and reliefs of the drift beneath, as it is but a veneer that overlies the drift with quite impartial variation in thickness.

Loess is commonly found broadly spread over the Kansan drift near the borders of the Wisconsin and Iowan drift sheets and capping the morainic hills and paha in the same regions. Numerous isolated patches have also been found somewhat remote from the more extensive areas.

In Butler county typical loess is confined to the hills of the New Hartford moraine and the pahoid hills in Washington and Monroe townships. North and west of Dumont a modified form of loess may be seen on the ridges lying between the two branches of the West Fork. It is more clayey than ordinary loess and is somewhat mottled and streaked. It may not be entitled to the name, but in its position, uniformity of texture and behavior under weathering, it strongly suggests at least near relationship. Its thickness here is unusually variable. On some of the slopes the Buchanan gravels were exposed, making large patches nearly destitute of vegetation. The maximum thickness noted was on the county line in section 19, Pittsford township, where it was about six feet. The average is probably from two to three feet.

Soils

Loess, alluvium and Iowan till intermingled more or less with accumulations of organic residuum have given to Butler county an enviable reputation as a prosperous agricultural district. The hill tops and slopes near the Beaver in Washington township are largely residual. A comparatively small part of the morainic area near New Hartford is an unproductive waste of bowlders and gravel. These with one or two patches of æolian sands and a few insignificant swamps and peaty areas make up the sum total of soil variety.

In this county the one great productive source of plant food in the soil is that marvelous mixture of disintegrated and decomposed rocks of every variety, still relatively fresh and unleached, which made up the great bulk of the deposit gathered by the Iowan drift sheet as it irresistibly forced its way over the face of the northern lands. For the loess is composed of the finer particles of this deposit caught up and borne along by the winds and finally dropped upon the comparatively ancient Kansan hills and ridges that stood above the thin Iowan glacier like islands in the sea and the alluvium is that fine rich silt which the run-off waters have been constantly filching from the Iowan till ever since it has been uncovered by the melting of the ice sheet and which they have been depositing over the extensive flood plains of all the larger water courses.

Though the till has lost much in this way, its fertility is unimpaired as it has exhaustless supplies of mineral salts which, when exposed by tillage to the action of the weathering agents, are continually being set free and made ready for the use of vegetation.

These three varieties of soil endure drouth unusually well; the till, by reason of the under clay which, when once it is fully laden with water, retains it well, imparting it to the growing crops somewhat stintedly to be sure, but with a steadfastness that insures their success; the alluvium, because deeply underlain with the valley train gravels which serve as a never-failing aquifer, that readily imparts its store of moisture; the loess which, despite its seeming compactness, is minutely porous and therefore has a high degree of capillarity.

ECONOMIC PRODUCTS

Building Stone

Ample supplies of limestone of good quality for foundation walls and all forms of rough masonry are well distributed in the county. No quarries have been extensively worked, as no attempt has been made to meet more than the local demands. Mills, shops, barns and other out-buildings with walls of stone, are not infrequent, and as a rule the material is proving durable and otherwise suitable. With the increasing cost of lumber, recourse to stone will become more and more desirable and even necessary. The Cedar Valley limestone has been most freely drawn upon not only because of its wider distribution and more usual outcrop, but unquestionably because certain of its beds are really superior in quality. Limestone from the Owen beds of the Lime Creek shales, taken from several different localities, has been used to a limited extent, though little opportunity to note its durability or appearance where used has been afforded the writer. Mr. Thomas Faint in Madison township has a large and substantial barn made from stone of the Owen beds which gives promise of great durability. The few quarries in the Kinderhook limestone have opened a good quality of stone, the product of Brower's quarry in Washington township having the appearance of being exceptionally good.

Lime

Years ago a lime kiln was operated quite extensively near the outcrop of Cedar Valley limestone along the creek west of Bristow. Possibly there were others elsewhere. The introduction upon the market of lime made from the dolomitic limestones in the eastern part of the state soon made the work in Butler county unprofitable, and it has been abandoned.

Brick Clay

The manufacture of brick and tile has never secured a foothold in the county, and nature seems to have given little encouragement along this line; though it would seem that the loess here as elsewhere would prove suitable for the purpose. Its location apart from the towns and the lack of facilities for transportation undoubtedly account for the failure to attempt to utilize it for this purpose.

Sand and Gravel

Sands and gravels in such variety as to meet all the common uses are widely and generally distributed throughout the county. So common are the deposits that to make enumeration of any of them would seem to be superfluous were it not that convenient location has led to a more general use of some of them. Both the Rock Island and the Great Western railways have made large use of the gravel deposits at Clarksville for the betterment of their road beds, for which purpose they are unusually well adapted. The Butler pit just north of Greene yields large supplies of sand and gravel of excellent quality for a variety of uses. The increasing interest in good roads has made the upland deposits of Buchanan gravels that are favorably situated particularly valuable, and free use of them has already been made in some localities to the manifest improvement of the highways. Two such pits west and northwest of Allison, as well as one west of Dumont on land owned by Mr. T. H. Ahrends, may be mentioned as having been freely drawn upon for material for the betterment of the roads. When suitable provision for drainage has been made, any country road within a few years can be made passable for loaded teams at any season of the year by a judicious use of these gravels. In a short time every road in the county could be thus improved. Properly managed, it could be done at scarcely more than a nominal expense, since ample supplies of material are readily accessible in every township.

Oil

In the immediate vicinity of the West Fork north and northwest of Dumont an iridescent film, which may be iron oxide, appears on the surface of the water that oozes from beneath the banks of the creek and its tributaries. This has long attracted the attention of the residents of the neighborhood and a suspicion that great reservoirs of oil exist somewhere in the subjacent rock strata has arisen. Men familiar with the topographic conditions of some of the well known oil regions have visited the locality and a company has been organized and an attempt has been made to secure options on the rental of all the lands in the region with a view of making test borings. Inability to secure options on some of the land has deferred such borings. As similar conditions elsewhere have repeatedly excited interest in the question of the probable existence of oil in paying quantities in the state the subject has been fully treated in a previous volume of the Survey,* and therefore its discussion need not be entered into here. Suffice it to say that there is only the remotest possibility of finding oil in paying quantities anywhere in Iowa, due to the lack of certain conditions universally required as essential to the storage of oil in the earth.

Water Power

As has already been stated the larger streams have low gradients and little opportunity is afforded for securing adequate power for practical purposes. Fairly good power has been secured upon the Shell Rock, however, and small grist and flouring mills have been run to a good advantage.

Water Supply

IMPORTANCE AND GENERAL SOURCES.

The water supply of any territory is a matter of prime importance, the prosperity of its inhabitants being vitally related to its adequacy and the facility of its attainment.

In the earlier days of the settlement of this county, the superficial supply afforded by the streams and springs was mainly relied upon, but the increased demand made by the more complete settlement, and the changes wrought by the cultivation of the land and the clearing of the waterways from the accumulated impediments of centuries, has greatly curtailed this source of water supply and wells of one form or another have become almost universal. At first shallow wells ending in the Buchanan gravels or in the ordinary till sufficed, but later this source failed, especially in the drier portions of the year, and shallow rock wells were resorted to; even these in many instances have had to be deepened, and others are giving promise of such necessity in the near future. For sanitary reasons it is fortunate that

*Calvin: Iowa Geological Survey, Vol. XI, pp. 22-27.

it is so, as many of the shallow wells were scarcely better than pits for the accumulation of surface water, which, when for convenience they were located near outbuildings and barnyards, readily became contaminated. Ordinarily the deep rock well when properly curbed and cased yields not only an adequate supply of water, but the water is of excellent quality, though it is likely to be moderately hard.

The lowering of the ground water surface, or water table, is a matter of no little interest, for should it continue as rapidly as in the past fifty years, it will soon become the occasion of grave concern. Taking into consideration, however, the more obvious causes of this lowering in the past, as are indicated above, it is not unlikely that they have already produced their maximum effects, very nearly, and while there may be some further withdrawal of the upper boundary of the ground water, in all agricultural communities, reliance may well be placed in ordinary deep rock wells, recourse to the deeper lying aquifers, such as the sandstones of the Saint Peter and the Jordan, being necessary only in cities where there is a demand for large quantities in relatively small areas.

WATER HORIZONS.

The following horizons yield water in varying degree:

1. The lowland phase of the Buchanan gravels in the alluvial plains.
2. The upland phase of the Buchanan gravels.
3. The calciferous sandstones of the Kinderhook.
4. The base of the Owen beds.
5. The shelly rock layers at the top of the Cedar Valley limestone.
6. The earthy limestone just below the lithographic beds of the Cedar Valley limestones.

In the alluvial areas the great water horizon noted above as number 1, is very generally relied upon. The gravels range in depth from a few feet to fifty or more. The supply is abundant at all seasons of the year. As the gravels are more or less iron stained, the water sometimes has a decided taste of iron, though it does not seem to be objectionable to those accustomed to its use. Water from this source from several localities has been analyzed at different times and never more than a trace of organic matter has been reported, yet the porous nature of these gravels, the very feature that makes them superior aquifers, creates a necessity for unusual care in the disposal of sewage and other waste, to prevent contamination from seepage.

Horizon number 2 was once the main reliance of the settlers upon the upland plains, but with the increased drainage facilities inevitably attending the more complete settlement of the country and the general cultivation of the land, the wells drawing upon this horizon began to fail during the drier seasons, and deeper wells had to put down. Today little, if any, dependence is put in wells ending in this horizon.

So far as noted the sandstone of the Kinderhook beds afford an ample supply of good water.

Accurate or reliable data respecting the merit of horizon number 4 could not be secured to any great extent. It would appear, however, that some wells in the Lime Creek shales area have been put down to horizon number 5, penetrating the Hackberry beds known locally and among the well drillers as soapstone. Usually horizon number 4 seems to afford a sufficient supply for all demands.

Horizon number 5, in the Cedar Valley limestone region, was the next recourse of the farmer who had found the upland phase of the Buchanan gravels failing him, and though this horizon is not so copious in its supply as number 1, or number 6, many still find it capable of furnishing enough water to meet all their needs. Many, however, within a few years have found it necessary to deepen their wells and go down to horizon number 6. This latter so far has proven entirely reliable, always affording an abundance of good wholesome water. Some wells are reported as ending in the Kansan drift, where perchance they have struck some unusual pocket or streak of gravel or sand that serves as a local aquifer; others are reputed to end in the midst of the lithographic beds or some local modifications of them, but they are exceptional and worthy of little notice here.

WELLS.

For convenience the county may be divided into seven districts on a topographic basis.

District number 1: This area embraces all of the county northeast of the valley of the Shell Rock. It includes all of Fremont township and, loosely speaking, the northeast halves of Butler and Dayton townships. The topography is that of the Iowan drift plain. The mantle rock is thin, the rock, especially in the northwest portion, often coming to the surface. Dug or driven wells do not occur. Little in the way of exact data respecting the wells could be secured. The following, believed to be accurate, concerns a well situated in the north half of section 22, Fremont township. A drilled well completed in 1894 has a diameter of five inches and a depth of eighty-seven feet. Soil and Iowan drift followed by Buchanan gravel, seven feet. Yellow clay and broken stone twenty feet. Cedar Valley limestone with occasional clay partings sixty feet; ends in limestone. Water medium hard, plentiful. From such other information as could be secured it is believed that this fairly represents the wells of this district, allowance having been made for surface altitude, and for the varying depths to which the wells have been sunk into the rock after the true water bearing beds had been reached. The aquifer of the district is the soft limestone below the lithographic beds.

District Number 2: This includes the alluvial valley of the Shell Rock river. As a rule the wells of this district are of the dug or driven type, the exceptions being at Clarksville and Shell Rock chiefly, where the rock lies near the surface. At Shell Rock driven wells twenty to thirty feet deep supply the southeast portion of the town with water of good quality, but elsewhere the wells are sixty to eighty feet deep, entering the rock within ten to twenty feet of the surface. At Clarksville a well, reported to be a typical one, is twenty-five feet deep, the upper twenty feet being in gravel. Greene has a public well of the driven type which affords an ample supply of pure water, as has been proven by repeated analyses. However, many private driven wells are in use. These wells are about twenty-five feet deep. The eastern part of the town is upon an elevated bench and there the wells are about fifty feet deep.

District Number 3: This district embraces all the area of upland between the valleys of the Shell Rock and the West Fork of the Cedar. In the east half of section 22, Shell Rock township, a drilled well is 140 feet deep, forty feet in rock. Water good, abundant. Water was found in drift, but not plentiful enough. A half mile north of this in the same section is a dug well seventy-five feet deep, and near it a drilled well ninety feet deep, fifteen feet in rock, very good water. One mile north of the latter is a drilled well 128 feet deep, four feet being in Iowan, fifty-one feet in Kansan, five feet in gravel and sixty-eight feet in rock.

In the northeast quarter of section 10, Jefferson township, is a well 128 feet deep, twenty feet in rock. In the southwest quarter of section 23, Jackson township, a drilled well is 128 feet deep, sixteen feet in rock.

In the north half of section 18, Jefferson township, a drilled well is 185 feet deep, eight feet of this depth being Iowan, twenty feet weathered Kansan, 142 feet dense blue Kansan, rock fifteen feet.

In section 32, West Point township a well is 200 feet deep, forty feet being in rock. Wells in this vicinity average from 160 to 180 feet in depth.

In the east half of section 22, same township, a well wholly in the drift is eighty feet deep and yields good water in abundance.

In the northeast quarter of section 33, Coldwater township, a drilled well is 138 feet deep, twenty-six feet in rock. In the north half of section 31, same township, a drilled well is 100 feet deep, forty feet in rock.

In the northeast quarter of section 19, Benezette township, a well is 207 feet deep. The owner could not be certain of all data, but reported sixty feet of drift, thirty-nine feet of loose rock, and that the well ends in solid rock. A letter to the well driller, seeking more definite information, brought no reply. The loose rock reported here is believed to belong to the Owen beds of the Lime Creek shales. A kind of "soapstone" was also reported below these beds which, no doubt, answers to the Hackberry beds. The well ends in the Cedar

Valley limestone. Another well one-half mile south gives good water at a depth of 189 feet. Another, one mile north, is but seventy-five feet deep, the water being found in the Owen beds.

In the northeast quarter of section 5, Pittsford township, a well is 106 feet deep, six feet being in loose rock which belongs to the Owen beds probably; for it is but a few miles east of an exposure of these beds, though it must be not far from their eastern border.

Water in all cases noted above has been reported as abundant all the year round and of a good quality, and all those wells ending in rock, excepting the last two, find water in the Cedar Valley limestone.

District Number 4: This district includes the alluvial plain of the West Fork which is from two to three and a half or four miles wide, and more than thirty miles long. None but dug or driven wells have been reported in this area. They vary from ten to thirty feet in depth, the difference being due to the thickness of the Buchanan gravels, any part of which usually furnishes water in good supply.

District Number 5: This is the upland area between the West Fork and the Beaver. Its western end is wide and more varied in topography as well as in the underlying rock than any other of the districts. It narrows towards the east until it is occupied almost exclusively by the Kansan morainic hills described under the topic, Topography. It is to be regretted that very little reliable data could be secured for the greater part of this district.

In the west half of section 8, Madison township, a well 376 feet deep is reported, but no details could be secured. Some wells in this neighborhood are reported as shallow, ending in gravel.

A well in the north half of section 35, Madison township, is 180 feet deep, reaching rock. It is near the Bear Grove cluster of hills, reported elsewhere. Two miles north of Austinville, section 10, Washington township, a well is forty feet deep, three feet in the Kinderhook limestone. The well driller says water is hard, but plentiful. The broad valley of a tributary of the Beaver shares with the latter the most of the area of Monroe township, in which the wells are all driven and shallow.

In the eastern third of this district where the morainic hills constitute the prevailing topography the following wells are characteristic. Along the line between sections 3 and 10, Albion township, a well is seventy feet deep, ending in gravel. In the east half of section 28, Beaver township, a well twenty-six feet above the creek plain is fifty-five feet deep, no rock appearing. In section 23, a drilled well is 141 feet deep and ends in coarse gravel beneath Kansan blue clay. Water is soft and plentiful.

Near the center of section 27 a well is 101 feet deep, ending in rock, depth in rock not learned.

In the northwest quarter of same section a drilled well on top of a hill seventy feet above the creek valley is 190 feet deep, ending in gravel beneath blue clay.

In the northwest quarter of section 22, a drilled well is 180 feet deep, ending in gravel under Kansan clay.

In section 15 a drilled well is 122 feet deep, ten feet being in limestone. This well is on the northern border of the hills.

District Number 6: This includes the alluvial plain of the Beaver, more narrow than the other alluvial plains, but in other respects quite similar. It does not extend into the last few miles of the course of the Beaver where it has cut its channel through the Kinderhook formation. The wells are of the driven type, usually, and rarely exceed twenty feet in depth, the average being from ten to sixteen feet only. The public well at New Hartford is a driven well and derives its supply from the Buchanan gravel of this area. Austinville, Aplington and a portion of Parkersburg are in this area and derive their water supply from the valley train material.

A mere border of the upland south of the Beaver is in this county. A few wells are given. Two miles east of Parkersburg a drilled well eighty feet above the creek valley is 180 feet deep, twenty feet in limestone. In the southeast part of Parkersburg a drilled well gives the following section:

	FEET.
Drift	142
Limestone, water-bearing but not sufficiently so	28
"Soapstone," described as a greasy, compact clay	87
Limestone, firm	5

Water plentiful but hard.

There is no outcrop in this vicinity. The nearest rock exposure is a limestone of the Owen beds, three miles northeast. The limestone above the "soapstone" is evidently of these beds, while the soapstone belongs to the Hackberry beds. The water bearing limestone in which the well ends is the Cedar Valley limestone. In the southeast part of Parkersburg at an elevation of thirty or forty feet above the railroad station a well is 142 feet deep, ending in gravel just above the rock.

Most of the wells in south Parkersburg are driven and end in the gravels of the drift, probably of the upland phase of the Buchanan gravels, though this could not be ascertained with certainty.

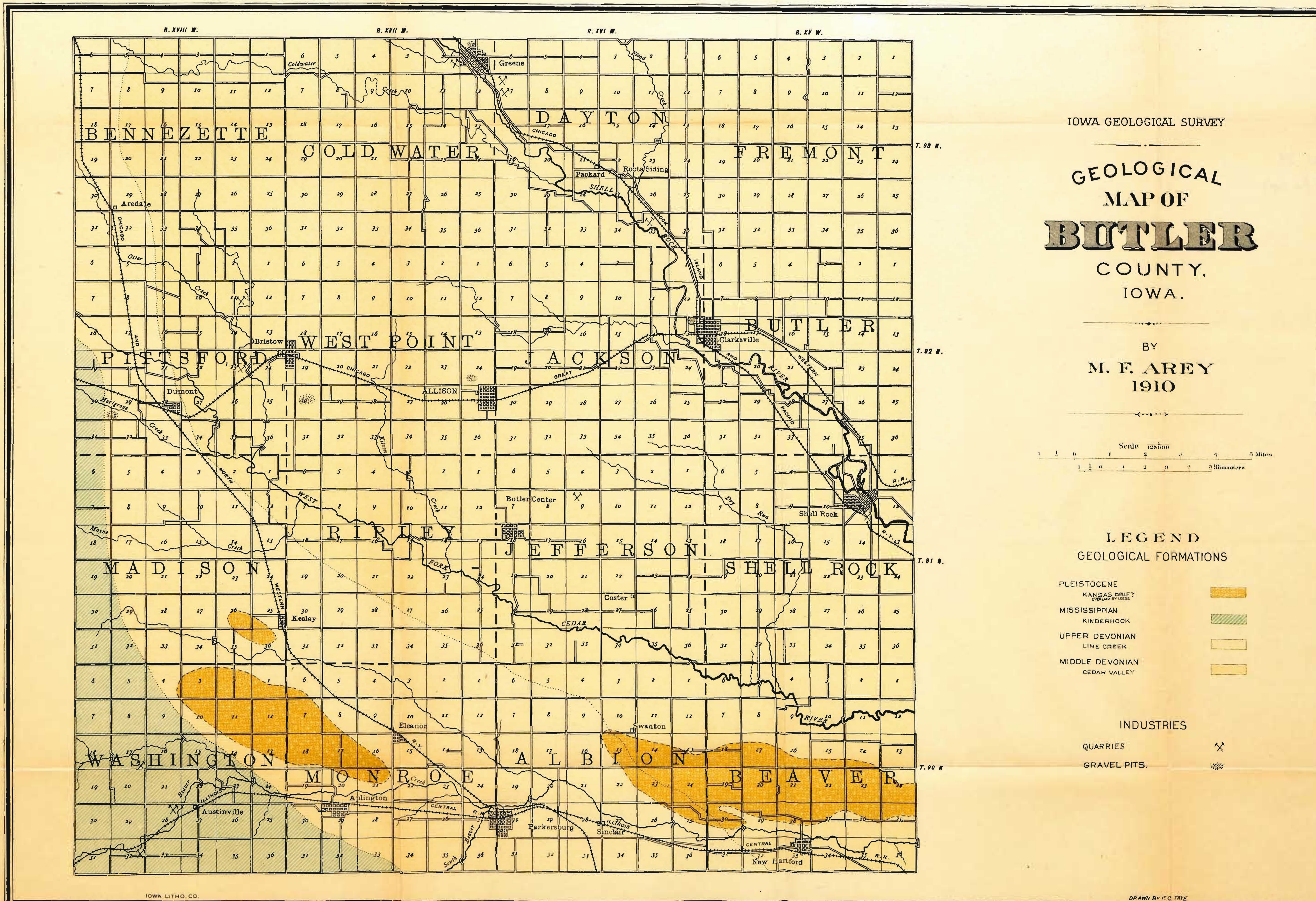
Three miles west of Parkersburg a drilled well is sixty-five feet deep, the last five feet being in rock, undoubtedly of the Owen beds.

In the east half of section 32, Washington township, a drilled well is thirty feet deep, fourteen feet being in rock. This is in the Kinderhook area and the surface is at least forty feet above the creek level. The character of the rock could not be ascertained.

SPRINGS.

Small springs are not uncommon in some portions of the county. Many of these have their source in the drift and issue from some slope where the interglacial gravels chance to be exposed. They can rarely be relied upon for a perennial supply of water in considerable quantity. A few springs issue from limestone or sandstone where stream erosion has sectioned the beds. A spring of this kind is in the southeast quarter of section 11, Pittsford township, near Jackson's quarry. Another is near the center of section 31, Washington township. Yet another is in the southwest quarter of section 28, same township. The rock here is a calciferous sandstone, as, undoubtedly, is that of the one previously named, since the horizon is the same, though the rock could not be seen.

Springs of the type first mentioned are in the southwest quarter of section 29, Fremont township, in the northeast quarter of section 11, and the southwest quarter of section 15, West


IOWA GEOLOGICAL SURVEY
GEOLOGICAL MAP OF BUTLER COUNTY, IOWA.
BY M. F. AREY 1910
Scale
5 Miles.
5 Kilometers
LEGEND
GEOLOGICAL FORMATIONS
PLEISTOCENE
KANSAS DRIFT OVERLAIN BY LOESS
MISSISSIPPIAN
KINDERHOOK
UPPER DEVONIAN
LIME CREEK
MIDDLE DEVONIAN
CEDAR VALLEY
INDUSTRIES
QUARRIES
GRAVEL PITS.
R. XVIII W.
R. XVII W.
R. XVI W.
R. XV W.
T. 93 N.
T. 92 N.
T. 91 N.
T. 90 N
BENNEZETTE
COLD WATER
DAYTON
FREMONT
PITTSFORD
WEST POINT
JACKSON
BUTLER
MADISON
RIPLEY
JEFFERSON
SHELL ROCK
WASHINGTON
MONROE
ALBION
BEAVER
Coldwater
Greene
Packard
Roots Siding
Aredale
Bristow
Clarksville
Dumont
Allison
Butler Center
Shell Rock
Kesley
Coster
Eleanor
Swanton
Aplington
Austinville
Parkersburg
Sinclair
New Hartford
SHELL ROCK RIVER
CEDAR RIVER
CHICAGO ROCK ISLAND AND PACIFIC R.R.
CHICAGO GREAT WESTERN
ILLINOIS CENTRAL R.R.
Otter Creek
Hartgrove Creek
Mayne Creek
West Fork
Dry Run
Beaver Creek
South Beaver
IOWA LITHO. CO.
DRAWN BY F. C. TATE

Point township. Several are reported in Shell Rock township that afford sufficient supply for the stock in the pasture. Professor Norton reports a hillside spring on the place of Annias Best, near Clarksville, that has been piped to the buildings and that gives a good supply of excellent water.

ARTESIAN PROSPECTS.

Artesian water from water-bearing beds anywhere above the Saint Peter sandstone is not likely to be found. Water from the Cedar Valley limestone rises at varying heights above the water-bearing beds, but, so far as could be ascertained, in no case does it reach the surface. Experience with wells at Waterloo, Waverly, Sumner, Ackley and elsewhere gives assurance that, should the occasion arise, water can be secured from the Jordan sandstone, if not from the Saint Peter, sufficient to meet all demands that are likely to be made. The necessary depth would vary, but from 1300 to 1800 feet ought to suffice in any part of the county.

ACKNOWLEDGMENTS

The writer is under obligations to many who have kindly given information and otherwise rendered assistance in the prosecution of the work. Dr. T. A. Dumont of Dumont has been especially helpful. Harry L. Eells, principal of the Schaller schools, was a valuable volunteer assistant in the summer of 1906. Professor Samuel Calvin, the State Geologist, has freely given his counsel and has identified all fossils referred to him. To all our sincere thanks are given.

GEOLOGY OF GRUNDY COUNTY

BY

MELVIN F. AREY

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CONTENTS

GEOLOGY OF GRUNDY COUNTY

INTRODUCTION

LOCATION AND AREA.

The name of this county was given in honor of Felix Grundy of Tennessee. Its territory was once a part of Benton and Buchanan counties successively. It contains approximately 504 square miles in fourteen townships. The counties immediately west of Grundy lie one township's width farther south than do the counties east of it and while Grundy's north line conforms wholly with that of the counties west, the eastern half of its south line is the same as that of the counties east, the other half conforms to that of the counties west, by which fact it suffers the lack of two townships that now constitute a part of Tama county. The civil townships correspond in boundaries with the congressional townships in every instance. Four counties intervene between it and the Mississippi river while Butler, Floyd and Mitchell are between it and the Minnesota line. Butler lies immediately north of it, Black Hawk and Tama adjacent to its east line, Tama and Marshall bound it upon the south and Hardin upon the west. It contains no large city, but it has several enterprising centers of trade activity along the railroads that cut its territory. Its reputation as an agricultural region is unsurpassed.

PREVIOUS GEOLOGICAL WORK.

Grundy county offers little inducement to the paleontologist or to the student of the indurated rocks. It is not surprising, therefore, that the record of geological observation is a brief one. Hall makes the first allusion.* He says the Burlington limestone "has been traced through the westerly part of Iowa, Tama and Grundy counties." The Paleozoic rock formations were well represented in New York and Pennsylvania where

*Hall: Geol. of Iowa, Vol. I, Part I, p. 93, 1858.

they were thoroughly studied by the earlier geologists and a careful system of stratigraphical notation was adopted which naturally became a standard for subsequent workers in other states. Conditions in Iowa and the Mississippi valley generally were so different from those in the east that the problem of correlation of the Iowa formations with this standard was a very difficult one, and a wide divergence of views arose as investigation proceeded, but out of it all there has been reached at last a satisfactory agreement in all major particulars, the result of which as far as Iowa is concerned may be seen in the Paleozoic portion of the geological section of Iowa as made by Professor Calvin and published in the Journal of Geology.*

At the time the above quoted statement was written the term Kinderhook was not in use, but the deposits now known under that name, along with some others now unhesitatingly referred by Calvin to the Devonian, were grouped as Chemung, as is evidenced by Hall's section at Burlington. The term Burlington no longer has geological significance except historically, but the limestone to which that name was applied and certain related strata have been grouped together under the designation Osage limestone. The extent of the Osage in Iowa does not warrant the inclusion within its range of Tama and Grundy counties, or indeed of Iowa county beyond a small portion of its southeastern corner. The Kinderhook of today occupies by far the larger part of the territory of Iowa attributed to the Mississippian series, and to it belong the very limited outcroppings of rock in Grundy county.

This county lies just within the western border of the area included by McGee in his Pleistocene History of Northeastern Iowa, but with a single minor exception, only general allusions are made to it in discussing the subjects, topography, streams and drift. The exposure of Kinderhook limestone at Conrad is mentioned by him as it has been at different times by Keyes,† Beyer‡ and others.

*Calvin: Jour. of Geol., Vol. IV, p. 572. See also Jour. of Geol., Vol. XIV, 1906, and Iowa Geological Survey, Vol. XVII, pp. 193-200.

†Keyes: Geological formations of Iowa, Iowa Geol. Surv., Vol. I, p. 58.

‡Beyer: Geol. Surv. of Iowa, Vol. X, p. 270, and Vol. XVII, p. 379.

PHYSIOGRAPHY

Topography

The surface of the county is that of an extended, elevated drift plain gently sloping northeast, southeast and south, but more abruptly to the southwest, the culminating point being near section 28, Shiloh township. The original drift surfaces have been very little modified, since the drainage is effected by small headwater streams of low gradient and consequently of slight erosive power. Considerable areas in the southwestern part of the county have been covered with loess, but, as usual, it has conformed to the eroded surface upon which it was deposited, and so has produced no other effect than slightly to increase the elevation.

The topography of the north tier of townships is unmistakably that of the Iowan drift, while in Felix, Clay, Washington and the greater part of Melrose and Palermo townships it is as unmistakably Kansan in all essential particulars. The intermediate territory is a neutral zone, or better perhaps, it partakes of the nature of both. The salient features of these two drift deposits become toned down as the distance from each distinct area increases. They blend in places and in other places the one gives way to the other somewhat. Upon the whole it may be said that the eastern half of this zone exhibits more of the Iowan characteristics, while the Kansan predominates in the western half.

In Felix and Clay townships especially the interstream areas are very flat, though in the western border, the short tributaries of the Iowa river in making their descent from the divide with high gradients have cut deep V-shaped valleys, giving more of the rugged Kansan aspect to the landscape, though there is little of the dendritic type developed in the streams.

If we except the slight exposures at and near Conrad and Beaman, there are no limestone escarpments along the streams, nor are there any other outcroppings of rock to introduce a little variety into the universally prevailing drift topography. There is no reason to believe that the underlying rock anywhere contributes to the topographic features of the county, the wells invariably reaching rock below the level of the bases of the elevations into which they have been sunk. Glacial deposits alone account for whatever variation of level may be found anywhere in the county. In the northern half a very few superposed modified drift forms are to be noted. In sections 2, 11, 12 and 13, German township, and 7 and 8, Pleasant Valley township, a ridge of notable prominence runs through a gently undulating Iowan plain, rising in section 13 to a maximum of fifty or sixty feet above the general level. Its crest consists of a series of elongated, ellipsoidal hills with a trend of twenty to thirty degrees north of west and running not in line, but *en*

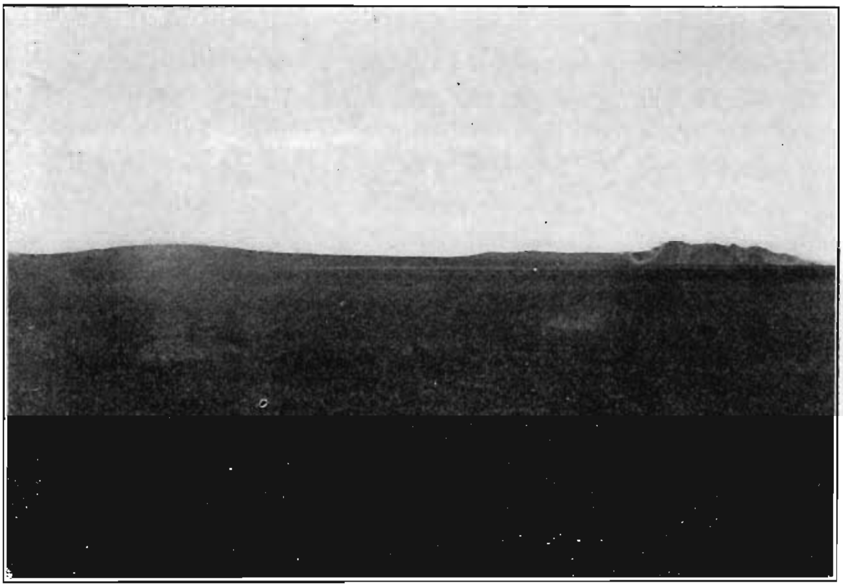


Figure 6. East end of the pahoid hills in sections 7 and 8, Pleasant Valley township. Seen from the road at west side of section 7, near the southwest corner.

echelon. A cut ten feet or more in depth in the road on the east line of section 11 exposes to that depth a fine gray loess slightly tinged with yellow.

These hills are in all essential particulars very much like a more extensive group of paha three or four miles north in Butler county. So far as the writer knows they are the most southwestern representatives of a type of glacial deposits not uncommon in the south half of the Iowan drift area. Free from bowlders, usually well tilled, and having soft, smooth contour lines, they supply a most pleasing variation in the somewhat monotonous landscape of the ordinary Iowan drift plain.

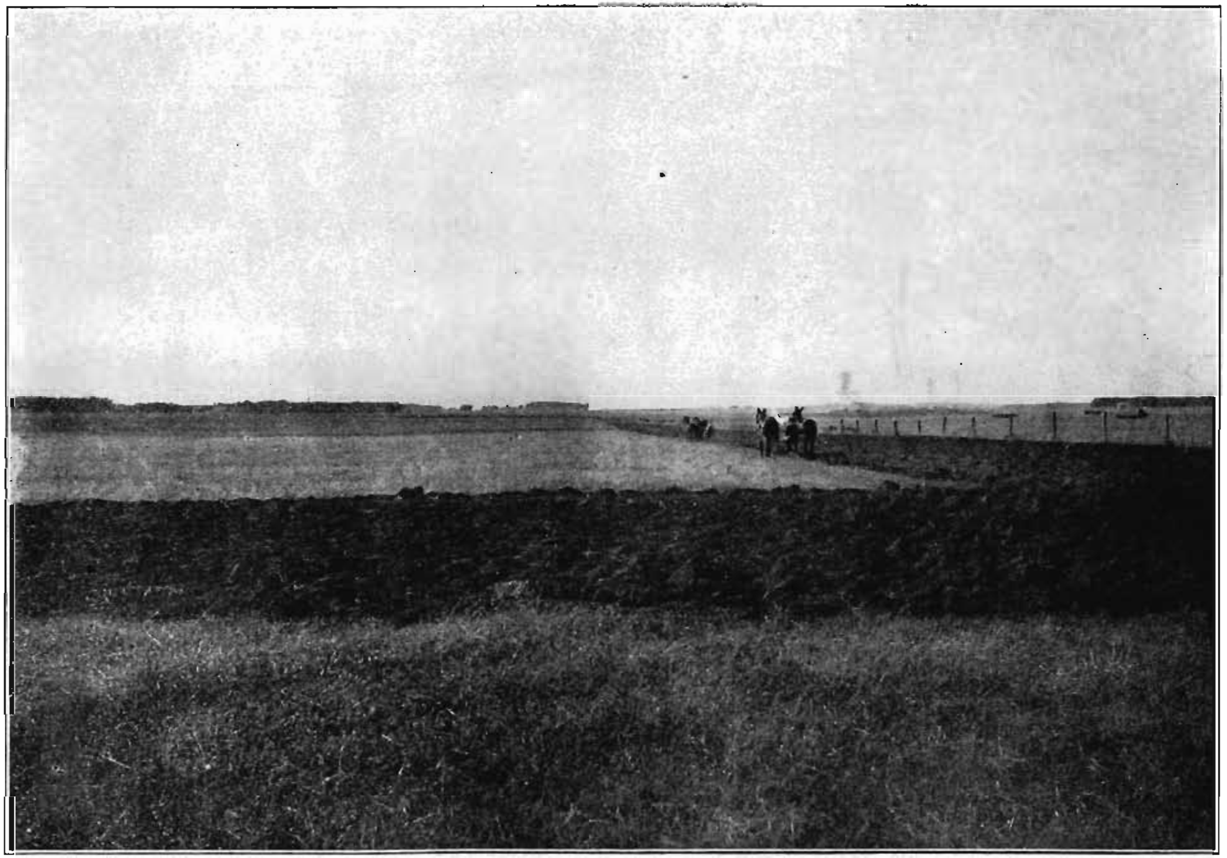


Plate IX. Flat-Kansan topography, Clay township, north of Beaman.

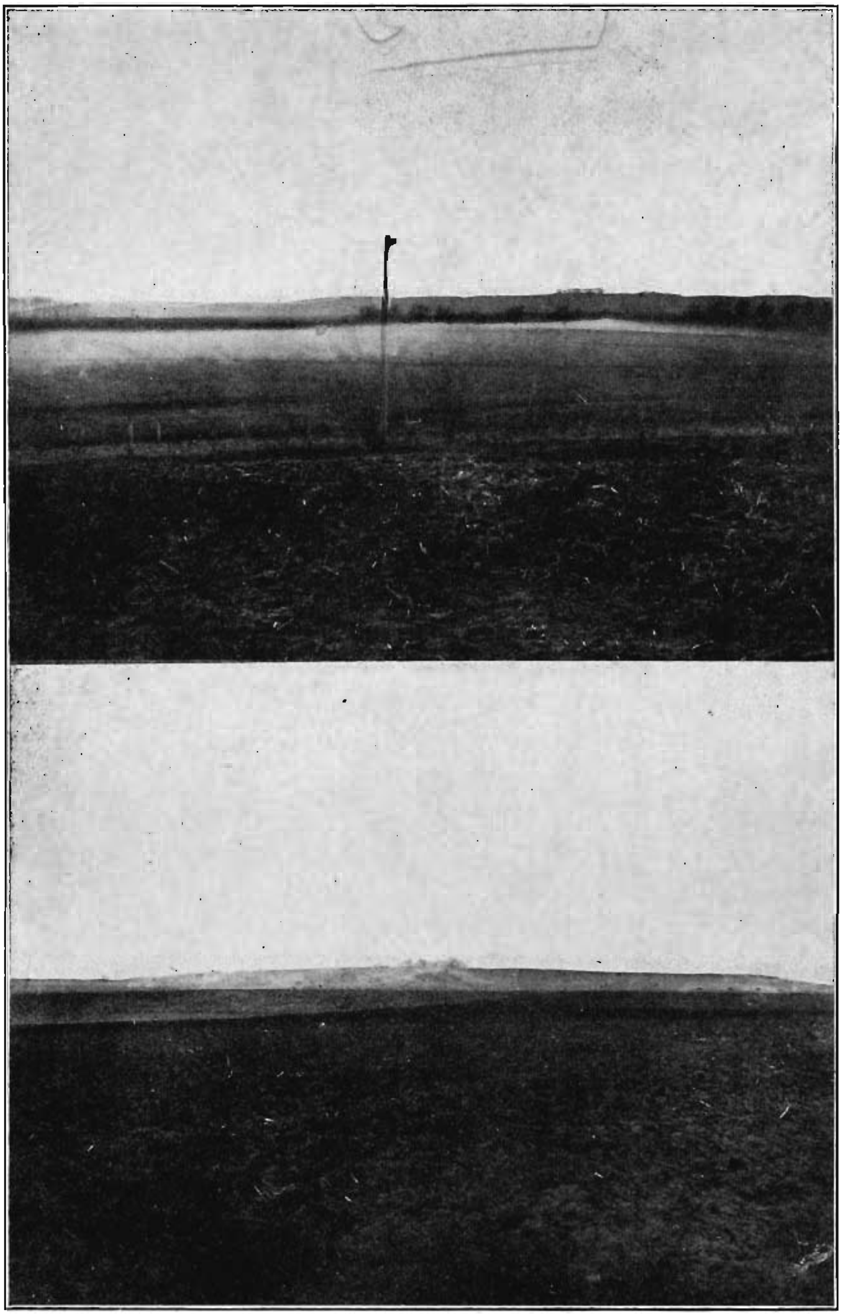


Plate X. Upper view—Pahoid hills in section 7, Pleasant Valley township. Seen from a point one mile to the north.

Lower view—The western paha, section 12, German township. View taken from road on south line section 12, near southeast corner of section.

The branches of Beaver creek in Pleasant Valley township approach each other in such a manner that their somewhat extensive valleys coalesce for unusual distances. The resultant broad valley is continued for a considerable distance beyond the points of juncture, so that a large part of the township consists of a rich alluvial valley of great beauty, readily suggesting the very appropriate name which it bears. The gathering of the water of the principal tributaries of Black Hawk creek in Black Hawk township has produced similar results there. Like conditions obtain along the North Black Hawk in the neighborhood of Dike.

Thus briefly, unless we descend to the most unimportant particulars, is told all that distinguishes topographically the area of an entire county, bringing it into sharpest contrast with the much dissected surface of the counties of the driftless area on the one hand and on the other with those where both glacial and erosive activities have combined to give striking and varied effects without stint. Foremost, perhaps, in agricultural importance, it stands unique, undoubtedly, among all the counties of eastern Iowa in the paucity of its geological details.

Comparatively few altitudes within the county have been computed, or at least are accessible. The following have been taken from Gannett's Dictionary of Altitudes:

TABLE OF ALTITUDES.

STATION.	FEET.	AUTHORITY.
Beaman	984	C. & N.-W. R. R.
Cleves	1070	C., R. I. & P. R. R.
Conrad	1010	C. & N.-W. R. R.
Grundy Center	976	C., R. I. & P. R. R.
Hicks	906	C. G. W. R. R.
Holland	995	C., R. I. & P. R. R.
Morrison	947	C., R. I. & P. R. R.
Reinbeck	929	C. G. W. R. R.
Wellsburg	1058	C., R. I. & P. R. R.
Whitten	1041	C. & N.-W. R. R.

The greatest altitude in the county is on the divide two or three miles southwest of Wellsburg. It is not likely to exceed 1080 feet. The range of altitude in the county is well within 180 feet.

Drainage

Save about forty square miles comprising the westernmost sections of Felix, Melrose and Shiloh townships, Grundy county lies in the Cedar river basin. The portion excepted above is drained chiefly by Pine, Bear and Dowd creeks, streams that after a short course to the southwest empty into the Iowa river.

The divide between the Iowa and the Cedar rivers nowhere runs more than four miles from the west line of the county. Wolf creek and its tributary, Little Wolf creek, drain about seventy square miles, including all of Clay and parts of Felix, Melrose and Palermo townships. All of German and Pleasant Valley townships, the north and east three-fourths of Shiloh and Fairfield, and the north fourth of Beaver townships are within the jurisdiction of Beaver creek. The run-off waters of all the rest of the county are taken care of by the Black Hawk and its tributaries.

With the exception of the South Beaver all the streams of the county have their sources within its borders. They are therefore all small and belong for the most part to the usual prairie stream type.

Most of the tributaries of the Iowa in Grundy county are very short headwater streams and have made no unusual impress upon the topography, but Dowd creek, by far the largest, which rises near the center of Melrose township and runs near to and parallel with the divide for five or six miles with a comparatively low gradient, having thus accomplished three-fourths of its course without distinguishing itself from the neighboring streams, suddenly turns towards the west and rapidly descends to the level of the Iowa through the deepest and most impressive valley of the county and yet one which in many regions of the Kansan area would appear very tame and insignificant.

Wolf creek, which without apparent good reason, bears the name of Big creek in the last ten miles of its course, enters the Cedar at La Porte City, Black Hawk county. It takes its rise in Melrose township two or three miles east of the sources of Dowd creek, nearly parallels the course of the latter for five or six miles and then, turning to the southeast, leaves the county near the southeast corner of Clay township. In the lower half of its passage it has a narrow valley with moderately low banks.

Formerly, perhaps, this valley was well wooded, but today only scanty traces of timber remain near Conrad and Beaman. Two small branches join it, the one some two miles west of Conrad, the other at Beaman.

The South Branch of the Beaver joins the main stream well within the borders of Butler county at Parkersburg. It has three principal sources; one in the southwest of Etna township, Hardin county, develops what is called the South Fork, another near Ackley, begins the Middle Fork, and the other in the north of German township, gives rise to the North Fork. These streams converge as they go eastward and unite their waters in section 28, Pleasant Valley township, beyond which the South Branch takes a northeasterly course to the Beaver, very directly as to its general course, but with numerous small sinuosities which indeed are quite characteristic. Farther east the northern border of the county is drained by small tributaries of the Beaver.

Fully one-half of the area of the county, including the central and eastern portion, is in the basin of Black Hawk creek, which enters the Cedar within the western limits of Waterloo. Its course in Black Hawk county is through a comparatively narrow valley, but in Grundy county it has a more decidedly dendritic character, though its contributing streams are usually small and without running waters during the dry seasons. The North Branch, however, is an important exception, as its drainage area includes one-third of the entire area of the Black Hawk basin within the county.

STRATIGRAPHY

Geological Formations

It has already been stated that outcrops of indurated rocks are almost wholly wanting in this county. It may be said further, that owing to the meager records of well drillers little reliable information in detail is obtainable concerning the position in the geological column of the rock that immediately underlies the Pleistocene deposits. It may be confidently determined, however, from the nearest outcrops in neighboring counties as well as data secured from well drillers that the Devonian underlies the northeastern part of the county and the Kinderhook stage of the Carboniferous is in all the other parts.

SYNOPTICAL TABLE.

GROUP.	SYSTEM.	SERIES.	STAGE.	FORMATIONS.
Cenozoic	Quaternary	Recent		Alluvium
		Pleistocene	Iowan	Iowan loess Iowan drift
			Kansan	Buchanan gravels Kansan drift
Paleozoic	Carboniferous	Mississippian	Kinderhook	Limestone
	Devonian	Upper Devonian	Lime Creek	Owen shale
		Middle Devonian	Cedar Valley	Limestone

DEVONIAN SYSTEM

Middle Devonian Series

CEDAR VALLEY LIMESTONE.

No exposure of this rock occurs anywhere within five miles at least, of the borders of this county. Neither have any wells been reported that give unmistakable evidence that the rock reached by them belongs to either of the common types of the Cedar Valley limestone. It is undoubtedly true, however, that the drift of the northeast corner of the county, including about ten square miles of Fairfield township and portions of Grant, Lincoln and Black Hawk townships is underlain immediately by the Cedar Valley limestone.

Upper Devonian Series

LIME CREEK SHALES.

Well drillers report finding at varying depths, in portions of Beaver, Fairfield and Grant townships a relatively soft, greasy, homogeneous, blue clay, commonly known as "soapstone," beneath a shaly or somewhat fragile limestone and above a somewhat firmer textured limestone, in which water is found. The upper beds of limestone are recognized as the Owen limestone, outcrops of which occur a few miles northwest in Butler county. The blue clay answers to the description, both in character and position, of the Hackberry beds as given by Calvin* in his report on Cerro Gordo county. Accurate details of none of these wells were obtainable, but reports of all the wells in the territory named above agree as to the occurrence of rock material of the nature and order of succession given above. There can be no doubt then that the Lime Creek shales have a southeastward extension into Grundy county, at least to the neighborhood of Dike. Approximately correct well sections of this region are given later in this report.

CARBONIFEROUS SYSTEM

Mississippian Series

KINDERHOOK STAGE

While there is little superficial demonstration of the fact within the limits of the county, there is no doubt that by far the greater portion of the county is underlain with rock of the Kinderhook series. As has been stated elsewhere already the only actual rock exposures are on Wolf creek near Beaman and Conrad. At the latter place an abandoned quarry gives the only opportunity for an examination of rock in place where a section can be secured. Owing to the downwash of the soil and the mingling of the residual layer with the other layers below, as well as the accumulation of a considerable talus, much difficulty was experienced in securing anything like a satisfactory section. The following is a composite section secured from different points and may not be altogether exact.

		FEET.
3.	Loam and loess	5
2.	A greenish residual clay well filled with loose, cherty fragments and iron nodules	8
1.	A yellowish gray, somewhat granular, but fine grained limestone, apparently made up largely of fragments of crinoid stems. Some layers near the upper part were crinoid fragments so loosely cemented and so little changed as to form a breccia after the manner of the Florida coquina	7

*Iowa Geol. Surv., Vol. VII, p. 161, *et seq.* 1896.

A section made by Professor Beyer eight or ten years before the above was taken is here quoted.*

		FEET.
5.	Drift (modified Kansan probably)	5
4.	Limestone, residual, consists chiefly of cherty concretions imbedded in a matrix of greenish clay streaked and mottled with ferruginous and marly material	3
3.	Limestone, slightly oolitic, composed essentially of a shelly breccia almost identical with No. 1 in the Eagle City section	4
2.	Limestone, hard, subcrystalline, containing numerous brachiopod casts	2
1.	Limestone, typical oolite in heavy beds, a Straparollus and a turreted form of gastropod were noted; also numerous brachiopod casts	5

The base of the section is about four feet below the Chicago and Northwestern railway track and 1,010 feet above tide.

Doubtless numbers 2 and 3 of the present writer's section were taken from the same portion of the quarry as were numbers 4 and 5 of Beyer's section, but as the rock below had been buried in talus at this point since the earlier section had been made, we were compelled to seek it at a point several rods away where it came out near the surface of the hillside, and where it had suffered weathering to some extent. This will account in part at least for the variations in the rock noted by the two observers.

It may be noted that the general character of the rock in number 1 of the writer's section readily suggests that found in Brower's quarry in section 17, Washington township, Butler county.† Outcrops of the Kinderhook in sections 28, 31 and 32, Washington township, Butler county, in some places within a half mile of Grundy county border, contribute very materially to the conclusion that the Kinderhook underlies the drift of the northeastern portion of Grundy. Well sections, while not very reliable, since the data were from memory of the well driller, indicate the same underlying rock horizon in interior portions of the county.

*Beyer: Iowa Geol. Surv., Vol. X, pp. 270-271.

†See the writer's section of this quarry in his report in Butler county, present volume, page 37.

In 1909 Ford Brothers, contractors and prospectors of Marshalltown, sunk a deep well at Wellsburg which contributes somewhat to the data bearing upon the question of the eastward limit of the Hardin county lobe of the Des Moines stage; though by no means doing away with the difficulties connected with a satisfactory solution of the problem. The following is a section as supplied by Mr. E. A. Ford.

Surface elevation, 1,054 feet.

		THICKNESS.	DEPTH.
7.	Yellow clay with sand and gravel	80	80
6.	Blue clay	84	164
5.	Limestone, soft, porous, yellow, ferruginous	24	188
4.	Blue shale with thin strata of limestone and sandstone in upper part, and gray shale below interspersed as in upper part	222	410
3.	Bluish limestone	10	420
2.	Shale, highly fossiliferous	20	440
1.	Limestone, alternating strata, buff, white, blue and dark brown	117	557

Numbers 1, 2 and 3 are unquestionably Devonian, 2 and 3 being Lime Creek shales. As to the other numbers, comparison with the Ackley well, which is about ten miles to the northwest, is interesting. The elevation of the Ackley well is 1,115 feet. The drift is 100 feet thick followed by fifty feet of fine blue shale which in turn is succeeded by five feet of coarse buff sandstone. It is possible that close discrimination would determine the lower part of the blue clay attributed to the drift in the Wellsburg section, to be a blue shale corresponding to numbers 85 and 86 in the Ackley section. This would also account in part for the apparently unusual thickness of the drift at Wellsburg. Numbers 4 and 5 correspond very well in depth, thickness and general character to numbers 75 to 84, inclusive, of the Ackley well, though Mr. Ford did not give the details in his section. Norton* refers these numbers to the Carboniferous as an outlier and finds no Kinderhook represented. Beyer† in his report on Hardin county, from observations upon the elevation of the top of the Kinderhook and from outcrops of rocks of that stage in Hardin and adjacent counties and from outcrops of the Des Moines in that neighborhood, concludes that the

*Iowa Geol. Surv., Vol. III, pp. 191-192.
†Iowa Geol. Surv., Vol. X, pp. 262-263.

strata under consideration belong to the Kinderhook. It may be added that about nine miles north of Wellsburg and within three miles of Ackley along a tributary of the South Fork of the Beaver in Butler county there are escarpments of Kinderhook rock at an elevation from 1,000 to 1,050 feet. It may be said that the nature of these strata is more suggestive of the Des Moines than of the Kinderhook and their total thickness is very unusual for the Kinderhook, yet in other particulars they would be regarded as Kinderhook.

The summary of formations for the well may then be given as follows:

Pleistocene	164
Kinderhook	246
Devonian—	
Lime Creek	30
Middle	117

Pennsylvanian Series

DES MOINES STAGE.

From the presence of the Des Moines in Hardin county along the Iowa river in the neighborhood of Eldora and Steamboat Rock and eastward on Pine creek within two miles of the Grundy county line, it may be inferred that material of this series runs over into Grundy somewhat, though no certain proof of this is at hand. The writer has, therefore, followed the last state geological map in indicating the presence of the Des Moines in small portions of Shiloh and Melrose townships.

THE MANTLE ROCK

Residual Material

GEEST.

Naturally little material that is the result of local rock decay, or wastage, will be found in a region where the indurated rock is so completely covered with later deposits as is the case in Grundy county, but in the single locality where rock exposure does occur, there is to be found an unusual thickness of geest, or rock residuum. At the Conrad quarry it has a thickness of eight feet in places. It consists of a greenish clay marbled with numerous ferruginous streaks and blotches in which as a matrix lie small blocks of chert and iron nodules. The chert was a part of the original rock, doubtless forming a band in the limestone, as is the case in much of the Kinderhook limestone of this horizon, while the iron nodules have concreted since the disintegration of the limestone.

A hundred rods, perhaps, east of Beaman a bank along the north side of the track of the Chicago and Northwestern Railroad gives a shallow section as follows:

		FEET.
3.	Loess	3-4
2.	Mingled sand, gravel and pebbles	1-2
1.	Residual material, a gray, or green marl or clay in which are fragments of a red brown sandstone and of a rock similar in color to the matrix	4-5

Owing to the slight inclination of the bank and the mingling of its components by wash, it was difficult satisfactorily to determine the thickness of each kind given above. The residuum was more of a marly character than was that at Conrad. It would seem that the upper portion of the original rock was a brown sandstone of no great degree of coherency, while the lower rock was a limestone, but distinct layers could not be made out, though the sandstone fragments appeared as a rule to be uppermost.

The material described above was largely, if not wholly, of preglacial origin. To be sure rock decay has always been going on wherever the weathering agents have had opportunity to operate, but the products have not been left in place to form a distinctive part of the rock mantle to any great extent, unless conditions were favorable. The preglacial products, for the most part, were borne away and intermingled with other forms of glacial debris to form that remarkable composite of incoherent earthy matter called till. Accumulations of geest of more recent origin are sometimes to be found where the moving ice sheet shattered the underlying rock and at last left it but thinly mantled with drift, so that weathering agents have had ready access to it ever since. Circulating waters have decomposed the walls of joints in the weaker rocks, leaving the insoluble portion to partially fill the spaces thus made. Oftentimes it is difficult to determine whether such accumulations were formed in the one or the other epoch, or perchance, in more than one.

The drift deposits also have suffered various forms of modification since they were laid down. Especially is this true of the superficial part of the Kansan, but such leached and otherwise modified drift is never classed with the other forms of residual earths commonly known as geest.

QUATERNARY SYSTEM

Pleistocene Series

KANSAN STAGE

Kansan Drift: No certain evidence of any glacial material older than the Kansan has been recognized in this county. The Kansan, however, is probably everywhere present, either as the superficial drift deposit or overlain with loess, Iowan till or alluvium. A satisfactory superficial line of demarkation between the two great drift sheets cannot be drawn, as their distinctive features insensibly fade away as they approach the border, or are more or less intermingled over a somewhat broad neutral zone. It seems not improbable that the Iowan ice sheet was extremely thin in this county along its southern border. Only a few of the smaller bowlders were carried along with it. Detached ice floes bore some of these down the swollen streams and left them well within the Kansan area. Low ridges of Iowan till were formed in places. Elsewhere the Kansan was ploughed up and mingled with the meager load of the Iowan. Portions of this thin ice border soon melted leaving the exposed surface to be veneered with loess in common with the neighboring Kansan.

The boundary as drawn upon the map is given tentatively and merely indicates where on one side the Iowan and on the other the Kansan features predominate. Yet on the north side of this line there are some areas that, taken by themselves, might well be regarded as Kansan, as for instance, ten or twelve sections in the immediate neighborhood of Fern, Beaver township; while on the south side of the line there are patches that in the same way might be regarded as Iowan, in illustration of which the country north and east of Ivester, Melrose township, can be designated. In general the whole drainage basin of the Black Hawk, excepting perhaps, that part lying south of that creek in Black Hawk and Washington townships, may be included in the doubtful zone, while the area drained by the Beaver is unmistakably Iowan. Could careful and reliable data of well sections be secured generally over this doubtful area, all questions as to where this doubtful zone belongs would be settled, but such data have not been accessible.

Buchanan Gravels: While engaged upon the detailed survey of Buchanan county, Professor Calvin gave special consideration to certain gravel deposits that were well distributed throughout the county and which were particularly well displayed in certain pits that had been opened up by the Illinois Central Railroad. While they had been noted in several localities previously, they had escaped investigation as a specific deposit. Calvin now not only gave them a name, the Buchanan gravels, but described them so fully, that little that was really characteristic has been added since, and they have been accorded a permanent place in the geological column of the state. They occur generally over the Iowan drift area, and for some distance south of it, though no mention is made of them in the report upon Clinton county, and little note is made of them in Bremer, Benton, Cedar and Marshall counties. Macbride in his report upon Sac and Ida counties* and elsewhere mentions this formation beneath the Wisconsin and above the Kansan. It is noted by Udden† as of rare occurrence in Muscatine and Louisa counties, which are well without the borders of the Iowan.

The Buchanan gravels are accounted for as the result of outwash from the border of the melting ice as the Kansan glacier retreated northward. At first the swift flowing waters carried much unsorted detritus, but they soon lost their impetuosity and perforce dropped all the coarser part of their load. Later, gathered into well defined channels and proceeding with much dimished velocity, they aggraded their beds with the finer portion of their original burden. Thus are found two quite distinct phases of these gravels: the one, the upland phase, containing good sized pebbles, cobblestones and sometimes even bowlders a foot in diameter, the other, the valley phase, made up of material much more uniform in size, but varying in fineness with distance

*Iowa Geol. Surv., Vol. XVI, pp. 533-534.
†Iowa Geol. Surv., Vol. IX, pp. 339-340, Vol. XI, pp. 105-106.

from the ice border whence it had been taken. These gravels are always oxidized and iron stained. The granitoid constituents are usually in a condition of disintegration. The upland phase exhibits these features in higher degree usually than does the valley phase. Naturally there was much difference in the details attending their deposition and consequently as much variation in the conditions of the different beds, but the general agreement in their distinctive characteristics is quite obvious.

In the north half of the county sands and gravels that may be referred to the Buchanan formation without hesitation are not infrequent. They are of both phases and are usually of a character to make them valuable for use in improving the roads, though no such extensive use has been made of them for the purpose as in the adjacent counties of Butler and Black Hawk. The topography of the county has not favored the exposure of the beds to the same extent, and it is doubtful if the deposits themselves are as extensive in the main. At and around Grundy Center, Holland and Wellsburg, however, they are abundant, though the overlying loess makes access to them somewhat difficult. In the south half of the county sand and gravel are by no means common, especially in the four southwest townships. When found their appearance and relations both indicate that they are different in character and origin from the Buchanan gravels. As an instance, along the railroad an eighth of a mile east of Beaman, beneath three or four feet of loess, there is exposed a slope of four or five feet, the lower part of which is made up of a greenish marly clay in which are fragments of a gray-green rock. In the upper part the proportion of clay lessens, the rock fragments are of a red brown sandstone with which are mingled pebbles and gravel. At the top gravel predominates. This gravel does not seem to have been washed in here, but rather to have been part of the ground moraine pressed into and mingled with residual material. Similar conditions seem to prevail at the Conrad quarry.

IOWAN STAGE

Iowan Drift: The boundaries of the Iowan sheet of till in Grundy county, no less distinct, usually, in topography than in the character of the material of which it is composed, have been considered under the topics, Topography and Kansan Drift. Little remains to be discussed in this place. Every feature of it finds expression in the county, leaving no chance for disputing its existence as one of the formations to be considered. In the north tier of townships firm granitic bowlders are everywhere to be seen and in some places, as in the west part of Pleasant Valley township and in some parts of Fairfield, they are unusual

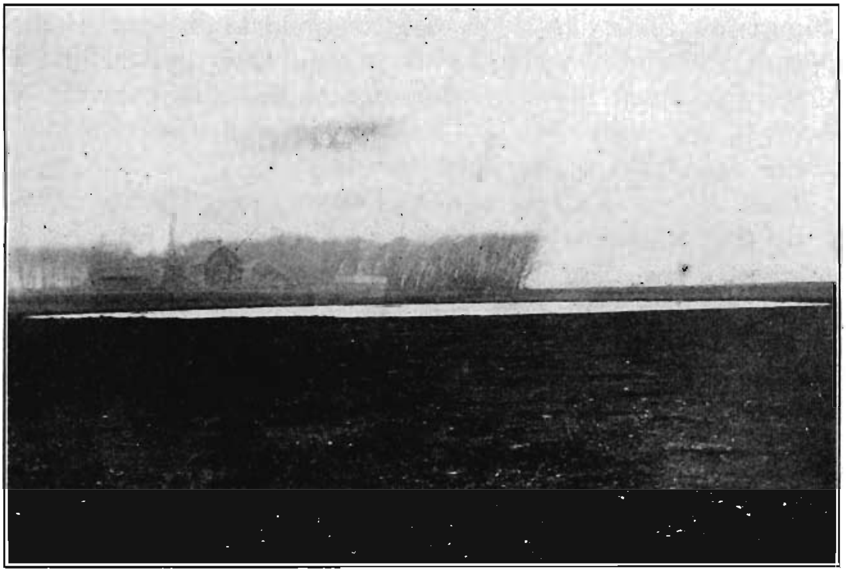


Figure 7. A small pond in the Iowan plain in the southwest quarter of section 5, Pleasant Valley township. Seen from the east.

both in numbers and size. The Iowan in this as in neighboring counties is relatively thin, nowhere exceeding eight or ten feet.

Modified Iowan Drift Forms: Near the middle of section 8, Beaver township, is a neat conical hill, rising higher than any of the surrounding elevations, which in this vicinity are relatively low. Near the middle of section 17 of the same township a cemetery has been located on a somewhat lower and broader hill. A road cuts the south slope of the latter near the base, exposing a rather fine sand somewhat oxidized and containing about five per cent of pebbles and an occasional cobblestone. Among the pebbles a few decayed granites and iron nodules were seen. Eight feet of this material is exposed. There are indications that the whole elevation is made up of sand or gravel. These two hills a mile apart on a north and south line are unique in form and composition in this neighborhood. Superposed on Iowan till they suggest the kame, so common in some places as a feature of the landscape and, doubtless, should be classed with it.

Eight miles farther south in sections 30 and 31, Lincoln township, a low esker-like ridge of gravel and sand, with a northwest and southeast trend, terminates abruptly in a conical hill of sand of about the same elevation as those in Beaver township. A few rods south is a smaller hill, and within two miles two or three still smaller ones may be seen.

From the order of succession of these sandy elevations, it is likely that a subglacial stream loaded to its full capacity had its course here. Emerging from the free edge of the retreating glacier under some pressure and in the face of some hinderances it heaped up these cones one after the other, or, meeting with some obstruction while yet confined within the walls of ice, it aggraded its channel and thus formed the esker.

Bowlders: In the southeast quarter of section 32, Pleasant Valley township, is a pear-shaped, coarse grained, pink granite bowlder thirty-two feet long, twenty-eight feet wide and ten feet high, the extent of which underground is undetermined, but which apparently equals the height above ground. In the northeast quarter of section 13, Fairfield township, another coarse granite bowlder is twenty-seven feet long, twenty feet wide and seven feet above ground. It is quite regular in outline, flat topped, with a ridge running through the middle from north to south. This bowlder, in common with many others, has the reputation locally of being the largest in the state, but it may be noted that the one in Pleasant Valley mentioned above exceeds it in maximum dimensions, though it is not of uniform shape and possibly does not contain as many cubic feet. The western portion of Pleasant Valley township has an unusual number of large bowlders, as do portions of Beaver and Fairfield townships.

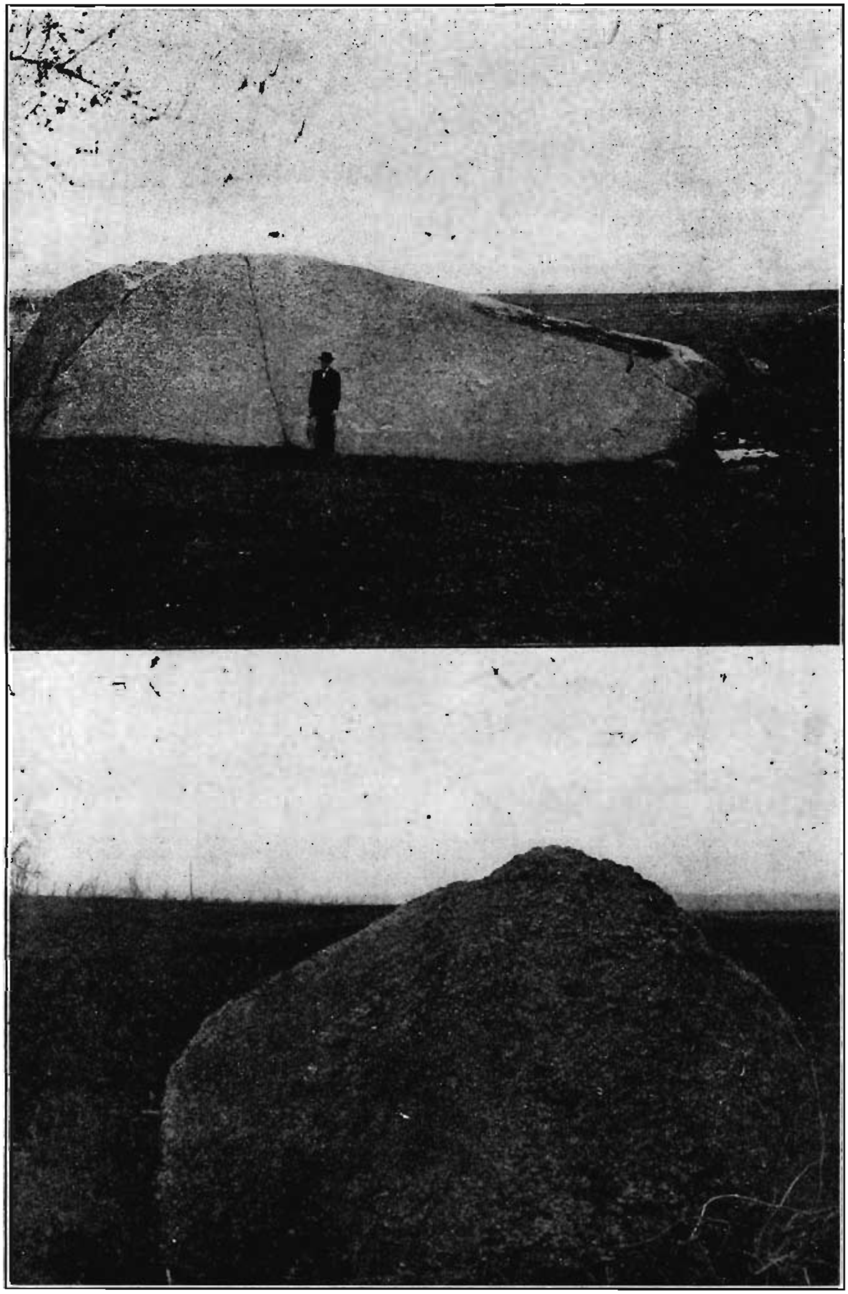


Plate XI. Upper view—Iowan bowlder of granite in section 32, Pleasant Valley township.

Lower view—Decaying granite bowlder in section 16, Pleasant Valley township. This bowlder is similar in composition and texture to that shown above.

Iowan Loess: Loess is the name given to that seemingly homogeneous, pulverulent, yellow to gray, silico-argillaceous earth usually overlying the Kansan till near the Iowan drift border, though rarely it lies upon the Iowan. In Grundy county it is an eolian veneer that is found very generally over the upland plains of the south half of the county, though the northern limit of its occurrence is as far south as Wellsburg in the west

Figure 8. A bowlder-strewn vale in the Iowan drift. Such swales are common in the northern tier of townships.

and nearly as far south as Reinbeck in the east. It also contributes the upper part of the paha in German township, where in a road cut it is exposed to the depth of about ten feet without revealing the nature of the immediate subjacent deposit. In the railroad cut at Wellsburg it has a thickness of six feet over Buchanan gravel. At the Brick and Tile Works at Grundy Center it has a depth of seven feet over Buchanan gravel.

A section taken here gives the following.

		FEET.
4.	Yellowish gray loess	7
3.	Gravel	1
2.	Sand, gray with tinge of yellow, moderately coarse, with scattered pebbles of granite and greenstone. Sand grains are mostly a white or transparent quartz with a small per cent of red jasper and greenstone	12
1.	Blue Kansan till?	

Water hinders excavation to a greater depth, but blue Kansan till is reported at no great distance below. Sand is reported as everywhere underlying the loess in Grundy Center, but it is not as thick elsewhere as given in the above section. The thickness of the loess, as given at the above named points, is believed to be exceptional, the average thickness being much less.

Alluvium

Deposits of alluvium are common in the valleys of nearly all the larger streams and are unusually widely extended near the confluence of the forks of the South Beaver in Pleasant Valley township and also in the region of the confluence of the branches of the Black Hawk in Black Hawk and Grant townships. Wolf creek and its branches have rather narrow alluvial plains or none at all, while the small tributaries of the Iowa river in Grundy are entirely without alluvium as their swift currents would prevent any aggrading whatever.

SOILS

Three types of soil prevail, those based respectively in the loess, Iowan till and alluvium. All are soils of exceptional richness and adaptation to the requirements of the Iowa farmer. Grundy county has always had the reputation of standing among the foremost of Iowa counties in its agricultural resources. Its population is almost exclusively engaged in farming and everywhere within its borders may be seen evidences of thrift and prosperity. There are no steep slopes, only in few localities are bowlders a real detriment, water distribution is equable and yet drainage is such as to rarely admit of the flooding of the cultivated alluvial areas to a harmful extent.

ECONOMIC PRODUCTS

Building Stones

Excepting the Conrad quarry and possibly one or two outcrops in the neighborhood of Beaman, there are no reasonable possibilities of obtaining building stone within the county. The Conrad quarry has been abandoned, since, with further progress, the thickness of the mantle rock increases rapidly, making the cost of the quarry product greater than that of equally good rock that can be shipped in from other localities.

Brick and Tile Making Material

The loess at Grundy Center and at Reinbeck and doubtless at other points is of excellent quality for brick and tile. At Grundy Center a brick and tile company under the management of Mr. F. D. Fronig is turning out a very good red brick the demand for which is in excess of the capacity of the plant. In 1906 the output was 700,000 tile and a half million brick. The company uses the stiff mud process, steam drying, a sixty horsepower engine, the car system and has three round, down draft kilns.

The Gethman Brick and Tile Company began operations at Reinbeck in 1904. The stiff mud process is in use here too. Both pressed face brick and common brick are made. Quality is excellent. The output in 1906 was twenty-five kilns of brick at 80,000 per kiln and thirteen kilns of tile at 25,000 per kiln. The round, down draft kilns are in use.

Sand

The sand uncovered by the removal of the loess at the brick and tile works at Grundy Center is of a character to make it suitable for all the ordinary purposes for which sand is used. Not only is Grundy Center and vicinity thus supplied, but many carloads are shipped annually to towns along the railroads that are less fortunately favored in this particular. The supply is apparently unlimited.

Road Materials

The Buchanan gravels are almost invariably excellent for improving the surfaces of country roads, especially if suitable provision is made for drainage. Any poorly drained road fails just when a good road would be best appreciated. The custom of preparing a well drained roadbed and surfacing it with a good gravel or even a coarse sand has not been well established in this county, though the use of the gravels that are within easy access is beginning to be practiced in a number of localities. If every year the worst stretches of road were carefully improved as suggested above, it would not be long before travel would become very tolerable even in the worst seasons. The agitation for good roads and the spread of information respecting better methods of road making is having its effect very noticeably, and the discredit attaching to the rural roads in Iowa is very likely to be removed in the next ten or fifteen years, especially within the Iowan drift area, where the material for improving the roads is particularly abundant and most suitable.

Water Supplies

Springs: As would be expected in a region where there is little range of elevation within narrow limits, strong springs are not common, though an occasional seepage spring of real value may be found.

Wells: The general distribution of water courses with easy gradients has contributed largely to the necessities of stock in pasture. Where these have been wanting or have failed shallow wells have met the ordinary demands in the earlier settlement of the county. On the uplands dug or drilled wells ending in the drift were depended upon largely in the past. More recently deeper wells ending in or just above the rock, especially in the southwestern townships, have been resorted to. Accurate data of the wells have been difficult to secure. A few, though somewhat meager as to details, are here given.

At Conrad the public well is ninety feet deep, about sixty feet of which is in rock. In this neighborhood all wells are drilled, reaching rock at about twenty or thirty feet and ending in rock from sixty to one hundred feet from the surface. Water is of good quality and unfailing in supply.

Wells in Beaman are reported to be from fifty to ninety feet deep. They just reach rock, or go through the first bed which is not very thick, shaly in character and overlies a clay. The underlying rock is reported to furnish a better supply of water and the later wells are seeking this supply. Most of the variation in the depth of these wells is due to the variation in surface elevation, which is considerable in this immediate vicinity.

In section 7, Clay township, a well is sixty-eight feet deep, in which Kinderhook limestone occurs at thirty feet. This is a region of flat Kansan topography. All wells in the neighborhood are reported quite uniform in depth and in reaching rock. Water is abundant and of good quality. In the southwest portion of Palermo township, where the topography is more varied, there is a corresponding variation in the depth of the wells, indicating that in all this neighborhood the surface of the indurated rock is very nearly level.

The public well at Reinbeck is 356 feet deep, about ninety of which is in rock. Sand is reported to interfere with the profitable use of meters, from which it is inferred that the water comes from a sandy aquifer, though it was not so reported in the data secured.

In section 24, Black Hawk township, drilled wells are in use. They have an average depth of 240 feet, forty of which are in rock. A few wells from eighteen to forty feet deep, ending in the drift, are in use in the low grounds. Drilled wells in the Black Hawk valley, which enter the rock, reach water at a depth just about as much less than those on the uplands as the hills are higher than the creek valley.

A well in the north half of section 10, on high ground, is said to be 370 feet deep. Depth in rock could not be ascertained. A well three miles northeast of Morrison is 270 feet deep, reaching rock.

A well near the center of section 5, Palermo township, is 110 feet deep, six or eight of which are in rock. Another in the east half of section 6 is 200 feet deep.

On the Merritt farm in section 2, rock was reached at 200 feet. Seven miles west of Grundy Center rock occurred at 100 feet.

Grundy Center has a public well, but no reliable data could be secured, beyond a statement that its depth was 450 feet.

On the Flater farm, in the northeastern part of Colfax township, the well is 294 feet deep, sixty-nine of which are in rock.

In section 20, Grant township, on Mr. Murphy's farm, the well is 195 feet deep, seven feet of which are in a firm white rock. At eighty feet a bed of sand thirty-five feet thick was found. A well near this struck rock at 200 feet.

Six miles south of Dike a well 180 feet deep ends in the drift.

In section 34, Lincoln township, a well eighteen feet deep furnishes a plentiful supply of good water, while in section 36 a well in the drift is 180 feet deep.

At Dike the public well is 260 feet deep. A section as reported by Mr. Frank Dann, the driller, is as follows:

		FEET.
4.	Sand	60
3.	Blue clay	40
2.	Sand	30
1.	A firm white limestone (Cedar Valley limestone?)	130

On Peter Johnson's farm, northeast quarter of section 12, Beaver township, the well is 274 feet deep as follows:

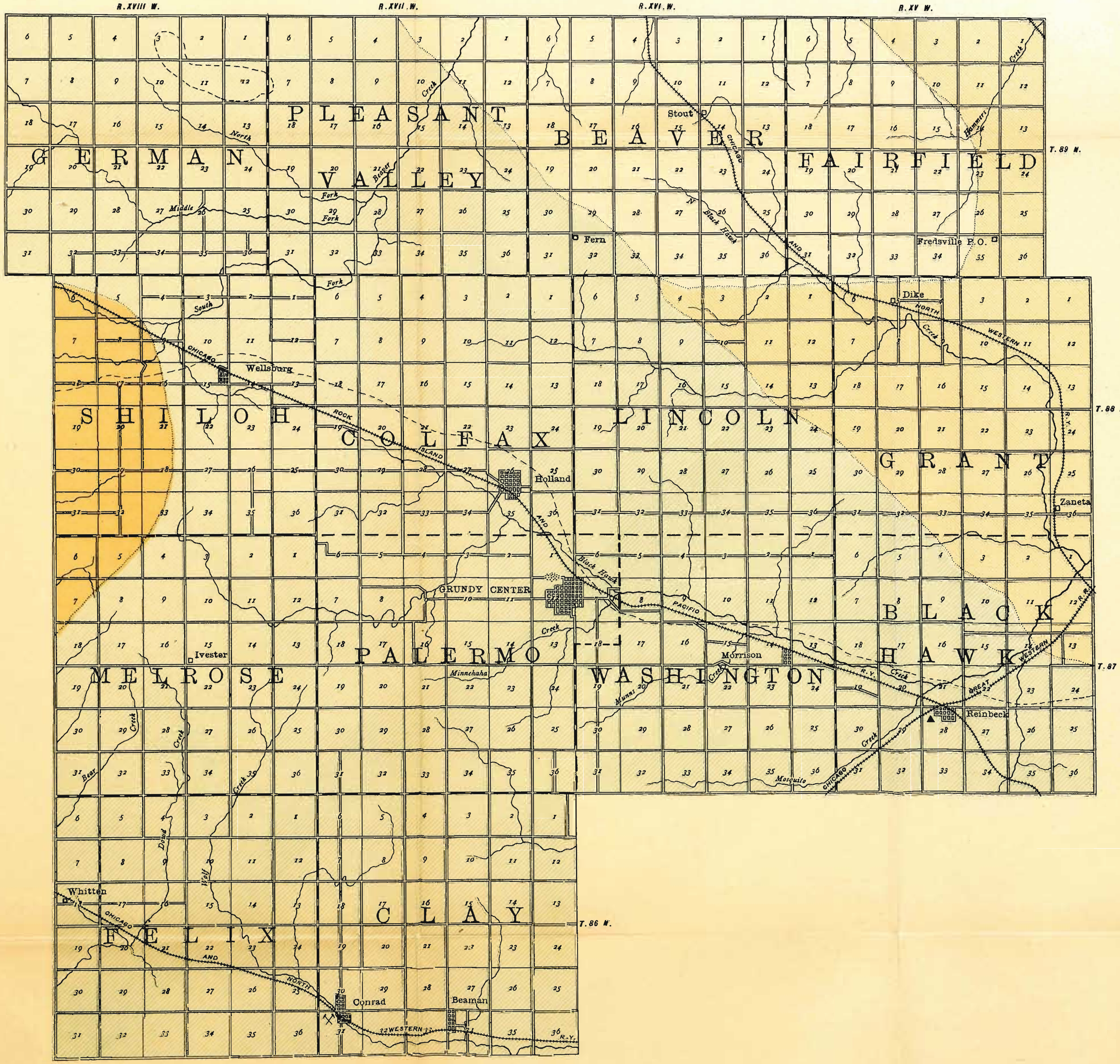
		FEET.
4.	Drift	112
3.	Shelly rock	14
2.	"Soapstone"	110
1.	Firm limestone	38

Making allowances for lack of accurate discrimination on the part of the driller and for possible errors in recalling the figures for the several depths, there is little room for doubt that number 1 is Cedar Valley limestone and numbers 2 and 3 are Lime Creek shales.

On William Wright's farm in the northwest quarter of section 13, Beaver township, the well is 310 feet deep, 200 feet in rock, passing through the "soapstone."

On Robert Fortune's farm in the northeast quarter of section 7, Fairfield township, the well is 231 feet deep, 110 feet in rock. Thirty or forty feet of soapstone were penetrated.

Numerous other wells in Fairfield and Beaver townships are reported as entering or passing through "soapstone." The same reports are made across the border in Butler county, from which it is manifest that the Lime Creek shales extend across Butler into the northeastern part of Grundy county, but no reliable data show their occurrence anywhere in the townships



IOWA GEOLOGICAL SURVEY

GEOLOGICAL MAP OF GRUNDY COUNTY, IOWA.

BY

M. F. AREY

1910.

Scale $\frac{1}{125000}$

5 Miles

5 Kilometers

LEGEND

GEOLOGICAL FORMATIONS

PENNSYLVANIAN
DES MOINES

MISSISSIPPIAN
KINDERHOOK

UPPER DEVONIAN
LIME CREEK

MIDDLE DEVONIAN
CEDAR VALLEY

THE SOUTHERN MARGIN OF THE IOWAN DRIFT IS INDICATED BY THE BROKEN LINE. THE AREA IN GERMAN TOWNSHIP INCLOSED BY THE BROKEN LINE IS LOESS-KANSAN.

INDUSTRIES

QUARRIES

CLAY WORKS

GRAVEL PITS.

IOWA LITHO. CO.

DRAWN BY R.C. TATE

south of Fairfield and Beaver. It is doubtless true that the southernmost boundary of the Lime Creek shales is not far from the south line of these townships.

A well put down by the municipality of Wellsburg, a section of which is given under another chapter, presents the following data:

It is situated upon a side hill 200 feet from the postoffice. It is 557 feet deep. Its diameter for the first 325 feet is ten inches, for the rest of the distance it is eight inches. The principal aquifer is a soft porous limestone underlying the drift at a depth of 164 feet. At 400 feet a less important aquifer was found. Water rises at the maximum of eighty feet from the surface and at a minimum of 230 feet. A Smedley deep well lift pump operated by a gasoline engine brings the water to the surface at the rate of twenty-five gallons per minute. No analysis of the water is at hand, but it is reported to give traces of iron and sulphur. It is used to supply stores and residences, the number of consumers being one hundred.

ACKNOWLEDGMENTS

Grateful recognition of the kindness and unvarying courtesy shown the writer by all from whom information or favors of any kind have been sought in the prosecution of the work is hereby expressed. Thanks are especially due Professor Samuel Calvin, the State Geologist, for his ready helpfulness manifested in many ways.

GEOLOGY OF HAMILTON AND WRIGHT COUNTIES

BY

THOMAS H. MACBRIDE

GEOLOGY OF HAMILTON AND WRIGHT COUNTIES

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CONTENTS

GEOLOGY OF HAMILTON AND WRIGHT COUNTIES

INTRODUCTORY

Two Iowa counties form the subject of the present memoir, Hamilton and Wright. Hamilton lies almost in the center of the state; Wright immediately north of Hamilton. Both are prairie counties, at first glance not unlike a score of other counties of northwestern Iowa, and yet they are not the same; Hamilton should be compared with Webster to the west, and Wright with Franklin to the east if geological affinity or continuity should determine the order of our discussion.

LOCATION AND AREA.

All the bordering territory has been already described, county by county, in these reports; Hancock[1] and Humboldt[2] by the present writer, Webster[3] by Wilder, Boone,[4] Story[5] and Hardin[6] by Beyer, and Franklin[7] by Williams. All these descriptions are made contributory to the present discussion.

Each county has its full quota of congressional townships—sixteen; and civil townships and congressional townships in general coincide. The counties are accordingly each twenty-four miles square.

PREVIOUS GEOLOGICAL WORK.

Previous to the present studies these two counties have received small attention at the hands of our natural history authors. Owen,[8] in his magnificent sketch of the geology and geo-

[1] Iowa Geological Survey, Vol. XIII, pp. 84-110.
[2] Ibid. Vol. IX, pp. 113-154.
[3] Ibid. Vol. XII, pp. 63-191.
[4] Ibid. Vol. V, pp. 175-232.
[5] Ibid. Vol. IX, pp. 155-237.
[6] Ibid. Vol. X, pp. 241-306.
[7] Ibid. Vol. XVI, pp. 453-507.
[8] Report of a Geological Survey of Wisconsin, Iowa and Minnesota; by David Dale Owen, Philadelphia, 1852.

graphy of the upper Mississippi Valley passed the mouth of the Boone river in his ascent of the Des Moines. His report presents a topographic map of the greater stream as far as the mouth of Lizard creek at Ft. Dodge. On this map the terrene north and east of the mouth of the Boone is described as "beautiful prairie." The "beautiful prairie" lies about the old village of Homer in Webster township of Hamilton county. Worthen, under Hall's direction, described the counties of the northeast quarter of Iowa but seems to have stopped just short of our two counties. Dr. White* visited both counties. He noted the northward extension of what is now called the Gary moraine in Wright county and in Hamilton county contented himself with a brief reference to the coal exposures along the Boone river. About 1880 Mr. Warren Upham,† studying the morainic deposits of Iowa, visited the region here discussed and mapped with more or less exactness, the trend of our principal moraines. The artesian wells of Wright county receive notice, as originating in glacial deposits, in a discussion of Iowa artesian waters by Mr. R. E. Call.‡ Beyond these comparatively brief references, Wright and Hamitlon counties have no place in the scientific literature of the country. Of course there is reason for this seeming neglect. Counties are but artificial divisions, and are accordingly lost in topographic description where uniformity of surface and soil seems to affect the broader area. Our two counties are to ordinary travelers but a fractional part of the great "northwest prairie," and as such are simply reckoned a more or less fertile corner of a vast fertile field, part and parcel of the great maize-garden which enriches year after year the most fortunate commonwealth in the world. Nevertheless, even in the northwest prairie there are differences. It requires but a little careful attention to discover that even the surface of the country varies from township to township if not from section to section and a wider and larger survey may even reduce such variation to order and raise the suspicion, at least, that the

*Report of the Geological Survey of the State of Iowa, by Charles A. White, M. D., Des Moines.

†Ninth Annual Report of the Geol. and Nat. Hist. Surv. of Minnesota, pp. 298 *et seq.*, Saint Peter, Minn., 1881.

‡Iowa Climate and Crop Report, Vol. III, p. 5, 1893.

diversity discovered is after all intelligible, proceeds in order, and follows as effect to some widely efficient cause. In this way the apparent simplicity of the prairie takes on a more than passing interest and becomes, county after county, as studied, so many pages in a volume which is at length to delight us as it makes clear to all men, at once the history of the past and the meaning of the present.

PHYSIOGRAPHY

Topography

The region we study although as a whole comparatively level is by no means the monotonous prairie that some people are wont to imagine. With a gentle slope to the south of perhaps no more than fifty feet in as many miles, there are yet distinctive topographic contrasts, level prairies and precipitous steeps, far-stretching valleys, and prominent hills, besides a thousand subtle inequalities and surface variations attractive to the attentive student and as a whole lending to the ordinary observer landscape after landscape of delicate and fascinating beauty.

Topographic features generally, aside from the primeval great orogenetic wrinklings of the world, are all resultant from erosion. That is, generally speaking, the inequalities of surface with which all men are familiar are due to the transporting power of moving waters, storm-water principally, which in form of more or less continuous streams erodes and carries away vast masses of the seemingly solid ground. All our creek and river valleys, nearly, offer familiar illustration. Such topography the prairie before us exhibits; but strange to say, not well. The case is all the more interesting for this reason. Even the Boone river, the largest stream in the two counties, has no typical valley. Its waters are almost limited to a channel: i. e., the valley is yet comparatively very narrow; nowhere more than three-fourths of a mile, often much less, as at Webster City. It lacks the pinnate branching of a real river valley and has in fact almost no tributary streams. This, I say, makes the erosional topography in, say Hamilton county, peculiar. All things considered, the Boone river occupies a great ditch rather than a typical river valley, and when at length, near the southeast corner of the county, it empties into the Des Moines, its waters enter another deep but narrow ditch just like that in which they have been streaming. Let anyone stand on the east bank of the Boone a mile or so north of old Hooks Point and look west into the valley of the Des Moines and he will appreciate erosional topography as exhibited in all this portion of the northwest.

Such erosion is new, new as goes geologic time, new, in fact in its result, unfinished, incomplete. The banks of the Boone at the point just referred to, are perhaps one hundred and fifty feet high, and so steep as to be in places altogether perpendicular. The soft earth and clay of which the bank is made would have fallen long ago, save for two reasons: first and chief, the drainage of the country here, as in many another place, is back *away from the river!* and, second, the banks of our Iowa streams are wooded and small trees and bushes here in a score of species, the juniper and red cedar among them, hold fast the soil in very steep declivities, where the rain alone affords erosive energy.

The banks of the Boone, then, from Webster City south afford many of these peculiar precipitous bluffs, erosional wholly, and maintained in their steepness by the river which slowly cuts away the base in any case, and so prevents accumulating talus. These high, steep walls afford often charming landscape views. Thus from the farm of F. D. Carson in section 5 of Webster City township one may obtain a beautiful prospect of the Boone valley and study the entire progress of the river's simple history. The river is slowly cutting away its eastern bluffs, piling the debris to the west where the valley is now three-quarters of a mile in width. Sometimes, though rarely, the incoming of a tributary checks erosion long established, and sets the stream back to work over again its own deposits. An illustration may be seen just north of the Northwestern railway bridge below Webster City, where the Boone has abandoned the eastern bank and is now cutting west across its own flood plain.

Similar erosional topography, but on a minor scale, may be noted along the Skunk river in southeastern Hamilton county.

In an older topography where the soils to be eroded are loose or at least not indurated rock, the effects of erosion are at length very different in appearance, as may be noted by anyone who

Plate XII. A mound in the meadow, Ellsworth farm, Wright county.

Plate XIII. Behind the moraine, looking southeast.

will compare the topography say of Crawford county where a succession of hills separated by long, sloping valleys fill the landscape.

But within the limits of these broad counties are other singular topographic features well deserving intelligent attention and discussion. The bluffs along the streams are by no means the only hills we here encounter. There are scattered here and there from north to south some of the most curious-looking hills that any student ever saw, does he but take the trouble to look at them. Sometimes a single hill, quite regular in shape stands out all by itself, far enough from any stream, on a plain entirely flat and innocent of all erosion, a hill fifty or a hundred feet high perhaps, like the mound that commemorates Waterloo, just as artificial-looking but more imposing-looking. Some there are who say the Indians strove here in savage fury, and, urged by strange infatuation, sought thus to transmit the memory of their inhumanity. But no! there are scores of such hills. Generally they are grouped together. See the beautiful cluster of such hills a mile or two northwest of Dows where the late Mr. Ellsworth built a most picturesque country-seat and every summer sent his mowers winding around these precipitous prairie mountains to cut still the wild forage from such singular grassy cones.

Once we begin to be familiar with this remarkable topographical feature of the country, once we learn well to distinguish these hills from the ordinary sculpture of erosion, illustrations start up and salute the traveler on every hand. He is surprised, for instance, if he drive south and east from Stratford to find the prairie dotted with knobs and hills, some of them sixty or seventy feet above the plain, visible for miles. One particularly in section 26 in Marion township is symmetrical and beautiful in the extreme, while in sections 15 and especially 35 and 36 are dozens less notable but all unique; at the southwest corner of 36 evidently forming the continuation of a remarkable group of such curious natural structures stretching across township after township in Boone county and away south and west, looming blue now in the summer haze, the long famous "mineral ridge," known as a landmark to the primitive red men nor less serviceable to their successors, the pioneers of sixty years ago.

These are surely remarkable hills. No brooks or rills rise or run between them: Squaw creek flows around them, seems to shun them: only lakes and swamps or marshes lie undrained against their flanks. Clear Lake in the township of the same name is an example. The Twin Lakes of Wright county constitute another. These hills, then, are not erosional; they are *constructional,* since they represent the result of forces which affected the whole topography prior to the beginning of the erosion which we see now so actively in operation around us.

If we study the case a little more closely it will appear that after all there is something of system in the arrangement of these seemingly scattered mounds. The mineral ridge has been already noted, extending as it does from east to west across the northern townships of Boone county.* The ridge continues only a comparatively short distance in an east and west direction but soon divides at the eastern extremity and sends nearly north a range of hills which, entering Hamilton county near the southwest corner as we have seen, and in interrupted fashion extending far north across both counties here described, by way of Stanhope, Kamrar, Blairsburg in Hamilton county, and all the eastern half of Wright county, are especially noticeable about the Iowa river, which here so far drains their slopes and accompanying overflowing marshes. See Plate XIV

A second series of knobby mounds passes north from Wall Lake about Jewell in Hamilton county, trends east and north, north of Randall, and then north by scattered swells and knobs, coming to a culmination in curious peaks east of Iowa Lake in Rose Grove township and perhaps constituting part of the chain which becomes so conspicuous near Dows, as already noted, and leaves Wright county about three-fourths of a mile south of the line of the Great Western Railway, say in section 1 of Blaine township.

Such hills and knolls as noted here are called *morainic* hills; those which fall in series and are thus traceable, more or less continuously, far across the country, counties at a time, are thought to represent the modified remnants of an ancient *moraine,* a glacial deposit left here at some time in the history

*See maps of Boone county in Rep. Geol. Surv. Iowa, present series, vol. V. p. 202.

Plate XIV. Why the Iowa river runs northeast. In the moraine, looking nearly east; the Iowa river in the background.

P. [112] (v.20)

of the world, not very long gone by, when the great mass of snow and ice which still persists about the north pole of our world came very much farther south, even here to Iowa, a vast glacier pushing and spreading by its own weight along the ground, leveling the hills, filling the valleys, *so long as it moved*, and finally leaving these scattered piles of drift and debris where its margin rested when finally a warmer climate, by some cause ushered in, began to melt the glacier along its southern border, checked its southeast advance, shortened it, diminished it, caused it to recede ever farther and farther north until it paused at last only as a great snowcap to the planet, covering Greenland and other icy lands generally away north of the arctic circle, even as we see this day.

Wright and Hamilton counties are just inside the limits of the old glacier's furthest eastward spread or push. Traces of similar topography extend almost to Ackley along the line of the Illinois Central and almost to Hampton along the Great Western Railway, but the high hills of Dows and those about Iowa Lake are the most striking evidences of the glacier's pause, and while points near Hampton and Ackley may fix for us the very farthest reach of glacial action, the hills referred to mark perhaps a second limit when the glacier, once melted quite away, came down again, only once more to meet with check, once more dissolve away, and this time disappear for good. The moraines in these counties may be therefore termed recessional; they mark a period of wavering, of uncertainty, when the forces that have since controlled had not as yet quite attained their full dominion.

It is a notable fact that in topography such as here described, hills and *lakes* generally go together. The deepest and widest lakes are usually not far away from abundant hills and knobs. That is to say, the lakes of this region are morainic lakes; they owe their existence to the same conditions which have been cited in explanation of the hills. None of the lakes hereabout are very deep. They are all marsh-like, only distinguished from a thousand marshes by the courtesy of the pioneer who called them lakes to suit his fancy, recognizing their greater width and possibly, in some cases their bluffy shores.

The lakes of the region which have thus seemed in past days worthy of a name are, with the exception of one, all nearly in a straight line from north to south. *Twin Lakes,* the most northern in Wright county, recently called Twin Sisters as if to distinguish from the Twin Lakes about six miles to the north, in Hancock county, are small bodies of water, beautifully situated amid fine morainic hills and knolls. These are especially developed southward and from their tops are seen rural prospects of wonderful beauty. The lakes are much visited, but are shallow; not deep enough to suppress the commoner types of aquatic vegetation so that rushes appear in islets over the entire surface. Perhaps three or four hundred acres are here submerged at the ordinary stage of water.

About three miles south over hills so precipitous that there is as yet no direct road, we encounter *Cornelia Lake,* which is at present nothing but a rectangular marsh covering about half a section crowded from side to side with rank aquatic vegetation. The shores are, however, sufficiently high and there is no lack of sandy beach, marked as is usual where the water of our Iowa lakes is persistent, by a distinct ice-terrace, or bench, formed by the long continued out-thrust of the ice in winter.

Immediately south of Cornelia Lake, half a mile away, is *Elm Lake,* a rather handsome sheet of water, deeper; surrounded by sloping hills and margined by curving, winding shores it deserves more attention than it receives. Native trees still stand along its beaches and if properly cared for and dredged a little at some points, Elm Lake might make a pleasant resort for all the people of Clarion as now for a few. The surface of the lake is a little more than a square mile, its greatest length nearly two miles.

Seven miles almost directly south of the lakelets named, is *Wall Lake* in a township of the same name. Here the thrust of winter's ice, acting through centuries, had gathered around the shores the bowlders originally found on the lake bottom. These discovered by the pioneer piled thus in windrows, named for him, not this lake only but one in Hamilton county, as well as a third, larger, of greater renown, already described in the report on Sac county.* Wall lake in Wright county is simply a gigantic

*See the present Series, Vol. XVI, p. 517.

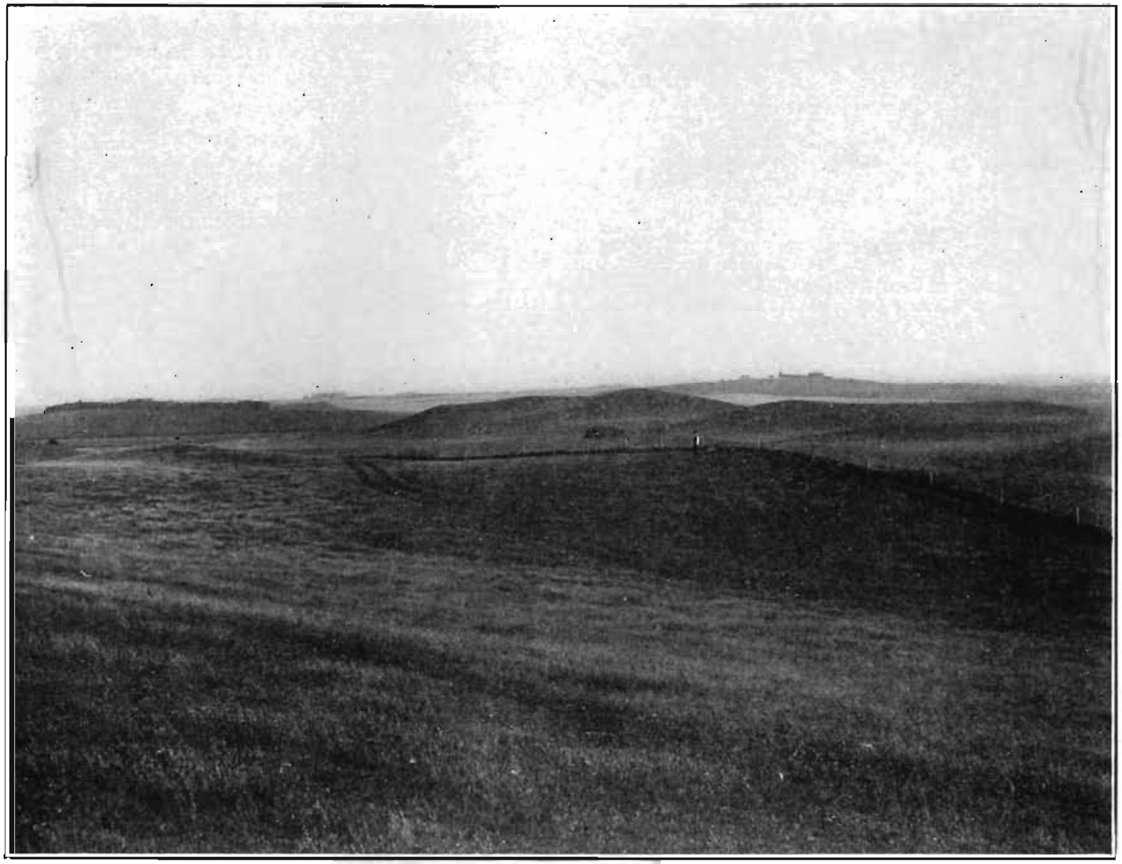


Plate XV. Such hills and knolls as noted here are called morainic hills. Part of the moraine in eastern Wright county, near Dows

"kettle hole" in the midst of the plain. The morainic hills here stand somewhat aloof, a mile or two, to the east and south, and another great marsh called Wheeler creek, but with no eroded channel, lies between Wall lake and the hills. The wall of the lake seems to have long since disappeared, hauled away to make foundation stones in structures they will doubtless again survive. Only at the southern end of the lake a few bowlders appear, heaped up now to help the highway that here skirts the shore. This is perhaps the largest lake in the two counties, covering more than two sections, but its shallowness makes it less attractive, and the wild rice and bullrush seem to thrive almost from side to side. Low morainic swells approach its borders on the west and afford warm, sunny slopes to many beautiful farms and groves.

In Hamilton county three lakes only have been thought worthy of the name. *Cairo Lake,* almost immediately south of the Wall Lake just described, a second *Wall Lake,* three or four miles southeast of Cairo, and *Iowa Lake* on the eastern border of the county, notable as one of the sources of the Iowa river. Of these lakes, the first has been imperfectly drained by an open ditch. The lake is still marshy over a section or two of land, appears to have enjoyed a good beach along the east and a grove of native trees still extant. Iowa lake is possibly quite as large, is now in process of drainage, and if the open ditch proves successful, Iowa lake will soon be a land of corn and meadows, girt round to north and east by beautiful, typical morainic hills.

Little Wall Lake, south of Cairo lake three or four miles, is a picturesque little pond, half a mile wide and a mile or more long, nearly surrounded by steep, wall-like hills. Had it depth Little Wall lake would be the attraction of the landscape, but its shallowness makes it simply a great marsh filled from side to side with aquatic plants. The margins are dark with sedges. In the middle the cat-tail lifts its blades undisturbed, while over the deeper waters the pond lilies spread their broad leaves like inverted shields and star the surface with flowers. Innumerable birds fill the air with strident, unmusical sounds; ducks steer their miniature fleets about; mud hens wade among the calamus roots; blackbirds cry as if life depended upon unceasing noise;

the tern hovers above the more open waters or sits upon the sand as if by sea; the bittern sits among the reeds, bill straight up, more like an inverted stake than any "stake driver"; and over all, in the evening, clouds of insects—mosquitoes make gray the air on every side. For the rest, bowlders now are few; occasionally a big one lies by the shore tumbled down by the undermining of the waves, here and there sufficient when the lake is full, to beat against the steeper shores. In the earlier morning the mists from the waters screen from the traveler the beautiful grain covered hills that slope down on every side and the lake lies in primitive wildness, an isolated reminder of the weird marshy topography that so recently characterized not these counties only, but all northwestern Iowa, the land of a thousand lakes.

But while the mounds and lakes are thus interesting features of this region, the wide, almost perfectly even plains on which these are displayed are none the less. The prairies of northwestern Iowa where not occupied by marsh or morainic knob are as a whole the still unweathered, uneroded floor over which the northern glacier moved; not absolutely level, of course, but often surprisingly near it. The general slope is south and west. Thus on the west side of the territory here described we have Thrall, altitude, 1144 feet; Highview, 1137; Stanhope, 1122. Going down the east line, we have Meservey, 1255; Alexander, 1253; Williams, 1212; Radcliffe, 1194. The prairies about Highview, *an almost absolute plain!* afford an illustration of this singular featureless topography. The whole landscape is at once in vision; diminishing houses, groves, villages disappear on the horizon, lost by distance only.

A terrene such as that just described is, of course, much lacking in drainage of the ordinary sort. The traveler today is amazed to see dredge boats steaming about athwart the meadows following the imperceptible slope of the prairie as by the construction of wide canals they furnish the necessary conduits for the conveyance of surface waters. Under such circumstances it would appear that little is to be said upon the general topic of—

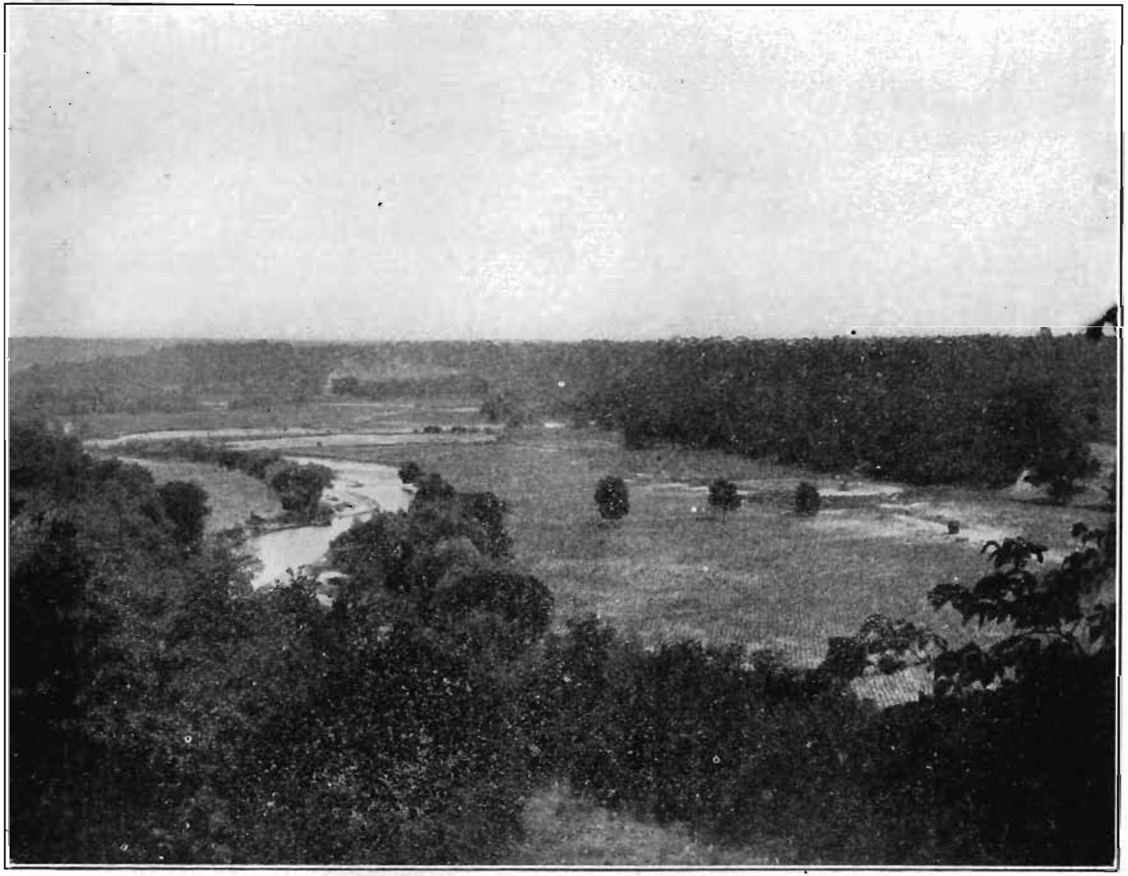


Plate XVI. Where the Boone winds across its flood-plain before entering the Des Moines valley just visible in the extreme left of the picture.

p.[120]
(V.20)

Drainage

The Boone river, which traverses almost entirely both these counties from north to south across their western townships, affords excellent drainage so far as it is developed. We are here near the mouth of the river which enters the deeply eroded Des Moines in Webster county not far from the southwest corner of Hamilton. The Boone accordingly shows for some distance up stream a channel almost as deep as that of the larger river; its banks are sometimes one hundred to one hundred and fifty feet high. Accordingly, lands immediately contiguous are generally well drained. However, such is the peculiar topography of this country that sometimes the drainage of the highland is actually away from the river, so that all this deeply eroded channel of the river avails but little. See Plate XVI

Several tributaries of the Boone are more or less serviceable to the drainage of Wright county. Otter creek, Eagle creek, and White Fox creek, all flow south in the western part of the county and in many places afford outlet for tile draining. White Fox is an eroding stream and farms adjoining it are well drained. The same thing may be said of Eagle creek, but in both cases the service is limited almost to the channel of the stream itself. There is no valley and there are few tributaries.

The south townships of Hamilton county are, for a Wisconsin drift region, well drained. Here we have the sources and head streams of the Skunk river. Squaw creek and the forks of the Skunk are erosive waters and drain a beautiful country. Long Dick creek is a typical prairie slough extending north and south through three or four townships but leaving the adjoining lands practically unaffected.

However, as above suggested, great open ditches are now everywhere in course of construction to help out these prairie water courses. It is possible that the unlimited tiling brought from the fields, from every direction, may afford sufficient perennial water to keep in the main ditch a constant stream strong enough to maintain the channel thus artificially offered.

STRATIGRAPHY

The indurated rocks of the older horizons are in these counties generally buried far out of sight and reach by the field of drift. We know of their presence in most places only on the testimony of the well-digger. However, as will appear, the Boone river has in its lower course cut through the entire drift series and reveals with more or less clearness the formations immediately below.

SYNOPTICAL TABLE

GROUP	SYSTEM	SERIES	STAGE	FORMATION
Cenozoic	Quaternary	Pleistocene	Wisconsin	Drift
			Kansan	Buchanan gravel Drift
			Aftonian	Gravel
			Nebraskan	Drift
Paleozoic	Carboniferous	Pennsylvanian	Des Moines	Sandstone, shale coal
		Mississippian	Saint Louis	Limestone

CARBONIFEROUS SYSTEM

Mississippian Series

SAINT LOUIS LIMESTONE.

In several places south of Webster City the Boone river has cut down through all drift and exposes the stratified rock of the country. Thus quarries along the Brewers creek near where it enters the Boone show the section following:

		FEET.
6.	Alluvial soil and gravel	3
5.	Weathered ferruginous gravel	1-3
4.	Pure white sand	3
3.	Laminated sandy shale	4
2.	Hard crystalline limestone	5
1.	Irregularly bedded and cracked limestone down to water level	10

A few rods farther west of the section thus diagrammatically shown, a drift section also appears above the indurated rocks:

		FEET.
5.	Soil	1
4.	Wisconsin drift, sandy, with abundant sand bowlders	12
3.	Grey Wisconsin drift	2
2.	Sand, white, grey, some ferruginous	3
1.	Irregularly bedded limestones	8

Number 1 in each section is referred to the St. Louis stage of the Mississippian; on lithological characters chiefly; but the position in the series suggests the same reference, the sand and sandstone above representing the Pennsylvanian. Lithologically the rock in question resembles that occurring in Humboldt county in and about the town of Humboldt and discussed at some length in volume nine of the present series, page 127 *et seq.* Beyer seems to have encountered similar beds in the northwest part of Marshall county, along the Skunk river in Story, and refers all these exposures to the St. Louis.*

Pennsylvanian Series

DES MOINES SANDSTONES AND SHALES.

The Pennsylvanian exposures are limited to the banks of the Boone river and its tributaries south of Webster City. There are many such; and coal for many years has been successfully mined at intervals all the way from Silver creek to the mouth of the river. While the mining has been extensive, of late the industry appears to have almost entirely lapsed, and there are at present not only no good exposures of the coal-seams and accompanying strata, but no mines were found in operation. Exposures occur where the river at flood undermines some portion of the unstable bank and produces a land-slide from above. Such slides have taken place at several points where mining had helped on the effect of basal erosion. The result is sometimes a good section of the upper drift sheets and complete sepulture of everything below. Such has been the history of the case in section 19 of Webster township, a short distance east of the tunnel.

However, by the aid of miners and others a tentative section may be studied at the mouth of Silver creek in section 36 of

*See of the present series Vol. VII, p. 227.

Freedom township. Here is a mixed exposure of something more than one hundred feet to be distributed somewhat as follows:

		FEET.
12.	Wisconsin drift	50
11.	Kansan gravels	2
10.	Sand, white or little colored	6
9.	Carbonaceous clay, with seams of "Black Jack"	5
8.	Shale	1
7.	Coal	1
6.	Sand and shale	3
5.	Coal	1-2
4.	Impure sands and clays	12
3.	Cannel coal	1½
2.	Sandy shales	15
1.	Limestone, heavy-bedded, St. Louis	8

This table shows the relative situation of successive horizons; the thickness in each case cited must be esteemed an estimate. Number 7 was well exposed and at the point observed does not exceed one foot in thickness. Number 5 was reported from twelve to twenty-four inches of good quality. The cannel coal lies some ten or twelve feet below number 5 and is reported twenty to thirty inches in thickness. On the east side of the river nearly opposite the mouth of Silver creek, erosion had removed everything above number 4 and a large part of this, so that the pioneer farmers by only light stripping done with the plow and scraper, obtained considerable supplies of what is called cannel coal, which seems to be entirely satisfactory for many domestic purposes.

The limestone at the river-edge appears to be the same as that exposed farther up stream and is referred to the St. Louis. It seems to dip out of sight up stream and is replaced in the bed of the river by a heavy-bedded sandstone which has been to some extent quarried.

Carboniferous sands and shales with seams of coal have been exposed by the river for many miles along its winding course, but such exposures are at present in almost every place covered either by sliding drift or, in the river bed itself, by bowlders and beds of gravel and sand. Coal has been taken from such eroded banks in several places as in section 13, section 21, section 30, Webster township. There is an apparent outcrop of coal in the bed of the river in section 30, almost directly north of Stratford, but this probably is not in place; the seam appears to be on edge and is likely a shear from the adjacent bank, here very steep.

In general, the Paleozoic rocks along the river are covered, even where exposure is to be expected, by recent slides of the overlying drift. This is particularly the case where coal mining has been in progress.

QUATERNARY SYSTEM

Pleistocene Series

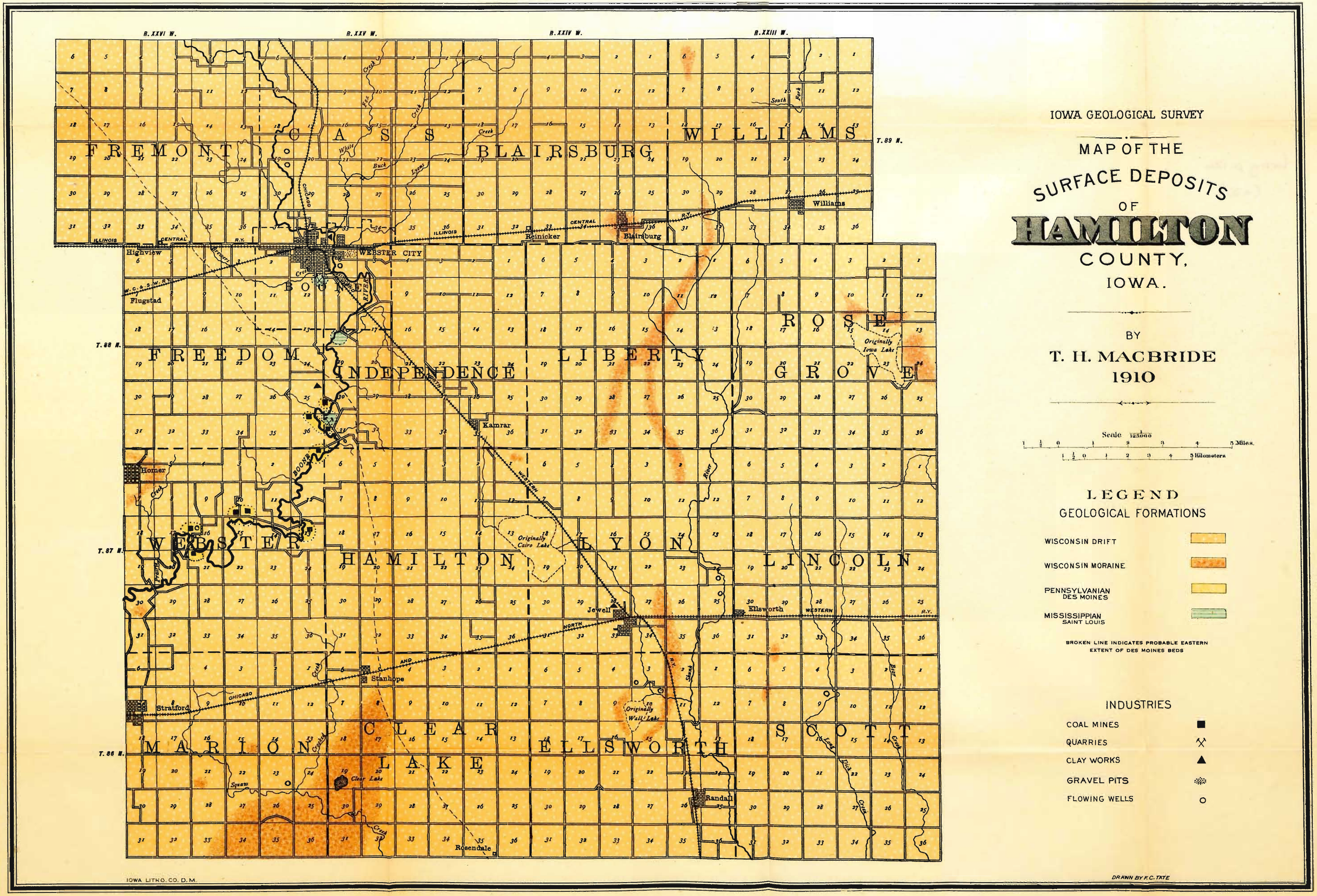
KANSAN DRIFT.

Exposures of the older drift are rare. There are, however, some sufficiently fresh to be legible. Those at the Webster City quarry and at the mouth of Silver creek have been already mentioned. As one descends toward the Boone from the north, in Webster township the contact of the older and later drifts may be sought. On the north side of a bridge crossing a small stream in the northeast quarter of 19, Webster township, occurs a peculiar exposure of what is probably Wisconsin, showing the curious gray drift, previously mentioned in these reports, capped by beds representing perhaps sand-bowlders, or some particular local condition at the time the drift was laid down. There are beds of sand and ferruginous gravel, evidently related to the ferruginous sands of the Carboniferous strata in the neighborhood. Possibly the gray Wisconsin represents simply that part of the deposit which contains an admixture from the coal seams, black and gray beds of material over which the glacier passed and which it may have found not covered by older drift, in this immediate vicinity. A piece of coal weighing a few ounces was found in the gray material in the exposure here described. This material has not traveled very far; it is local.

But farther south, the road cuttings, where that highway goes down to the bridge, show the older drift in several places, although, owing to continual wash from above, the contact was not well made out. On the north side of the river the Wisconsin deposits are about fifty or sixty feet in thickness; on the south side of the stream, in the roadway only the older drift appears, at least for a considerable distance up the hill; at the summit, the characteristic light-colored Wisconsin may be traced again and morainic swells show how the course of the Boone was long ago deflected west.

But although on these level, uneroded prairies the older drift is now generally invisible to the traveler, its presence everywhere beneath the surface is none the less exactly ascertained. The "blue clay" is a matter of universal testimony. Its tough unyielding consistence, its relation to underlying aquiferous sand or gravel, nor less the multitudinous inconvenient bowlders imbedded in its impervious mass, make the formation familiar to every well-digger, almost to every farmer. The blue clay is everywhere in Iowa recognized as representing the Kansan drift; and so in these counties, although the Kansan in its several members may not be seen and studied often at the surface, nevertheless it may be assumed as covering the indurated rocks or Carboniferous shales and clays over practically the entire area.

The thickness of the blue clay is a matter of practical interest but of record incomplete. Those who drill through it find it variable; nevertheless in these two counties no reports quote so much as two hundred feet; the usual statement is "fifty to one hundred and fifty" feet. This will be discussed more fully under the head of water supply later on. It is understood that the blue clay here referred to represents only so much of Kansan clay as has not yet suffered oxidation: Where the clay has long been exposed to the weather, it becomes yellow or brown as seen in the road-sections, already referred to, near the Boone. In fact as just stated this particular member of the Pleistocene deposits of Iowa may not be well studied in such locality as is now considered, simply because not well exposed. But we may not ignore a formation so widely and definitely recognized. It would be to science of the highest interest and to the community of no small practical value did every contractor who constructs a well on the Iowa prairies keep an accurate record of the course of his work. Were such records kept we should presently be in possession of a mass of facts relative to the structure of our soils and the surface and water sources of Iowa such as may be had so easily and speedily in no other way.


IOWA GEOLOGICAL SURVEY
MAP OF THE
SURFACE DEPOSITS
OF
HAMILTON
COUNTY,
IOWA.
BY
T. H. MACBRIDE
1910
Scale 1/125000
Miles.
Kilometers
LEGEND
GEOLOGICAL FORMATIONS
WISCONSIN DRIFT
WISCONSIN MORAINE
PENNSYLVANIAN DES MOINES
MISSISSIPPIAN SAINT LOUIS
BROKEN LINE INDICATES PROBABLE EASTERN EXTENT OF DES MOINES BEDS
INDUSTRIES
COAL MINES
QUARRIES
CLAY WORKS
GRAVEL PITS
FLOWING WELLS
R. XXVI W.
R. XXV W.
R. XXIV W.
R. XXIII W.
T. 89 N.
T. 88 N.
T. 87 N.
T. 86 N.
FREMONT
CASS
BLAIRSBURG
WILLIAMS
FREEDOM
INDEPENDENCE
LIBERTY
ROSE GROVE
WEBSTER
HAMILTON
LYON
LINCOLN
MARION
CLEAR LAKE
ELLSWORTH
SCOTT
Webster City
Highview
Flugstad
Reinicker
Blairsburg
Williams
Kamrar
Homer
Jewell
Ellsworth
Stanhope
Stratford
Randall
Rosendale
BOONE RIVER
Originally Iowa Lake
Originally Cairo Lake
Originally Wall Lake
Clear Lake
ILLINOIS CENTRAL R.Y.
CHICAGO AND NORTH WESTERN R.Y.
W. C. & S. W. R.Y.
IOWA LITHO. CO. D. M.
DRAWN BY F. C. TATE

In the counties of Carroll, Boone and Hamilton, there is a little difficulty in making sure of the identity of the blue clay in some localities, owing to the fact that in some places the lower Wisconsin may be taken for it. However, the gray Wisconsin is after all, once comparison is made, *not* blue clay; it is much less compact, of different color, much darker, especially where dry, and disintegrates much more easily and readily, lacks the peculiar slippery or soapy feel, which will be recognized by everyone who has had his hands on this peculiar deposit. But this we may better discuss under a new topic—

WISCONSIN DRIFT.

This name is now applied to the upper drift or pebble-clay covering all central and northern Iowa. In the two counties here described it forms the almost universal subsoil. It is exposed by the erosion of streams, and may be seen in "clay-banks" fifty or sixty feet high along the Boone where the undermining waters have caused the sliding of acres at a time, as in section 13 in Webster township, Hamilton county; it is exposed along all railways, as along the Great Western in Wright county; it may be seen on nearly every highway where a cutting of a few feet discloses the peculiar whitish or pale yellowish, calcareous pebble-clay. Tile ditchers toss it up in every field. The formation includes also the great piles of drift, beds of gravel and sand, making up the mounds and hills already described as characteristic features of the topography here. These hills are used commonly as sources of supplies for sand and gravel; but many times they consist simply of the same materials that constitute the more level grounds; they are drift, a mixture of fine yellowish clay-like material with abounding bowlders and pebbles of every dimension; in the present case the pebbles are largely calcareous and white. Under the influence of the weather the Wisconsin drift loses its pebbles in large measure; consisting of lime, they rapidly decay and we have left a fine clay-like soil, exceedingly sticky when wet, immensely productive of vegetation, and now black, with the accumulated organic stuff of many centuries.

Although the Wisconsin drift in these counties reaches in some places considerable thickness, as in localities where it seems to fill depressions in an older topography, or where it is evidently piled in hills and mounds, nevertheless the deposit as a whole seems relatively thin. Open ditches, ten to fifteen feet in depth, are commonly constructed on all the more level prairies, for the purpose of more effectively draining the abundant marshes. In constructing these ditches the shovel not infrequently encounters blue clay. This would indicate that in such places all the weathered Kansan had been pushed off or eroded in advance of the Wisconsin ice, and means, of course, a very thin deposit of the later drift. The average thickness of the Wisconsin drift in the counties here studied would not seem to exceed fifty feet.

Mention has been made of a dark colored or gray Wisconsin deposit. This has been observed in not a few localities hereabout. (See Vol. XII of the present series, pp. 133-135, where also Illinois reports are cited.) The present writer has observed difference in color in the Wisconsin deposits in the northwestern part of Carroll county, in Webster county a few miles south of Ft. Dodge, along the Des Moines river, in cuttings along the Newton and Northwestern Railway northwest from Boone, in the quarries and railway cut southeast of Webster City as noted in section for St. Louis limestone, p. 122, and in the section already mentioned south of Homer in Hamilton county. But the finest drift exposure seen in these two counties occurs in the very northwest corner of the town of Webster City. Here the river has undermined, for years has been undermining, the bank on the southern side. The result is a "clay bank," a bed of drift, seventy-five or a hundred feet high, extending perhaps half a mile along the river. A section of the drift here shows:

		FEET.
3.	Black soil, about	3
2.	Yellow Wisconsin, impure	12
1.	Gray Wisconsin with fragments of shale and coal	70

Inasmuch as the erosion seems to proceed steadily at the base of the bluff so that the face is kept nearly perpendicular, it seems probable that the blue clay here forms the bottom of the river; if so, the face of the bluff represents the total thickness and the character of the Wisconsin drift at this particular point. The dark colored drift here is almost of the same color as some of the

Carboniferous shales of the neighborhood, and fragments of such shales still persist as a common element in the make-up of the deposit. Fragments of coal are also not unusual. The gray drift is hard, compacted, rather inclined to a crystalline, splintery cleavage; not tough like the blue clay. It has been suggested that this variation in color is due to difference in age. Data are not yet at hand in number sufficient to warrant much inference; but so far as observed there is nothing in the sections noted to indicate any time factor whatever. The two colors wherever shown pass over into each other almost without a break.

It seems more and more evident that the local beds and peculiar local ingredients and not lack of oxidation must be responsible for the peculiar color. This supposition is not inconsistent with the relative position of the two members where seen in section. The yellow upper portion represents a burden brought in the upper ice and from far; the dark colored stuff was in process of accumulation when the movement ceased. These deposits, so far as reported are all marginal. At any rate there is nothing so far observed to indicate interrupted deposition.

Soils

The soils of Hamilton and Wright counties are nearly all of one sort, prairie of the blackest and richest. There are some alluvial benches along the course of the Boone in both counties, and along the Skunk river in the southeastern townships of Hamilton county, but these are not continuous and are of limited area. In the vicinity of the morainic hills the soils are lighter, conspicuously so in some places, as in the western part of Scott township, Hamilton county, and in the northeastern part of Rose Grove township; but in general we have a calcareous soil full of accumulated wealth of years unknown and long gone by, a soil that requires skillful tillage only, to become a garden to the satisfaction and service of men. The only hindrance so far has been the imperfect drainage, characteristic of all north central Iowa. This defect, however, is now in course of rapid correction. Great public ditches stretch from marsh to marsh and pass straight down the low valleys of natural drainage, offering to the adjoining farms outlet for tiles, which will soon in perfect network reach every undrained field.

Along the larger streams, notably along the Boone, the steep banks show exposures of unweathered drift. These were originally, and are largely still covered with native forest. Such localities should be preserved as woodland, to furnish a local supply of building materials and wood for fuel, fencing, etc. These steep banks cannot be cultivated; they are often too steep; in any case, once the timber is cut off, erosion cuts the whole hillside into gullies or causes it to slide bodily to the stream valley below. Bluegrass will generally succeed the forest and make of the less steep declivities fairly good pasture-fields; but even so, trodden by the cattle, the bluegrass burns out in the summer, weeds cover the face of the ground, and the whole valley becomes a waste useless to men and unsightly in the extreme. Such lands are better for wood-lots than for any other conceivable use; and in Iowa today, such is the liberality of our laws, the burden of taxation on lands devoted to forest is so light as to make wood-raising by far the most profitable service to which our hillsides may be turned. Besides all this we have the great advantage of landscape beauty, adding attractiveness to the entire region and so putting actual added value on every farm. It is indisputable also that the bordering forests contribute to the conservation of water in the streams, and in some measure influence the local rainfall; so that on every account wisdom suggests that the steep hillside bordering such a stream as the Boone, should be kept covered with groves of native species of trees. This matter is more fully discussed in our Forestry Notes further on.

ECONOMIC PRODUCTS

Limestone

There are no quarries in Wright county, but the several quarries already referred to at Webster City have afforded a great amount of rubble stone and for years furnished material for foundation walls, etc. Of late these sources are less used. Imported rock and artificial blocks have supplanted the local product. Stone was quarried in days gone by at Bell's Mill and the bridge piers there are constructed of local stone. Limestone was at one time quarried on the old Snell farm, section 16, Webster township, Hamilton county, and at several points up and down the stream from the Bell Mill, but none of these quarries are now in use. Sandstone has also been quarried to some extent; chiefly in section 13 in Independence township, Hamilton county. The foundations of the new bank building at Kamrar are reported to have come from these quarries. This rock is certainly of very fair quality and might be taken out cheaply in large quantities.

Lime was at one time manufactured at various places along the Boone river, from Webster City south, almost at every point where lime-rock was quarried, but the kilns have to all appearance been long unused. The St. Louis limestones do not make the most satisfactory lime, and although convenient at one time for the service of the pioneer, its place is now supplied by the product of distant kilns.

Sand and Gravel

The alluvial materials along the streams afford an abundance of sand and gravel, to say nothing of that obtained here and there from morainic hills and knobs. Gravel benches are not infrequent along the Iowa. There is a large pit used by the railways about three miles north of Belmond. Sand and gravel are also obtained conveniently along the Boone river. At Webster City there is a large deposit of such material south of the city. This is at present the basis of an extensive cement block industry. Sand is also found along the Skunk river near Randall; on Eagle creek east of Eagle Grove is a bed of gravel used in road making. In fact this suggests the value of these deposits to all this part of the country; they furnish the very finest road material. The streets of all the towns have been covered more or less completely with gravel and many a country road otherwise a marsh is made passable by use of the same cheap material.

Artificial stone is extensively manufactured also at Belmond and at Dows. The building blocks of such construction, here as elsewhere, are likely to leave more and more unused the quarries of natural stone. Even the bowlders lie undisturbed in the field or at best are simply rolled unbroken from the pathway of the plow to find lodging in long, straight files by the barbed-wire fence along the highway.

Fuel

The pioneers in these counties built their cabins of logs along the principal streams, and timber for both building and fuel was abundant. To the present day wood is a common fuel although the forests have been wastefully and ruthlessly destroyed in every valley. The groves planted on the prairies, primarily for shelter, are now also a convenient source of cheap fuel and are largely so used. Wright county has no fuel, of local origin, except wood. Hamilton county is more fortunate. The western tier of townships in particular fall within the limits of the Ft. Dodge coal-field and the banks of the Boone river for miles in the lower course, nor less the banks of tributary creeks and ravines, show abundant natural exposures of seams of bituminous coal in veins of various thickness.

COAL.

Coal has been mined for years, but in irregular, desultory fashion, from a point some four miles directly south of Webster City at intervals all the way to the mouth of the Boone. Many of the "mines" are nothing more than an effort on the part of the landowner to procure where convenient with least trouble and stripping, a temporary supply of fuel. At other points drifting has been practiced and seams followed for considerable distances into the bank or hill. On the Brockshink farm a vein reported three feet thick has been worked for many years. "Hundreds of tons of coal as good as any at Ft. Dodge," are said to have been taken here although at the date of visit, July, 1906, the mine seemed much, if not entirely, neglected. About one mile southeast of the Brockshink mines are the Silver properties. Here, beginning with exposures along the banks of a sharply eroded ravine, whose drainage is tributary to the Boone, a great amount of coal was at one time easily removed. The vein was probably the same as at Brockshink's, but there is no natural roof to protect extended mining, and at present slides cover almost all evidence of former activity. Along the river south of the mouth of Silvers creek, coal may be seen outcropping in several seams. The sliding bank on the west side affords an incomplete exposure. The section at this point has been previously given. The view of prospective mining is not encouraging at this point owing to the difficulty of either drifting or stripping.

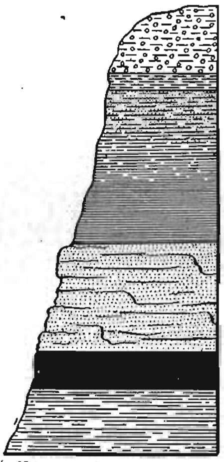


Figure 9. Section of bluff near the Silver mine, below Webster City.

		Feet.	Inches.
6.	Drift	2	
5.	Shale		6
4.	Shale, light and dark colored; somewhat sandy in places	4	8
3.	Sandstone, massive, with occasional bands of bituminous shale	3	4
2.	Coal	1	2
1.	Shale, drab, and fire clay (exposed)	2	

Across the river, east about thirty or forty rods, the stream, before the coming of the miner or of any creature who had use for coal, had already done a large amount of stripping and had left uncovered some acres of coal. This is in section 31 of Independence township. This supply of coal was, of course, quickly exhausted. The seam probably represented No. 5, in section on page 124, already referred to. At any rate cannel coal has been taken out lower down in the natural exposure in the same field, and cannel coal outcrops on the west side of the river as shown in the section.

Further down the river are the Claflin mines. These are worked more or less extensively during winter months and supply a local demand for fuel. Some of the drifts are timbered and veins two and one-half feet in thickness have been followed. The owner declined to give statistics so that probably the output is not large. Shafts at varying depths in the neighborhood reach good veins of coal, the depth depending in the main upon the surface topography. At the bend of the river in section 13, Webster township, drifting was at one time attempted on a large scale, but a great slide has obliterated almost every indication of human industry. Only here and there the entrance of a tunnel may be guessed by the topography or by the ruined frame-work still projecting and here and there masses of cone-in-cone along the river-bank indicate that the miner has been at work.

At Stockdale, about two miles west, in the southeast quarter of section 10, mining has been carried on for some forty years.

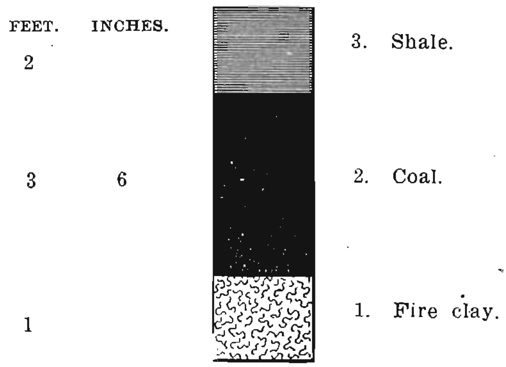


Figure 10. Coal bed in Stockdale opening, ten miles below Webster City.

There are a number of timbered openings yet in evidence and quantities of shale and refuse cumber the ground, but at the time of examination all work seemed long suspended.

Report has it in all these cases that the cost of timbering the shaft or drift, and the insecurity of the roof in many places, makes the mining of coal in Hamilton less attractive. Coal there is in abundance and of fair quality; some of it as good as the best; but at present it is of less value. Certain it is also that the coal company railway from Webster City goes to Lehigh and not to Stockdale, which may or may not be significant.

It remains to be said that well-diggers report thin veins of coal as far east as section 2 in Clear Lake township, but in general the coal field in this neighborhood probably does not extend very far east of the Boone river nor much north of the middle of township 88 North. However erratic bits and pieces of coal are to be found in the drift even north of Webster City which indicates that outlying patches of the Iowa coal district may occur yet farther north. Our only source of information here will be the record of the drill.

Brick and Tile Manufacturers

Kilns for burning brick and tile are in operation at several places in these counties but generally the material used is in whole or in part a Carboniferous clay or shale brought from Lehigh in Webster county. Thus at Eagle Grove where 400-500 M. tile and 150-200 M. brick are manufactured per year, all the clay is imported. The clay comes from Lehigh, the coal from Des Moines. At Webster City is a much more extensive manufactory. Three or four million brick are produced per year and a large quantity of tile. The material used is Lehigh clay mixed with the output of a local pit, in proportion of about two to one. The local material appears to be a river silt and is found along the stream about half a mile east of the tile works.

At Jewell Junction local material is used, and the result is less satisfactory, pebbles affording much trouble. However, about 200 M. tile per year are manufactured and about 100 M. second-rate brick.

At Goldfield there is an unusual deposit of rather superior brick clay. This is near the river and appears to be alluvial in character. The exposure shows about as follows:

		FEET.
5.	Clay remarkably free from pebbles	7
4.	Hard layer of drift, cemented by iron	1½
3.	Sand	3
2.	Bowlder clay	15
1.	Gravel and sand, many feet.	

Number 2 is probably Kansan. Numbers 3 and 4 may represent also older drift, as Buchanan gravels. In any event the clay is alluvial and is serviceable, 125 M. brick are turned out annually and 500 M. tiles.

At Dows is another plant using a local deposit. The clay here lies beneath an alluvial deposit full of pebbles, and is itself probably alluvial, since it contains much organic matter. It is very free from pebbles and the tile is of good quality. This factory is in Franklin county, just outside our present limits.

Water Supplies

Wright and Hamilton counties are well watered. The natural perennial streams already described are now supplemented in many places by long open ditches to be fed by miles of tiling. These will certainly remain living streams as if fed by springs, and although not without their inconveniences, such ditches will afford water for cattle for all the farms they pass.

The Boone river was at one time famous for mill-seats; and although at present there is found not a water-power in Hamilton county, there were at one time no less than five from the vicinity of Webster City south.

The tunnel mill in Webster township secured the needed fall by taking advantage of a long bend in the river where the current returns upon itself passing so near its upper course that a tunnel of a few rods length caught the stream at the higher level of a mile and a half above. The tunnel remains, but the mill has disappeared. Farther down stream is the ruin of the old Bell mill known to the earliest pioneer, but now forgotten of their children.

But the water supply of the two counties we describe is in large measure independent of the streams. Wells are universal and comparatively easy of construction. Good water is commonly obtained at moderate depth, from ten or fifteen to one hundred feet, generally from the sands and gravels under the drift. Some wells reach the St. Louis limestone and are deeper.

Flowing wells in these counties are by no means unusual. Indeed we seem here to be within the boundaries of an extended flowing well district which as we are coming to know it is sufficiently extended to merit careful investigation and study. Beginning at least as far north as Marshall, Minnesota, and extending in Iowa south and east in a strip, only a few miles in width, through Kossuth, Winnebago, Hancock, Wright, Hardin, Hamilton, Story, Marshall, Tama, Benton and Iowa counties, at least as far as Ladora, we have a region of flowing wells offering a geological fact of much interest and suggestiveness. This is not the place, nor are exact data at hand for a full discussion of this matter, but it may be stated in order to give a general view of the facts now before us that beginning at Marshall, Minnesota, and passing directly to Iowa there are flowing wells about and in Germania, near Titonka, thence south to Hutchins, and commonly in the western townships of Hancock county, about Renwick and Goldfield and Eagle Grove and Woolstock and Webster City, nor less about Swaledale (Cerro Gordo county), Belmond, Rowan, Popejoy, Alden, Buckeye; thence to Ellsworth and south to Story City, in the eastern townships of Boone county, about Ontario and Ames, east to Zearing, Marietta, Garwin, Gladstone, Belle Plaine and so on to Ladora and Victor. In a preceding volume (Present Series, Vol. IX, pp. 523-562) Mr. H. R. Mosnat discusses the Belle Plaine area and suggests the possibility of "a preglacial river valley now completely filled up and obliterated." Mr. Mosnat refers to the Story City wells but thinks the two fields hardly continuous. The facts of distribution, however, as just cited, seem to indicate that they may be. The Wisconsin flowing well field is undoubtedly one and it approaches the Belle Plaine area within sixteen or eighteen miles. The flowing of a given well, of course, depends in part upon the local topography; and until we know more exactly the head of water in the drift wells over the entire area discussed we may not be certain whether we have a continuous aquifer, or source of supply, or not; possibly not even then.

The situation is however, suggestive. A map of the district sketched would indicate at least a continuous pre-Kansan deposit of gravel and sand extending from far up in Minnesota to the southern part of Iowa. This again would mean the pathway, of course, of an old time current. The direction of this current marks the drainage of the pre-Kansan landscape and it is interesting to note that the general trend was apparently then the same as at the present day.

It remains to be noted that the flowing wells in the counties before us are exceedingly useful, the water usually potable and fine. Nearly always the report is that the water comes from below the blue clay, sometimes from sand just on the rock, which amounts to just about the same thing, since in our locality there is in general not much of any other formation between the Kansan and the St. Louis limestone, the country rock. The city water at Webster City comes from fourteen flowing wells, one ten inches in diameter, the others, four. The head here is said to be about ten or twelve feet above the ordinary level of the river. This magnificent fountain comes from a gravel and sand layer on the rock about one hundred feet below. At the tile works in Eagle Grove the water of a flowing well rises in an inch pipe at present eighteen feet above the surface. Flowing water is reported in this well at different levels; that which supplies the present current is 125 feet below the surface. The flowing well at Goldfield is near the railway station and has delighted travelers for many a year.

FORESTRY NOTES FOR WRIGHT AND HAMILTON COUNTIES

White men seem to have entered Wright and Hamilton counties by way of the rivers. The migration, like that of birds in spring, was by way of the woods and thickets. The narrow valley of the Des Moines was filled with the densest kind of forest, not less the smaller but no less chasm-like valley of the Boone. While all the level ground above was marsh or prairie, these deep furrows were dark with trees among which wound in transparent clearness, amid the bowlders, not without music, the fairest perennial rivers, confined by the vegetation to a restricted or but slowly changing channel. Among these trees and by these waters the pioneers built their cabins; cleared away a few acres where the alluvium was broadest and highest, and shaped their dwellings from the logs. They never dared occupy the bare fields above them. Storm swept in winter and fire swept in autumn or in spring—the prairies seemed impossible of occupation. Plate XVII.

It is curious to note that the fires which year by year mowed the vast plains seem seldom to have entered these deep and narrow valleys—probably in winter these received more than their quota of snow; old residents tell how the valley of the Boone seemed sometimes in its upper channel almost filled with driven snow. The snows in such case lingered longer here in

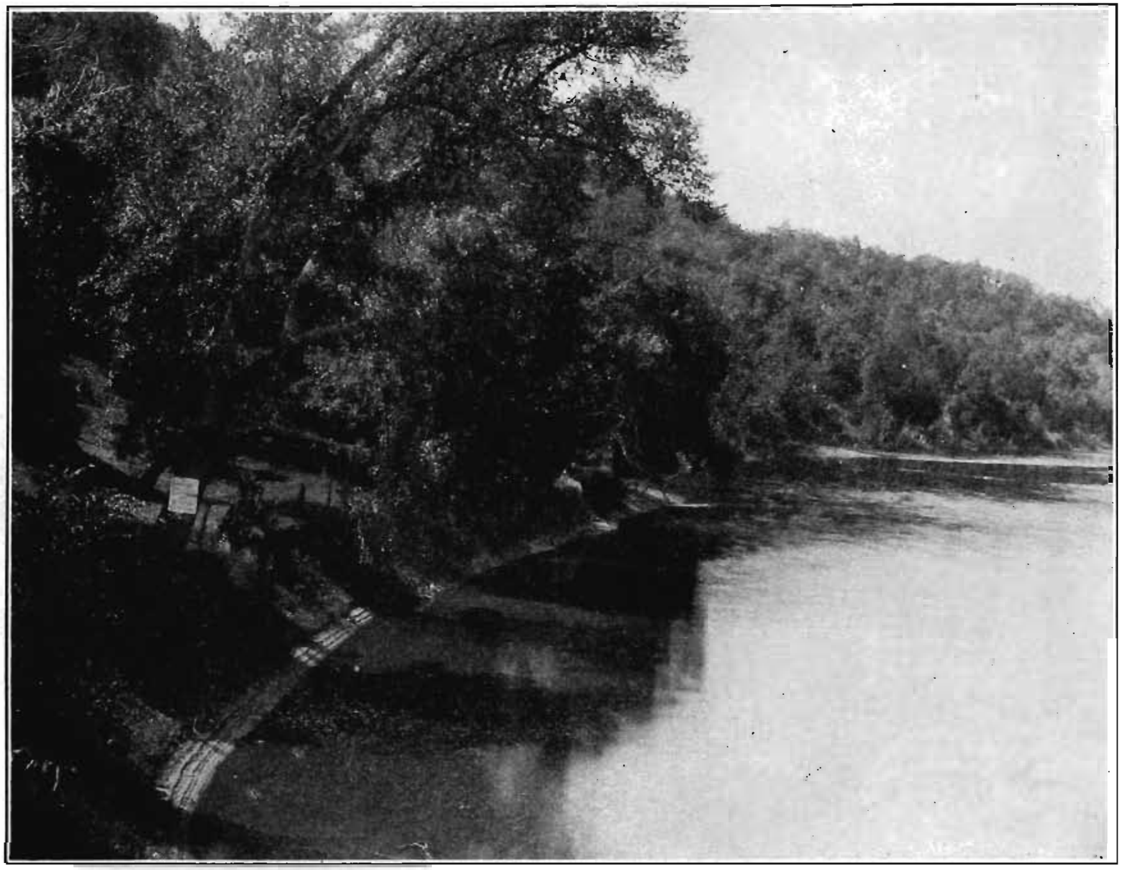


Plate XVII. The narrow valley of the Des Moines was filled with forest. The Des Moines river, looking south from the bridge northeast of Stratford.

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spring and so defended from fire the vegetation of such protected strongholds. Did the fire sweep the prairies late after the frosts of autumn, still in these river canyons the vegetation remained longer green. Besides, the mists of the river perhaps dampened, at least a little, everything day by day quite up to the valley-rim.

Be all this as it may, it is still the testimony of those who know, and present conditions verify the story, that only along the streams did forests flourish. We say present conditions reveal this fact, for, although nearly all the original forest has been rigorously cut away, yet here and there in places less accessible, some of the old trees still stand and these are almost invariably within the trough-like valleys of the streams. Since by the coming of white men and particularly by the cultivation of the prairie, especially during the last forty or fifty years, the prairie fires have ceased, the forested area has been much extended. Young trees of all native species spread out over the margin of the valleys, occupied with thrifty groves the sharp ravines of secondary or tributary streams or even narrow drainage coulees and until within comparatively recent years, bade fair to show in these prairie counties a wealth of woodland greater than the past had seen. Within the last two decades, however, the great increase in the value of agricultural lands in Iowa, even of lands unfit for tillage but suitable as thought for pasturage, has made profitable, at least in seeming, the artificial use of every accessible acre. The axe has been applied to every wooded slope, as well as to the thickets of the more serviceable and convenient lowlands, and the forests disappear.

Now there is no question that there are some tracts of land, not generally extensive, once tree-covered, which now serve excellently for pasturage or tillage; nevertheless it will usually be found that lands in the prairie regions primarily forest are when denuded subject to various disadvantages that diminish measurably the profit of their use. Such lands are either steep or close along the banks of streams. In either case they are sure to suffer from the erosive effect of storm water. If steep, the best soil speedily washes off, even if the whole surface does not cut into gullies or slide bodily an acre or two at a time.

If by the river, high water is apt to change frequently the course and current of the streams and to leave instead of a fine meadow or forest simply a widening desert of rocks and gravel and sand, into which in summer the very river seems inclined to sink out of sight. All these results may be noticed in all parts of Iowa where from our stream banks, the primitive fringe of forest has been cut away.

It is true, such is the beneficence of nature, that in Iowa, the removal of the trees is usually followed by bluegrass affording feed for cattle; but even bluegrass does not hold the soil like trees. Bluegrass on the steep hillsides, closely grazed, does not even hold its own. There are hillsides in Iowa today so grown up with ragweed of an *impoverished sort* that even goats find their occupation gone.

On the other hand there are many and good reasons why our native woodlands along the Boone and Skunk should be preserved as such. In the first place, as intimated, this is the most convenient use for these lands so subject to erosion and wear. Trees will hold these lands and use them indefinitely. In the second place, the tree cover protects the local water supply, by holding back too rapid drainage of the slopes. This at the same time prevents torrential streams, and floods that destroy the valleys and render vain and worthless all the toil of the farmer as his meadows and crops are swept away. But the trees themselves are of value. At present prices for lumber no farmer can any longer afford to be without his own woodlot. In days gone by when great forests of pine covered Minnesota and Wisconsin, this matter was of less concern, but today when lumbermen are prizing every stick from six inches up, when our two by four scantlings are made of mere saplings where only one piece of lumber is taken from a tree, it is evident that times have changed. Six-inch trees will grow in Iowa as quickly or more quickly than anywhere else, and the time is near when we shall raise our own supply of building material. Today portable sawmills are busy sawing into dimension stuff the very cottonwoods that our fathers planted but which have heretofore been thought worthless for lumber.

Finally, it is cheaper to keep a woodlot than to raise one. Our native groves offer a great variety of self-renewing species; a little care gives to the farmer a perpetual supply of fuel and lumber.

This matter has seemed to our legislators of such importance that in Iowa forestry statutes practically exempt from taxation lands devoted to orchard, grove and wood. When this fact becomes generally known the wooded area of the state will doubtless rapidly increase.

The most important woody species in the Boone valley—and this is typical of all the wooded parts of Hamilton and Wright counties, where woods are confined to stream valleys or borders of lakes and ponds—are here listed. In preparing this list the author acknowledges the generous assistance of Mr. M. P. Somes, an authority on the flora of this part of Iowa.

1. *Juniperus virginiana* Linn. Red Cedar.

This seems to be the only evergreen native to this part of Iowa. It is a fine little tree, whether for ornamental or more practical purposes. It grows in the shade of other trees and hangs to the steep banks of the river below Webster City, especially as the Boone approaches the Des Moines. There are large trees still standing in Webster township and small specimens are abundant. Cedar makes a good hedge, a fine border to the windbreak, and cedar posts are among the very best. Good cedar posts are raised in twenty years from the seed; from nursery plants in much less time, for the tree grows rapidly under favorable circumstances.

While this is the only native evergreen it must be understood that all other common species flourish here when planted. Larch, white pine, spruce, do well and may be made to contribute to the farmer's service.

2. *Populus deltoidea* Marshall. Cottonwood.

This is the old friend of the pioneer, planted everywhere by the bolder men who left the native grove and essayed the prairie. The seeds of the cottonwood are carried for miles on the winds of early summer and germinate immediately they find lodgment and moisture. Consequently they are apt to spring up at the borders of lakes and sloughs, on the sandy bars and banks of rivers, where they come up from year to year in uncounted thousands. On the open prairies the fires generally kept the seedlings down, but occasionally a lone tree grew old and storm-tossed, a landmark for travelers.

As already suggested, cottonwood makes good dimension-lumber, since men have learned how to pile and dry it. "Tortuous and errant in its course of growth" the boards, if tossed out carelessly from the saw, twist to worthlessness; but when carefully handled there seems no reason why cottonwood may not for many important purposes take the place of pine.

Cottonwoods are not social trees, are efficient only at the margin of our plantings, some other species must be used to fill up the interior.

3. *Populus grandidentata* Mx. Aspen.
The aspen or upland quaking asp, is one of the quick growing trees of our native woods. It springs up quickly and reaches early maturity. The trees generally occupy a definite place on a hillside, form fine straight poles, forty or fifty feet in length, but presently die or are supplanted by trees of other species. A very different tree from the ordinary quaking asp—next named species. Useful as affording poles of service to the farm and making excellent though light and quick-burning fuel.

4. *Populus tremuloides* Michx. Quaking Asp.
The quaking asp is a small tree found commonly in the border of native woods and groves. Often it occurs about an open area in the middle of a forest, especially where such opening is occasioned by a marsh or is an undrained natural meadow. In such cases the little stocky trees, their myriad dark green diminutive leaves all aquiver form a familiar and pleasing border to the somber wood behind. Except as an ornamental plant the tree has little value.

5. *Salix discolor* Muhlenberg. *S. amygdaloides* And. *S. nigra* Muhl. Willow.
These are the principal species of willow in our region. The first is the common species about prairie streams and marshes. Its leaves, bright green above and silvery below, make this a handsome ornamental shrub. The other two species named are the willow trees native to the river valleys, sometimes forty or

fifty feet high. They love the water and grow close to it. Useful chiefly for fuel and posts.

6. *Juglans nigra* L. and *Juglans cinerea* L.
These are the common Walnut and Butternut respectively. Of the black walnut the early settlers report large specimens in the valley of the Boone, and plenty of young trees a foot or more in diameter are still to be found in favored situations. Than the black walnut there is no finer tree. The old trees are nearly all gone, split into rails, sawed into lumber, cut for cord wood. But fortunately the tree springs readily from the seed and grows rapidly to utility and value. It is essentially a forest-tree, loves low rich sandy soils; but grows on the rich prairie soil very well too. It is however, very exclusive. No farmer can raise walnut trees and cattle on the same ground. The experiment is in process near Stratford with results sad to behold.

7. *Hicoria minima* (Marsh) Britt.
Hicoria ovata (Mill.) Britt. Hickory.
The hickories, so far as observed, are represented here by two species only. The first, the pig-nut or bitter-nut, has small thin-shelled and thin-husked fruit, inedible, except by the pigs, and possibly the squirrels. The second is the familiar hickory-nut tree. Both trees are valuable for fuel; the second affords a particularly strong and serviceable timber, now becoming scarce and costly. It is needless to tell a farmer the value of hickory poles for wagon stock. This tree is certainly worthy of protection if not cultivation.

8. *Carpinus caroliniana* Walt.
Ostrya virginiana (Mill.) Willd.
Corylus americana Walt.
These three small trees or bushes, form an interesting group of related forms, all worthy of preservation. The first is more often called blue beech or water beech. It is not a beech at all, rather an iron-wood; but it has beech-like bark and a small, somewhat three cornered seed, and these peculiarities possibly suggested the name. The tree, for small tree with us it is, grows close to the water, often right at the water's edge, by all

our northern streams, usually in thickets. The wood is exceedingly dense and strong and makes the best of tool handles, small repair stock, etc.

The second species named, the iron-wood, is a more common tree on all the hillsides; grows larger with us and is esteemed for fuel. The wood is also very hard and strong and is useful for several purposes, same as the last.

The third species is the familiar hazel nut. It is a border shrub, usually marks the transition to the fertile prairie, although by no means eschewing fertile soils itself. The nuts are the delight of healthy children and the plant should be preserved if for their enjoyment only.

9. *Quercus alba* L.
Quercus macrocarpa Mx.
Quercus rubra
Quercus schneckii
Quercus coccinea. The oaks.

This familiar group represents one of our finest series of trees, invaluable for every purpose for which wood can be used. The two species first named are the white oaks; the last three black oaks. Of the white oaks the first is the white oak proper, invaluable and eminently worthy the attention of every land owner; the second is the burr oak, so called on account of its rough cupped acorns. The burr oak is not quite so fine grained as is the white oak proper, but its wood when the tree is at its prime is exceedingly strong and fine. There are still standing many of the original native burr oak trees about the streets of Webster City, contributing much to the beauty of that town.

Of the black oaks less may be said; still *Q. rubra,* the red oak, furnishes a favorite lumber, beautiful for indoor finish. The black-oak group is notable for its pointed leaves, each lobe ending in a spine or bristle. The red oak has large cylindric acorns, the other two are with difficulty distinguished except by the careful observer; they commonly pass by the general name of jack oak.

10. *Ulmus americana* L.
Ulmus fulva Mx.
Celtis occidentalis L.

This is the elm group as represented in all western Iowa. The first is the common white, or American elm, of the trees of our lowlands, none finer. Perhaps also the most complaisant species we have, growing wherever and almost however planted, if right end up. No tree so commonly transplanted, no tree so generally abused in process. Very variable in habit is the white elm. Some trees are erect and regular, others low and spreading, some straight and symmetrical, others persistently crooked. This fact must be taken into account where one desires ornamental effect in planting. Elm wood is good for all purposes, and the old trees are rapidly passing into lumber throughout the whole country. The second species, the red or slippery elm, has much less economic value. *Celtis* is the hackberry, a beautiful forest tree, making fine fuel, and exceptionally handsome as an ornamental tree.

11. *Malus iowensis* (Wood) Britt.
Amelanchier canadensis (L.) Medic.
Crataegus crus-galli L.
Crataegus mollis (T. & G.) Scheele.

Crab apples and hawthorns are everywhere where Iowa supports forests at all. Our crab apple, in the opinion of botanists, is all our own and carries the name of the State to scientific fame. The second species listed is the June-berry or service-berry, beautiful in bloom in the very early spring when flowering shrubs are rare. The last two species are hawthorns; the first is distinguished by remarkable spines, long and slender; the latter by soft leaves, especially when young, and large red edible fruit.

All these are ornamental trees chiefly. They make an interesting border to our plantings, or stand in scattered clumps, beautiful at all seasons. The hawthorns can even withstand pretty well abuse by cattle and persist in the parched, hard-trodden pasture field.

12. *Prunus americana* Marsh.
Prunus serotina.

The wild plum and wild cherry form an interesting part of our forest flora. With us the wild cherry is seldom large enough for lumber, but eastward it attains great dimensions and makes fine cabinet material. The wild plum, the first species here named, has been deservedly popular for its delicious fruit. Birds scatter the wild cherry everywhere, while the wild plum has been often transplanted and is in some of its varieties the basis of our common garden fruit.

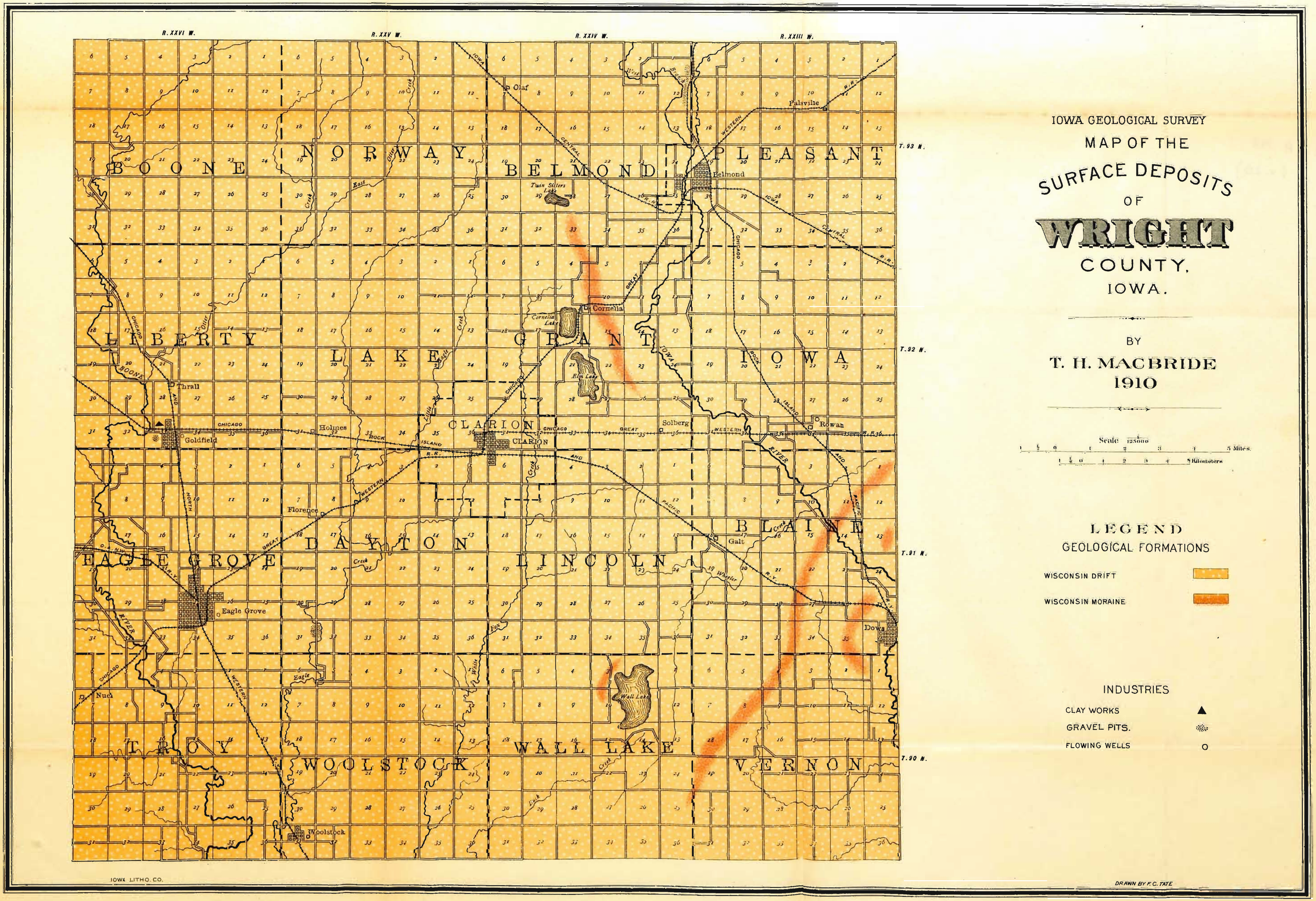
13. *Robinia pseudacacia* L.
Gleditschia triacanthos L.
Gymnocladus dioica (L.) Koch.

These are the pod-bearing trees of our Iowa woods and groves. Robinia is the common black locust, probably introduced, but now growing as if native everywhere; Gleditschia is the honey locust, a familiar and beautiful forest tree; and the third species receives in popular phrase the somewhat protracted title coffee-bean-tree. All are beautiful trees. The first two furnish wood of extreme value; nothing better for posts. The coffee-bean-tree makes good wood, but is withal an extremely handsome species, and even attractive in winter when, all its leaves discarded, its twigless branches seem as if stripped for storm.

14. *Acer saccharinum* L.
Acer nigrum Mx.
Acer negundo L.

The maples and willows are *par excellence* the Iowa farmer's trees. These have been universally planted. Especially is this true of the first species and the last in the list here cited. The soft or silver maple and the box-elder are our most commonly known trees. *Acer nigrum* is the present scientific or rather botanical name of the hard or sugar maple. This tree has its value every way and everywhere, but the soft maple and box-elder grow so rapidly and easily in all sorts of places that their utility as the basis of grove or windbreak on the inhospitable prairie is a matter of fifty years experience. It is time, however, that other trees affording better wood should come into general use. At least with such a variety as is here listed to select from, native to the region, there is no reason why our farms should not exhibit a far more pleasing diversity.

Near the mouth of the Boone river and especially along the Des Moines where it approaches our territory occurs a curious little buckeye, *Aesculus octandra* Marsh. This is another native species which deserves an introduction to our lawns and forest


IOWA GEOLOGICAL SURVEY
MAP OF THE
SURFACE DEPOSITS
OF
WRIGHT
COUNTY,
IOWA.
BY
T. H. MACBRIDE
1910
LEGEND
GEOLOGICAL FORMATIONS
WISCONSIN DRIFT
WISCONSIN MORAINE
INDUSTRIES
CLAY WORKS
GRAVEL PITS.
FLOWING WELLS
R. XXVI W.
R. XXV W.
R. XXIV W.
R. XXIII W.
T. 93 N.
T. 92 N.
T. 91 N.
T. 90 N.
BOONE
NORWAY
BELMOND
PLEASANT
LIBERTY
LAKE
GRANT
IOWA
EAGLE GROVE
DAYTON
LINCOLN
BLAINE
TROY
WOOLSTOCK
WALL LAKE
VERNON
Olaf
Palsville
Belmond
Cornelia
Thrall
Goldfield
Holmes
CLARION
Solberg
Rowan
Florence
Galt
Eagle Grove
Dows
Nuel
Woolstock
Twin Sisters Lake
Cornelia Lake
Elm Lake
Wall Lake
IOWA LITHO. CO.
DRAWN BY F.C. TATE

plantings, chiefly for its beauty. It is a small tree, as already noted, but its rich glossy foliage, curious flowers and fruits make it well worth our interest and attention. Unless cared for it is likely to disappear entirely.

15. *Tilia americana.* Basswood; Linden.
This beautiful species is well known and well appreciated. It is not so widely planted as it deserves. The soft wood is serviceable for lumber; but the chief value of the tree is for ornament and shade. The apiarist also puts in a claim on the source of pasture for his bees. Basswood honey is for most judges the very best.

16. *Fraxinus lanceolata* Borck.
Fraxinus nigra Marsh.
The ash is valuable for its wood. It makes excellent fuel, but more, its wood enters largely into the construction of machinery. The first species mentioned is the better and is that now widely planted. The ash grows more slowly than maples at the outset, but once started makes a good growth and is a clean, durable, in every way satisfactory contribution to our arboriculture.

In addition to these arboreal forms of vegetation, Hamilton and Wright counties possess as natives all the minor species of woody plants characteristic of north-central Iowa. We have snowberries and honeysuckles, sheepberry and elderberry, at least three species of dogwood or cornel; we have the wild grape and Virginia creeper, Jersey tea and wild indigo, burning bush and bittersweet; we even have plenty of *poison ivy;* then there are sumac, wild gooseberry and wild currants two or three species, one already in cultivation because of its beauty (*Ribes missouriensis*); we have wild roses, blackberries, raspberries—in fact all the small things that go to fill up the chinks and make up a woodland landscape. Everything needed to make beautiful the most unsightly corner of any farm or holding is already all ready for use. It remains only for human intelligence to supplement natural resources to make this part of Iowa a worthy portion of what is yet to be the most beautiful agricultural garden of the world.

GEOLOGY OF IOWA COUNTY

BY

S. W. STOOKEY

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GEOLOGY OF IOWA COUNTY

INTRODUCTION

LOCATION AND AREA.

Iowa county is situated in the southern part of the east central section of Iowa. The center of the county is about ninety miles directly west from the town of Princeton on the Mississippi river, while the southeast corner of the county is not more than half that distance from the river at its nearest point at Muscatine. It is about fifty miles east and twenty-five south of the geographical center of the state. Benton county bounds it on the north, Johnson county on the east, Keokuk and Washington on the south, and Poweshiek on the west. It is a square tract embracing sixteen congressional ownships, and on the supposition that the government survey is accurate, should contain 576 square miles or 368,640 acres. As a matter of fact, through inaccuracies in the survey, it contains nearly 369,000 acres. It includes Townships 78-81 North and Ranges 9-12 West of the Fifth Principal Meridian.

PREVIOUS GEOLOGICAL WORK.

Iowa county has not been an attractive field for geological work. It lies just beyond the coal fields of the state, and contains no mineral deposits of economic importance. The indurated rocks are exposed in only a few places, and in a very limited area. In the first study of a territory, the geologist generally directs his attention to the localities where he can conveniently examine outcrops of the indurated rocks, or where there is reason to suspect the presence of mineral deposits. Both these incentives are lacking in the case of Iowa county. Nevertheless there are a number of references to this county in the geological literature of the state. The earliest geologist to discuss the geology of this county was Dr. David Dale Owen. Dr. Owen, in describing a trip up the Iowa river in 1849, mentions certain gritstones found in section 26, Township 81 North, Range

9 West. He also describes the topography along the river and discusses the course of the margin of the Carboniferous limestone across Iowa county*. Hall and Whitney, 1858, speak of the almost total lack of rock exposures in this county, and refer to the bluffs of drift along the Iowa river. McGee, in his monograph on the Pleistocene History of Northeastern Iowa, included this county in the area described, it forming a part of the southern boundary of that area. He makes numerous references to Iowa county, particularly to the peculiarities exhibited in its topographical features as determined by its Pleistocene deposits, the behavior of the Iowa river in the county, and the Carboniferous outlier along the Iowa river. Mr. H. R. Mosnat, in his account of the artesian wells of the Belle Plaine area published in Vol. IX of the Reports of the present Survey, refers to the extension of that area into Iowa county, and describes a number of artesian wells of the area considered.

PHYSIOGRAPHY

Topography

This region, in common with nearly all the rest of the state, is covered with a thick mantle of drift, ranging in depth from a few feet to more than three hundred feet. Whatever topographic features the area exhibits, are expressed almost entirely in this universally distributed accumulation of loose material, which overlies the indurated rocks. Only in a very limited area, and to a very slight extent, do the indurated rocks have any part in forming the surface features.

The area under discussion exhibits topographic features of great interest and considerable variety. The Iowa river, entering the county one-half mile from the northwest corner, meanders in a direction a little south of east through a remarkable alluvial plain, and leaves the county about five miles south of the northeast corner. The flood plain of this river is bordered north and south by loess-covered hills rising from one to two hundred feet above the water level. Toward the north these hills extend

*Owen: Geological Survey of Wisconsin, Iowa and Minnesota, 1852, pp. 88-89, 99.

back from the river plain from one to three miles, ending in an irregular line of spurs and ridges which may be readily followed through Lenox township. These spurs and hills descend upon a gently rolling prairie stretching away to the north beyond the borders of the county. The loess hills south of the river are in most respects similar to those north of it, but more quickly and gently descend to the well drained rolling prairie that forms the southern and western three-quarters of the county.

The northeast part of the county, comprising twelve sections in Lenox township, exhibits for the most part the level or gently undulating topography that is characteristic of the Iowan drift plain. Scattered over the surface are bowlders of gray crystalline granite, such as are found generally distributed over much of the northeastern portion of the state in the area of Iowan drift. This extension of the Iowan drift plain into Iowa county is limited on the southwest by the range of spurs to which reference has been made, extending in a generally northwest-southeast direction. They may be traced from the northeast quarter of section 13, township 81 North, range 9 West, where they enter the county, in a northwest direction through the southwest quarter of section 12, Lenox township, thence in a westerly direction through the central parts of sections 11 and 10, thence in a northwesterly direction through the northeast quarter of section 9, and the southwest quarter of section 4, thence nearly due west across the southern part of sections 5 and 6, thence northwest through sections 1 and 2, township 81 North, range 10 West.

From any part of the comparatively level area of the Iowan drift plain, the traveler may see this conspicuous range of hills bounding his vision toward the southwest. They extend beyond the limits of Iowa county southeastward into Johnson county, and northwestward into Benton county. They mark the limit in this direction of the Iowan ice sheet.

Over the surface of these hills is a covering of sandy loess. This deposit is relatively thick, in places twenty-five and even thirty feet. About a mile south of the residence of Mr. August Schloemann in section 7, Lenox township, the roadway cuts into this deposit, which here exhibits indistinct stratification, to a depth of twenty-eight feet. In other places, as in sections 8 and 9, the road cuts show ordinary Kansan till underneath the mantle of loess. In numerous other places this relation of the Kansan till, overlain by a heavy deposit of more or less sandy loess, is readily seen. Everywhere the surface of the Kansan shows the effects of oxidation and leaching, the work of atmospheric agencies previous to the deposit of the loess. The loessial covering was spread upon a surface that had been long exposed to atmospheric agencies. In other words, these bordering hills of the Iowan area do not differ essentially from the loess-Kansan area in general, except in the thickness of the loess, and in the unusual proportion of sand.

Again there are reasons for belief that the border of the Iowan glacier was exceedingly thin in this region and could scarcely have piled up any considerable accumulation of true morainic material, either by push or dump. Here and there within the Iowan area are isolated groups of knolls or rounded hills, which rise from out the Iowan drift. These seem to be of Kansan age, and suggest the idea that the Iowan ice sheet was so attenuated in this region as to have failed to overcome these comparatively insignificant obstructions. A group of such hills is to be seen in the northeast quarter of section 9, Lenox township, on the Vette farm. Evidence of this thinning out of the Iowan ice sheet is also seen in the comparatively small amount of till spread over this border region. In places the wagon road cuts through the thin layer of Iowan till revealing the old weathered Kansan till beneath. Examples are found between sections 4 and 9, township 81 North, range 9 West. The Iowan plain in this region is not the typical plain seen further back from the border, with its almost level surface, its characteristic swells and sags, its imperfectly drained surface. Instead, one notes in places the undulations, the ravines and ridges characteristic of a region of more mature drainage. The explanation seems to be that the Iowan ice sheet failed completely, here along its border, to obscure the topography of the Kansan surface over which it spread, merely softening its ruggedness, but leaving the older topography partially revealed. If this is correct it would seem that the attenuated margin of the ice had little to do with the bordering hills further than perhaps to furnish the material of the loess which now caps them to a depth of several feet.

Here and there along this border region are also to be seen hills of sand, evidently of eolian origin. These sand dunes are especially well developed in the northern parts of sections 7 and 8, township 81 North, range 9 West.

LOESS TOPOGRAPHY.

The loess hills bordering the alluvial bottom lands of the Iowa river have already been referred to. On either side of the flood

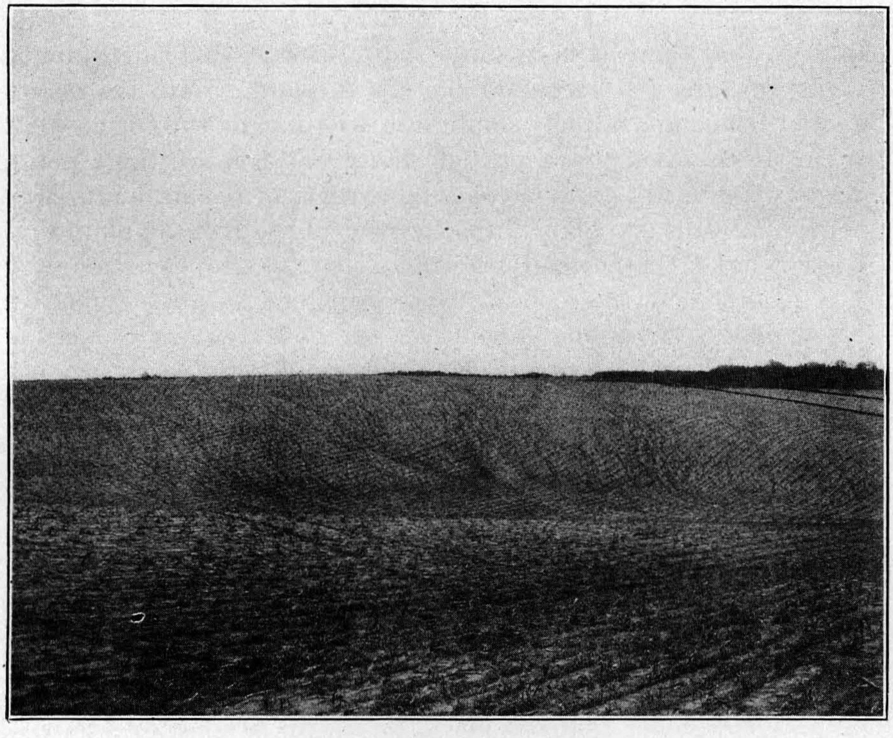


Figure 11. Erosion in a cultivated field of hilly loess. View taken near the north line of section 4, Township 81, Range 11 west.

plain, these hills rise from one to two hundred feet above the river. Not only so, but on traversing the maze of hills north and south of the river, it is found that they often rise a hundred feet above the general level of the plains into which they merge. As already indicated, the loess is everywhere laid down as a deposit upon the surface of hill and slope. It is by no means of uniform thickness, but the depth of the deposit shows no indication of dependence upon erosion. Sometimes the crests, sometimes the slopes of the hills show the thicker veneer. Whereever a natural or artificial section has been made, the loess is seen to be spread over the leached, oxidized and eroded surface of Kansan till. It is certain that if this covering of loess could be removed, there would remain the ancient land surface just as it existed at the time of the advance of the Iowan ice sheet. The general surface has been elevated by so much as the thickness of the loessial veneer, and thus stands above the adjoining plains. South of the river the mantle of loess thins out gradually, so that there is no definite limit, such as that north of the river, forming the border of the Iowan plain. With the exception of the comparatively small area occupied by the Iowan drift plain, Iowa county is a part of the great Kansan drift plain, which extends far south beyond the borders of the state into Missouri and Kansas. Like all that portion of the Kansan plain that borders upon the newer Iowan plain, its topography is more or less modified by the loessial covering which is spread upon it. Nevertheless, with the exceptions of those regions along the rivers where the accumulation is excessive, the loess has not greatly changed the original topography. One may travel over the southern part of Iowa and find the same prevailing types of topography that are characteristic of Iowa county. Stretching in a broad curve across the central part of the county—from east to west—is what is called "the divide." It is a strip of more level country six to eight miles wide including portions of Hartford, Lincoln, Sumner, Hilton, Troy, Iowa and York townships. Portions of this plain are quite level. It represents the greater part of the original prairie land of the county. The soil is here exceptionally rich and black, the farms are among the best in the county as evidenced by the unusually good farm improvements, and the satisfactions of the farm life, both in return for labor and in the ease with which the work is done, are at a maximum. The roads throughout this region run straight for many miles along the section lines.

If one traverses one of the more level portions of this divide, he will notice that it is moderately well-drained, the run-off from the surface finding its way into shallow swales, which if followed, will be found to unite with similar depressions coming in from the sides, the whole becoming more pronounced, and finally eventuating in a small creek, dry during most of the year, but carrying the run-off from the land during freshets. Followed further the run will be found to unite with others, until a considerable stream is developed carrying water during most of the year and trending toward the northeast or the southeast according, as its destination is the Iowa river to the north or one of the large streams to the south. Thus one passes from the more level middle portions of the divide, north and south to more and more broken and hilly country through which the larger waterways extend.

Similar areas, but of less extent, are found between the larger streams, in other parts of the county. Thus parts of Pilot, Troy and Fillmore townships are comparatively level, forming the interfluvial plain between Old Mans creek and North English river. The town of Parnell is situated in the midst of this plain.

These more level areas give some indication of what the topography of the whole region was originally, as left by the retreat of the Kansan ice sheet. They represent that portion of the original plain upon which the agencies of erosion have done the least work. During the time since the Kansan phase of the glacial period, the chief rivers and streams have been cutting deep into the deposits, widening their valleys and working back their slopes farther and farther, and encroaching more and more upon the level plains between streams. Every tributary is repeating on a smaller scale the same process, and heading back farther and farther into the divide. Thus finally, the divides themselves may become dissected and trenched by the same intricate system of dendritically arranged ravines, and the whole region will have reached the complete maturity of its drainage system.

In contrast with the more level reaches of the interfluvial areas, which formed the prairie land of the county, the country along the streams is dissected into an intricate system of ravines and ridges and hills. These parts of the county were originally wooded, and over much of the county they still remain so. It is true the primeval forests have been largely removed, but fine groves of black, white and burr oak, hickory, maple, walnut, elm, etc., have taken their places.

The following table of elevation of points within Iowa county is taken from Gannett:

TABLE OF ELEVATIONS.

LOCALITY.	ELEVATION.	AUTHORITY.
Amana	721	C., M. & St. P. R. R.
S. Amana	882	C., M. & St. P. R. R.
S. Amana	746	C., R. I. & P. R. R.
Conroy	883	C., M. & St. P. R. R.
Williamsburg	765	C., M. & St. P. R. R.
Parnell	859	C., M. & St. P. R. R.
North English	789	C., M. & St. P. R. R.
Homestead	864	C., R. I. & P. R. R.
Marengo	738	C., R. I. & P. R. R.
Ladora	783	C., R. I. & P. R. R.
Victor	805	C., R. I. & P. R. R.

Drainage

The Iowa river receives all the water of Iowa county. It enters the county one-half mile from the northwest corner and takes a southeasterly course. It forms the natural boundary line between part of Cono and Honey Creek townships, and all of Washington and Marengo townships. Amana township is trenched by it. As it meanders through a broad alluvial plain from one and a half to three miles wide, it is constantly changing its bed. The soft alluvium is easily worn back wherever the current is thrown against it. There is thus a constant tendency to increase the meanders, by the action of the current. This is overcome by a counter tendency which works toward the straightening of the channel. In times of flood the river overflows its low banks. At points where pronounced curves have been formed by the ordinary process of wearing, the swollen flood current fails to make the curve, cuts across instead, and thus forms a new channel. As the flood subsides the old curve may be resumed or the stream may be temporarily divided, part of the water keeping to the old channel and part taking the new, or the course may be at once changed to the new and straighter bed. In any case, sooner or later, the old channel is entirely abandoned and the new adopted. The entrance and exit of the old channels will be silted up in time, leaving an elongated lakelet of water. Thus are formed the so-called oxbow lakes, which are a characteristic feature of all rivers that meander through alluvial flood plains. A section of the Iowa river from Marengo eastward illustrating some of the steps and features of the process, is shown in Pl. XVIII.

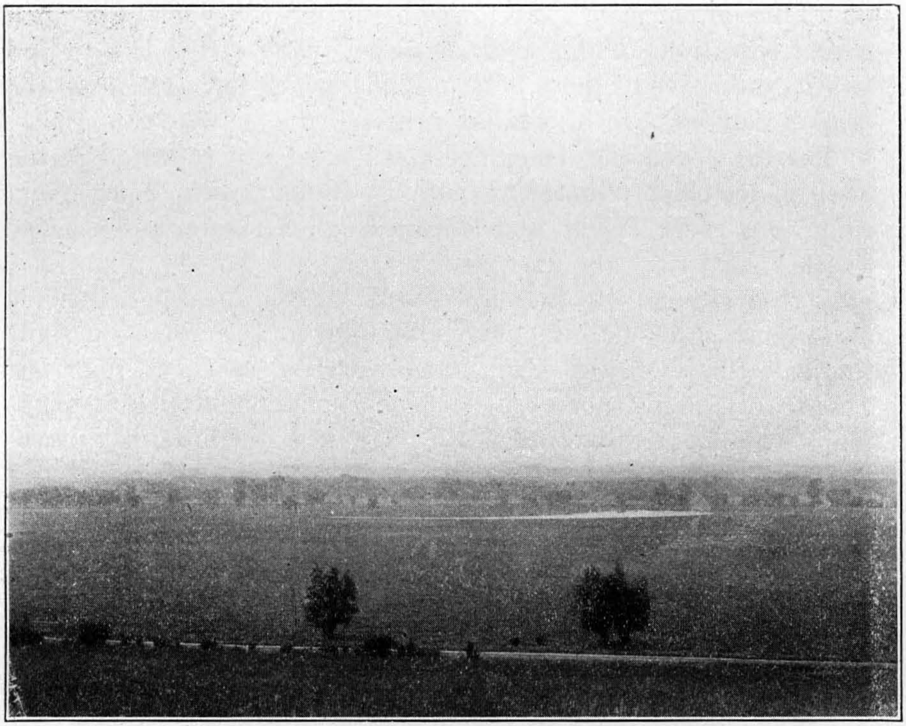


Figure 12. Broad valley of the Iowa river from near Hohe Amana.

In Amana township, the Amana Society has cut a channel from the west side of the township where the river enters to the bend in the river in section 26 of the same township, thus furnishing water power and supply to the villages of Middle Amana and Amana, and controlling to some extent the flood waters of the stream. This is the more effectually accomplished by the partial filling up of a depression in sections 27 and 28. Flood waters are gathered into this basin, preventing the inundations that would otherwise frequently occur.

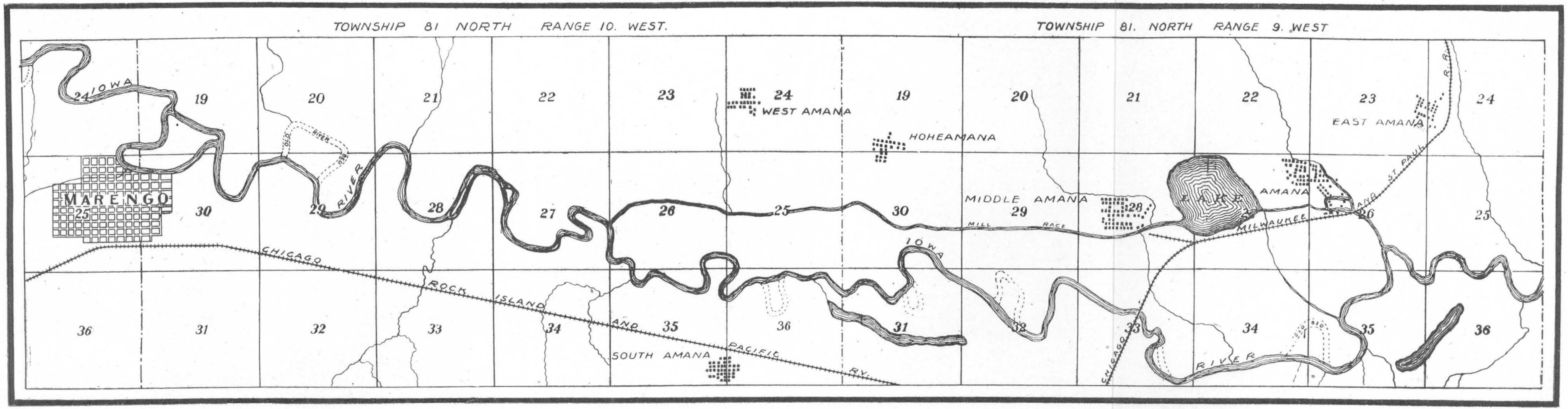
The valley of the Iowa river, as well as the valleys of all the principal streams of the county, are developed in the Kansan drift. Their history evidently dates from the retreat of the Kansan ice sheet. All are now partially filled with river gravel, sands, clays, and silts. These form the broad floors through which the streams now make their way in channels only from five to ten feet below the alluvial surface.

Along all the streams there are indistinct traces of terraces and alluvial benches. The towns along the river are built upon slight elevations of this character, and many of the richest and most productive of these bottom lands, which have rendered the region famous, are of similar origin.

The loess hills bordering the Iowa river are repeated in the case of its chief tributaries, notably Honey creek, Bear creek, Old Mans creek, North and Middle English rivers, and Gritter creek.

The drainage of the townships north of the river is through several small tributaries that flow into it almost at right angles. South of the river, Honey Creek, Marengo, most of Hartford, and the northern parts of Sumner and Hilton townships are drained by streams that flow in a northeasterly direction into the Iowa.

Honey creek heads in swales in section 6 of Hartford township and section 31 of Honey creek township, and flows through Honey Creek township into the Iowa at Koszta. During the spring and at times of heavy summer rains, this creek carries a large amount of water and overflows its low banks in its course across the flood plain of the master stream, sometimes destroying the splendid crops of corn that are grown upon these rich bottom lands. Bear creek and Little Bear creek enter from Poweshiek county and flow in a northeasterly direction through Hartford township to their confluence in section 4 of Sumner township; thence through Marengo township to the Iowa river about one mile northwest of Marengo. The Chicago, Rock Island and Pacific Railroad has availed itself of the flood plain of Big Bear creek for its road bed, leaving at Marengo the flood plain of the Iowa which it follows east of that town. Clear creek has



Segment of the Iowa River in Iowa county from Marengo eastward to the county line.

its sources in Hilton and Troy townships and flows in a southeasterly direction through Iowa township. It becomes a stream of importance in Johnson county.

The southern half of the county is drained by a series of streams which flow southeast almost parallel with the course of the Iowa river. The beginnings of Old Mans creek are found in Hartford, Sumner and Pilot townships. This stream takes a southeasterly course to Williamsburg, thence it flows almost south across sections 10, 15, 22, and 27, thence east through the southern part of York township. It becomes an important part of the drainage system of Johnson county.

Next to the Iowa river, the most important stream in Iowa county is English river with its confluents North English and Middle English rivers. These streams drain the southern group of townships. Lincoln, Dayton and English townships are entirely drained by English river, as are parts of Pilot, Fillmore, and Greene. The North English rises in Poweshiek county and flows in a southeasterly direction through the southern part of Lincoln township, thence across the southwest corner of Pilot, and the northeast corner of English township, to its confluence with the Middle English in section 20 of Fillmore township. It receives Deep creek and Devils run from the north and Jordan creek and Deep river from the south as its principal tributaries.

Middle English river also rises in Poweshiek county and, taking a course almost due east through Dayton and English townships, joins the North English as indicated above. Its principal branch is Gritter creek, which flows almost parallel with it through the southern part of Dayton and English townships, making its junction in section 25 of English township, one mile north of the town of North English.

The English river proper has a comparatively short course within the county. From the point in section 20 of Fillmore township where the North English and Middle English unite, to the point where it leaves the county in section 31 of Greene township, is not more than six miles.

STRATIGRAPHY

With a very few exceptions the whole surface of Iowa county is deeply covered by deposits of Pleistocene and Recent age.

The streams flow through filled valleys and have nowhere cut into the underlying indurated rocks. Certain sandstones of Carboniferous age are exposed in the bluffs on the north side of the Iowa river in Amana township, and limestone of Kinderhook age, not hitherto noted, is exposed in a very limited area in the bank of Price creek at Amana. All these are confined within an area of not more than eight or ten square miles, and are the only indurated rocks exposed within the county. The Pleistocene and recent deposits cover all the rest of the county to a depth varying from a few inches to several hundred feet. What the rocks are which underlie this surface deposit can only be inferred from their relation to the nearest exposures in other counties and from a comparison and interpretation of well records. Putting together all such data the distribution of the indurated rocks within the county may be represented with a fair degree of accuracy. (See map.)

TABLE OF FORMATIONS.

The following table shows the geological formations exposed within Iowa county or believed to underlie the Pleistocene drift.

GROUP	SYSTEM	SERIES	STAGE	FORMATION
Cenozoic	Quaternary	Recent	————?	Alluvium
		Pleistocene	Iowan	Loess Drift
			Kansan	Drift
			Aftonian	Gravels
			Nebraskan	Drift
Paleozoic	Carboniferous	Pennsylvanian	Des Moines	Sandstone
		Mississippian	St. Louis	Limestone
			Osage	Limestone
			Kinderhook	Cherty limestone, shale

DEVONIAN SYSTEM

CEDAR VALLEY STAGE.

There are no rocks of this stage exposed within the county. It is possible that they underlie the Pleistocene deposits in the northeastern part of the county, but as there are no exposures of rocks of Devonian age within several miles of the county line, the matter is entirely conjectural and no Devonian is included in the preceding table of geological formations.

CARBONIFEROUS SYSTEM

Mississippian Series

KINDERHOOK STAGE.

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

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

In the southern and southwestern part of Iowa county, well records show a limestone capping these shales. The Maple Mill Section as reported by Bain,* which is taken as typical of the sequence for the Kinderhook in the northwestern part of Washington county, shows the following formations:

		FEET.
4.	Limestone, ferruginous, arenaceous in places, fine grained, red, fossiliferous, cherty	10
3.	Gritstone, fine-grained, white to buff, fossiliferous	18
2.	Limestone, fine-grained, non-fossiliferous	1-6
1.	Shale, argillaceous, dark blue to drab, becoming almost black in places	12

At Wassonville, on English river, the shale (No. 1) seems inter-bedded with the limestone. The deep well at Washington shows eighty-two feet of shales, referred by Calvin to the Kinderhook. Mr. F. L. Pounds of Millersburg, a well driller and an intelligent observer, speaking of well records in the southern part of Iowa county, says: "The lime rock we strike here is not a continuation of the shale, but a distinct formation above the shale."

THE OSAGE AND SAINT LOUIS STAGES.

The limestone overlying the Kinderhook shales south of a line drawn from North English to Millersburg, thence west to the county line, may fairly be interpreted as representing these formations. Their exposures along the English river in Washington and Keokuk counties on the south indicate their presence underlying the drift in the southwestern part of Iowa county.

Pennsylvanian Series

DES MOINES STAGE.

At intervals in the bluffs along the north side of the Iowa river in Amana township is exposed a sandstone of the Des Moines stage. It has a futher extension eastward into Johnson county along the river as far as Knapp creek in Monroe township. Professor Calvin gives the following description of its characteristics, which applies equally well to the exposures in Iowa county:

*Iowa Geological Survey, Vol. V, p. 127.

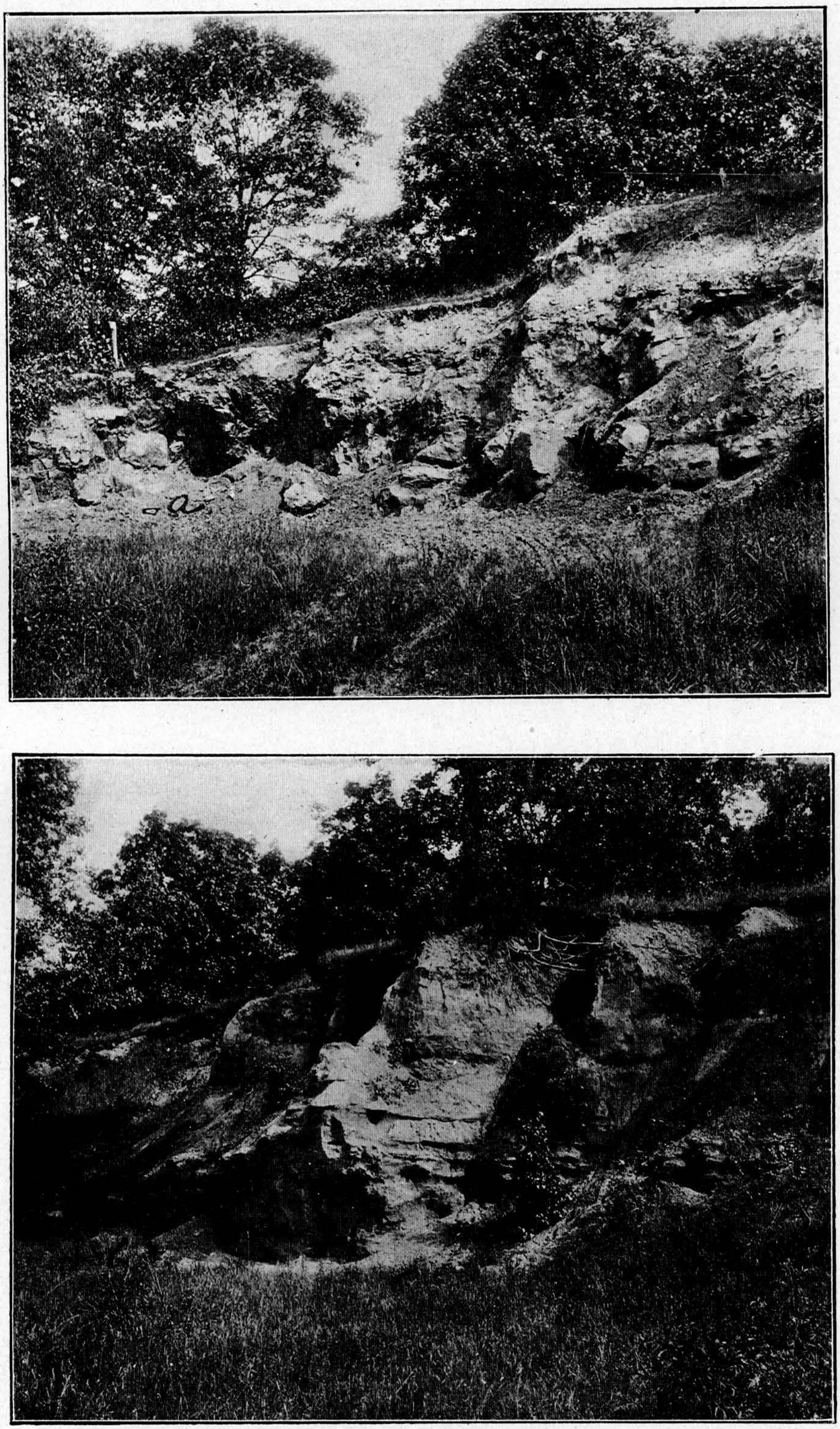


Plate XIX. Des Moines sandstone quarries west of Amana.

"The deposit is here a heavy bedded, and often crossbedded sandstone, composed of coarse grains of silica imperfectly cemented with iron oxide and calcium carbonate. The colors are dingy red and brown with some darker purplish streaks."

This isolated outlier of Des Moines sandstone occupying an area of probably not more than fifty square miles, is one of a number belonging to this stage scattered over eastern Iowa. Similar outliers are found in Linn, Jones, Jackson, Cedar, Clinton, Muscatine, Washington, and Johnson counties.

From the end of this Carboniferous outlier in Amana township to the eastern margin of the great body of the Upper Carboniferous series, which covers so large a portion of southern Iowa, is a distance of not more than twenty miles. It is a natural supposition that originally deposits of this age were widespread over this region, perhaps extending across into Illinois and connecting with the Coal Measures of that state. Professor Norton has thus stated the hypothesis:* "The views of Hall and White that the scattered sandstones were once laid down in isolated basins becomes less probable with each outlier discovered. Those now known are so numerous and widely distributed that they seem rather to support the view that over the depressed area of eastern Iowa the central and western coal fields were broadly joined, or united along a somewhat intricately dissected coast, the most northern known limit of shore or estuarian extension being in Jackson and Linn counties."

At a number of points, the sandstone is quarried for building purposes. Many of the houses in the villages of the Amana Society are constructed of it. It seems very durable above ground, but tends to disintegrate when used for foundations beneath the surface. The effect in buildings is not pleasing, owing to the tendency to discoloration from the contained iron oxide.

Aside from this outlying sandstone of the Coal Measures, there are no known rocks of this stage in Iowa county. The fact that the indurated rocks at no place outside of Amana township have a surface exposure renders it impossible to draw the limits of the geological terranes with certainty. It is possible

*Vol. III, Ann. Rep. Iowa Geological Survey, p. 133.

that other outliers may exist beneath the mantle of drift, although with one posible exception the drill, the only source of information, has given no indication of them. It is also possible that the eastern border of the Des Moines deposits may run through the southwest corner of the county, although again there is no certain evidence that it does so. The strong probability is that it runs several miles farther to the southwest.

QUATERNARY SYSTEM

Deposits of the Quaternary period all but cover the entire county. The bowlder clays, gravel, and sand deposits, and the superficial clays, as well as the extensive river silts, and other materials that fill the river valleys, all belong to the Quaternary.

Pleistocene Series

NEBRASKAN STAGE.

The oldest deposit of the Pleistocene Series in the county is a body of clay intermixed with pebbles and bowlders spread upon the uneven surface of the hard rock. At no point, so far as known, is the deposit exposed at the surface in Iowa county. It is recognized in well sections in various parts of our area. In the northwestern part of the county, lying within the Belle Plaine Artesian area, the drill, after passing through a yellow and a blue bowlder clay, penetrates a layer of sand or gravel, the aquifer for the region, and beneath this strikes another till described as dark in color, becoming lighter on exposure, bearing pebbles and bowlders.

At the time of the first ice invasion, before this ancient bowlder clay was deposited, the surface of Iowa county was covered by a soil derived from the disintegration of the underlying rocks. This surface was trenched by stream-ways cut deep into the sediments that had been laid down in Devonian seas and Carboniferous estuaries. Vegetation grew upon this ante-Pleistocene soil, consisting in part of a forest of gymnospermous trees. These facts are made evident by the inequalities of the surface of the indurated rocks as indicated by well-borings and by the fragments of wood found in connection with the till.

As the ice advanced slowly from the north over the county, the original soil, with its covering of vegetation, was overwhelmed; it was mingled with the material eroded by the ice from the partially weathered and disintegrated rock surface and also with morainic detritus brought down from the regions farther north; and all this loose rock waste of every kind was spread over the land to form the sheet of Nebraskan drift. The tendency was to level up the whole country, the ice sheet wearing down the elevations and filling up the valleys and depressions with the glacial debris. So great, however, had been the inequalities of the surface from the long period of erosion and stream action, that this levelling up process was only partial.

When at the close of this first phase of the Great Ice Age, the climatic conditions began to change and the ice to retreat, the streams probably resumed, to a large extent, their old channels and began to cut their way into the glacial deposits that had partially filled and choked them.

AFTONIAN INTERGLACIAL STAGE.

On the retreat of the Nebraskan ice sheet, there ensued a period of milder climate and the resumption of ordinary conditions. Atmospheric and aqueous agencies resumed their work. Oxidation, leaching, erosion, transportation of rock waste, the formation of soils, and the growth of vegetation ensued in normal order. The striking peculiarity of the time, however, was the accumulation at the surface of vast areas of sands and gravels. It is uncertain whether these are to be considered the result of the closing phase of the Nebraskan ice as it retreated from the country by melting, or whether they were accumulated during the inter-glacial period that followed. Doubtless coarse sands and gravels would naturally result in a general way by the removal of the finer materials through the movement of water from the melting ice as it made its retreat. In any case these deposits are found extensively between the Nebraskan till and the Kansan. In some places the presence of an old soil and forest bed is conspicuous, but in Iowa county the sands and gravels are more characteristic.

These accumulations overlying the Nebraskan drift are widespread. In Iowa county they form an important water bearing stratum. As shown by Mosnat* they form the aquifer for the Belle Plaine Artesian Area, which extends into Iowa county. As a general rule the wells of Iowa county are not sunk below this level, an abundance of water being found here, if not in the sandy inclusions in the Kansan drift above. In a few cases, however, notably in the uplands between the Iowa river and Old Mans creek, the drill passes through these sands without finding water. It is not known that these gravels are anywhere in the county exposed at the surface. The formation varies considerably in thickness and in the character of the deposit. Drillers report a depth of from five to thirty feet of sand and gravel referable to this stage. The material varies from coarse sand to coarse gravel. In some cases these Aftonian deposits rest upon the Carboniferous shales directly, the Nebraskan till being entirely absent. On the Wm. Thomas place, section 32, Hilton township, a body of sand is reported to rest upon soapstone.

The water from these Aftonian deposits is strongly mineralized. It corrodes metals and cements gravel and sand to the iron pipe.

KANSAN STAGE.

At the close of the Aftonian interval, a second extension of the ice carried its margin far toward the south into Missouri and Kansas, and there was spread upon the Aftonian surface a remarkably thick deposit of till, the ground moraine of the Keewatin glacier. The Kansan till in Iowa county varies considerably in thickness. It is a blue clay of rock flour, the product of the great ice-mill, with pebbles and bowlders intermingled. The upper portion, to a depth of many feet, however, has been changed to a yellow or brown color. In Iowa county where this bowlder till comes to the surface its color is brown or yellow. Well drillers describe it as a yellow clay with pebbles. Generally, this is the only phase seen at the surface, but everywhere the drill passes from the yellow till into the blue at an average depth of perhaps forty feet. Along with the oxidation

*Iowa Geological Survey, Artesian Wells of the Belle Plaine Area, Vol. IX, p. 532.

of the superficial portions of the till has gone a process of leaching. The lime constituent of the till has been removed generally from the upper three or four feet, and is frequently found accumulated at lower levels into lime balls or concretions.

A large percentage of the pebbles and bowlders of the Kansan till are not derived from the country rock, but have been brought from a distance. The crystalline pebbles, quartz, greenstones, granites, etc., found abundantly, have been carried hundreds of miles from their source. A considerable proportion, however,

Figure 13. Typical loess—Kansan topography. Seen in section 2, Township 81, Range 11.

consists of fragments of limestone and shale, derived from Iowa rocks, and these are either local or have been carried a comparatively short distance. These pebbles and bowlders are commonly faceted and striated, the work of the ice as it forced them forward over the underlying surface. Almost any roadside cut will furnish excellent specimens of such striation and faceting.

Everywhere the surface of the Kansan till has been deeply eroded. The drainage system of the region has been developed in it, and has already been described. The veneer of loess which generally covers it has not greatly obscured the erosional topography, and in many places disappears entirely, the bowlder clay coming quite up to the surface.

Lenticular layers of sand and gravel are common within the Kansan till. Such layers of sand and gravel form reservoirs for the accumulation of water and are the source of supply for many of the wells of Iowa county.

IOWAN STAGE.

The deeply eroded and oxidized surface of the Kansan till bears witness to the great lapse of time between the retreat of the Kansan ice and the deployment that spread the Iowan till. From the standpoint of geological history as a whole the Glacial Epoch forms but a minor episode in the development of the earth, but measured in years, the length of time required to develop such a topography as the Kansan drift shows, is enormous. But whatever the interval, in course of time the ice advanced again from the north, overspreading a large part of the area from which it had retreated, but not reaching nearly so far southward as before. In the direction of Iowa county its margin at its farthest southward advance stopped just short of the hills along the Iowa river. The margin of this advance has already been traced through Lenox township.

The till spread by this phase of glaciation differs in many important respects from the Kansan. Its thickness in general is not nearly so great, and along its margin, as already shown, it is exceptionally thin, so that it fails to disguise entirely the topography of the Kansan surface on which it was spread. The color of this till is yellow. Nowhere is there any covering of loess upon it, but the pebbles come quite up to the surface. A comparison of Kansan bowlder clay with Iowan will show a contrast in the pebbles and bowlders contained. The Iowan has its bowlders, often of large size, lying usually exposed upon the surface. The Kansan bowlders are smaller and buried out of sight. The bowlders of the Iowan are macro-crystalline and prevailingly light-colored. Kansan bowlders are more often dark colored and fine grained. Iowan bowlders also show far less variety than Kansan.

The Iowan drift sheet gives every evidence of its youth. Its surface is almost uneroded. In typical regions the streams flow almost at the surface in the midst of the plain. No valleys have been formed. Nothing like the maze of dendritically arranged ravines and ridges that are characteristic of the Kansan, is to be seen. The drainage system is in its youth.

An examination of the Iowan till shows further evidence that it is of recent origin as compared with the Kansan. The amount of leaching and oxidation is very small.

LOESS.

Overlying the gravel clay of the Kansan till in Iowa county is generally spread a silt-like deposit, the loess. The name is of German origin and refers to the rather loose, porous texture of the deposits of this character found along the rivers of Germany. The deposit does not appear in the northeastern portion of the county occupied by the Iowan drift, and in some portions of the middle and southern parts of the county the pebbly Kansan clay appears at the surface with no mantle of loess. In general it is thickest near the streams, where exposures may be seen in road cuts or ravines thirty or more feet in depth. It thins out toward the divides and in places disappears entirely. It forms the soil over the larger part of the county.

In composition the loess is a yellow clay with variable siliceous and calcareous constituents. In general there seems to be more siliceous sand in the deposits along the streams than in those farther back. The lime is frequently more or less leached from the loess and accumulated into curiously shaped nodules, called by the Germans, loess kindchen. A further effect of leaching and weathering is to render the deposit less porous and more plastic.

The loess is highly fossiliferous in some localities. In the clay banks of the old brick yard north of Marengo species of Helicina were found. Whatever the origin of the loess, it is generally conceded that a large part of the materials of our local deposits have been derived from the Iowan till. The age of the deposit is therefore contemporaneous with that of the Iowan drift or younger.

Recent Series

ALLUVIUM.

The alluvial deposits of Iowa county are relatively extensive. It is estimated that one-sixth of the entire surface of the county

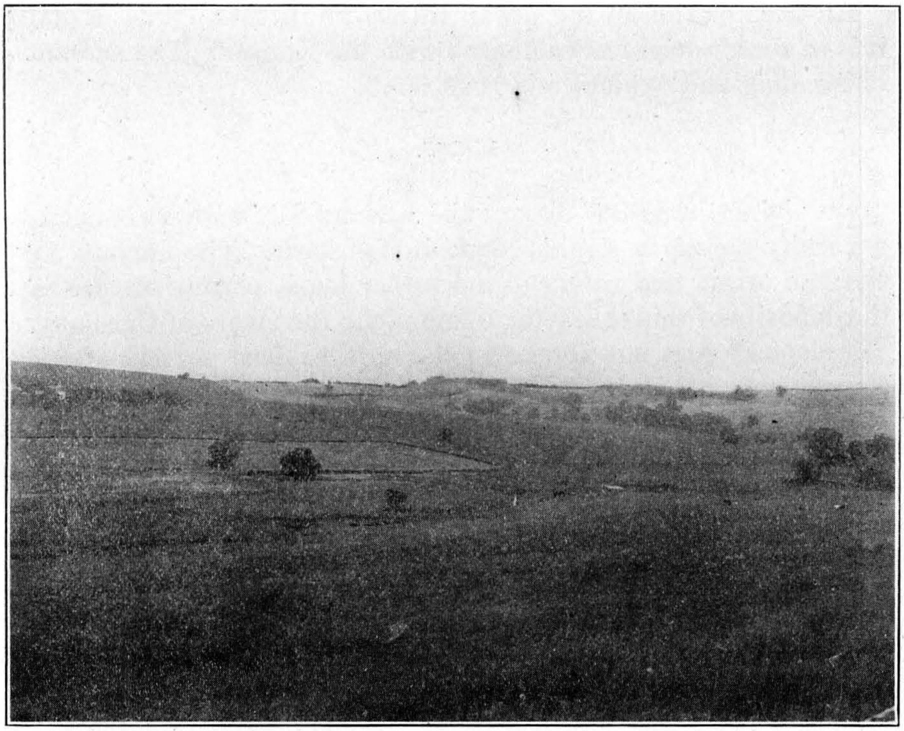


Figure 14. An alluvial valley typical of Iowa county streams. In section 1, Township 81, Range 11.

consists of bottom lands. All the principal streams meander through alluvial plains from a quarter of a mile to three miles in width. The alluvial plain of the Iowa river alone comprises an estimated area of sixty square miles. These bottom lands are for the most part rich sandy loams, and immense crops are raised upon them. Occasional inundations are destructive, but farmers believe that the total rewards of the cultivation of these lands are greater than of equal areas of uplands.

The Amana Society, one of the most interesting and successful communal organizations known, owns the bottom lands along the Iowa river in Amana township, and with its careful system of farming, raises fine crops of the various grains and grasses.

PREGLACIAL SURFACE

Although the almost universal presence of the thick mantle of drift and the lack of surface exposures of the indurated rocks in Iowa county render it difficult to restore the ancient surface upon which the drift was laid, nevertheless much may be inferred from well records. If these were sufficient in number and accuracy the whole surface could be restored with considerable detail. Unfortunately for this purpose, the number of wells that reach the bed rock is small, and drillers are not always careful to keep accurate records of those that do.

It has been shown by Mosnat that the Belle Plaine Artesian basin extends into Iowa county in a southeasterly direction as far as a line drawn from Marengo through Ladora to Victor. The hypothesis of a preglacial river valley running in a northwest-southeast direction through Tama, southwest Benton, and northwest Iowa counties has been generally accepted in explanation of the phenomena of the Belle Plaine basin. As the basin is some six miles in width and of considerable depth, the hypothetical river must have been at work during a long period of time cutting its gorge deeply into the sediments that had been laid down in the Carboniferous seas and subsequently elevated into a land surface; and in wearing down its slopes and widening its valley.

It was over such a surface as this that the first ice sheet deployed at the beginning of the Ice Age—a surface deeply eroded and dissected with stream valleys. The Nebraskan ice sheet was not able entirely to fill up these ancient valleys nor to reduce the elevations, although such was the tendency. When the ice retreated at the end of the Nebraskan phase, this broad valley still existed, although partly filled with glacial debris. It again became the channel of a river and the Aftonian sands and gravels were laid. The Kansan ice sheet again overspread the region and completely filled the valleys and leveled the whole face of the country.

There is evidence of the extension of this broad depression southeastward through Iowa county, although the artesian conditions that obtain in the Belle Plaine area do not exist. The thickness of the drift increases in a general way from the northeast and the southwest toward a line running in a northwest-southeast direction through the county. A section from Homestead to North English passing through Williamsburg and Parnell, would cut this basin almost at right angles. At North English the drill strikes rock at 599 feet above tide. At Parnell rock is found at 504 feet above tide, which is 95 feet lower than at North English, while the shale at Williamsburg is found at 400 feet above tide, or 234 feet lower than at North English. At Homestead the shales are found at 489 above tide, or 124 feet higher than at Williamsburg.

In Washington county Calvin calls attention to the buried river channel at the town of Washington, and Bain finds evidence of its extension into the northwestern part of the same county. The latter author suggests a connection of this with a buried channel in Poweshiek county at Deep River. It is probable that these are all parts of the ancient drainage system of the region, and that the principal waterway was the one occupying the valley traced from a few miles north of Vining in Tama county through Benton and Iowa counties and on through Washington county to its outlet.

ECONOMIC PRODUCTS

Soils

Loess clay or upland clay soil covers the larger part of the county. Its natural characteristics as a finely comminuted, complex mixture of mineral ingredients, possessing porosity, render it almost an ideal basis for a soil. Under the most favorable conditions, it can scarcely be excelled, and great crops of cereals are raised upon it. During the long period after this material was spread, a rank vegetation had possession of it, adding year by year and century after century a constantly increasing residuum of humus, gradually changing the superficial layer from a yellow to an ashen color, and assisting in preserving and increasing its life and porosity. These more level portions were the prairies and included the interfluvial divides. Year after year, century after century, the deep rooting perennials of the prairies brought from the deeper soils the plant food, and returned it in part to the surface either in their partially decayed tissues or in the ash left by the annual prairie fires. The atmosphere contributed its share to the enrichment of the soil, the rains and snows carrying down ammonia and nitric acid. Microorganisms, the nitrifying bacteria, and root bacteria, increasing with the growth of vegetation, elaborated in the soil more and more food in the most available form and in turn stimulated still further the growth of a rich vegetation. Thus, through centuries of time, the agencies of nature were elaborating and preparing the soils of Iowa county to produce immense crops under the culture of civilized man. The known processes by which soils are naturally enriched and made ready for large production should teach valuable lessons of soil management. The slow work of the centuries may by improper farming be destroyed and the soils rendered almost useless. The humus will soon be used up, the stored up food consumed in the gross-feeding cereal crops, the life and porosity of the soils lost under the leaching and washing unavoidable in cultural methods. These lessons have been learned too often by sad experience, and almost too late to apply the remedy. It was thought that these prairie soils were inexhaustible, but this is not true. The same natural agencies that have so generously operated in the ages past to prepare these soils are still here as active as ever, ready to cooperate with intelligence in rendering them still richer and more productive. The root-bacteria which grow upon the roots of the clovers, field peas, and other leguminous plants, will do their work in storing up food in the soil, and in producing an ideal mass of vegetable tissue to be returned to the soil as humus, if only given an opportunity. Fortunately these clay soils of the uplands of Iowa county are peculiarly adapted to the production of immense crops of clover. Valuable as this is as a forage crop, it will often pay many times better to return the whole crop to the soil, thus adding the necessary humus and vegetable acids, restoring the porosity necessary to the proper aeration of the soil, and proper action of capillarity upon the water in the soil.

The ability in a soil to stand well either excess of moisture or the lack of it, is dependent upon the presence in the soil of the qualities given by decaying organic matter. If the same thing is accomplished by the return of humus to the soil through stable manures, another set of bacteria is ready to assist in its proper elaboration into plant food. There is no reason why, by proper management, these soils may not be rendered increasingly responsive to culture and more and more productive.

Figure 15. Results of a common system of farming loess hills. Near the north line of section 4, Township 81, Range 11 west.

The loess soils in the more hilly regions along the streams furnish a problem of their own. Originally they were all wooded, and much of this area is still covered with trees and should be left so. The labor of farming these steep hillsides is excessive, and the returns are comparatively meager. In many places the soil is naturally poor from excess of sand. In other places the soil is naturally rich, but it washes badly, and the manure that is spread upon it is rapidly carried down the slopes and lost.

Where there is not excess of sand, the soil bakes, showing its loss of life and porosity. If such lands must be cultivated, their constant renewal by stable manures and especially by clover is absolutely essential to success.

The soil of the Iowan drift is in many ways in contrast with the loess-Kansan. The land is level or gently rolling. The soil itself is generally a rich black loam, and very productive.

The importance of the large body of alluvial soil in Iowa county has already been remarked. Much of this soil is exceedingly rich, warm and well drained. It seems as nearly inexhaustible as possible, producing year after year immense crops of corn, oats, and timothy. The rich agricultural lands possessed by the Amana Society are of this class. The occasional addition of silt and other debris to these bottom lands is an added source of fertility.

Water Supply

The water supply of Iowa county is from (a) the rivers, streams and springs; (b) ordinary drift wells; (c) ordinary wells drilled into bed rock; (d) artesian wells in drift; and (e) deep artesian wells. The region is well supplied with streams which furnish to the lands bordering them a fairly constant supply of good water. In times of extreme drouth, however, only the larger streams can be depended upon.

The principal source of water supply throughout the larger part of the county is the drift wells. Nearly everywhere the Kansan drift contains layers of sand and gravel which are reservoirs for an abundance of water of the best quality. Ordinary wells in rock are chiefly confined to the southwestern parts of the county, where an abundance of water is obtained in lime or sand rock at a depth of 150 to 250 feet. Throughout those parts of the county where the Pleistocene deposits are underlain by shale, the wells are in the drift. The shales are non-water-bearing, and rarely are they penetrated for the supply that might be found in the Devonian limestones beneath. At Williamsburg and Parnell are wells furnishing excellent water from Devonian limestone. As already noted, the northwestern part of the county as far south as Ladora forms a part of the Belle Plaine Artesian Area.

The Aftonian gravels form the aquifer at a depth of fifty to two hundred feet, varying with the location with reference to the axis of the basin. The water from these wells is strongly mineralized and corrosive. It is excellent for stock, but useless for drinking and cooking.

The town of Marengo has three artesian wells, one in the park, one in the public school grounds, and one at the Lovell House. The aquifer for these wells is the Devonian limestones. Homestead and Amana have deep artesian wells, strongly mineral.

Lime

In the early years of the colonists at Amana, they burned their lime for local use from the Kinderhook limestone exposed at their principal village. It proved of excellent quality as to durability and strength, but was dark colored. Later other limes were shipped in and at the present time, no lime is burned in the county.

Building Stone

The outlier of the Des Moines sandstone exposed in the bluffs along the Iowa river in Amana township has been quarried at several places, notably west of West Amana, east of Hohe Amana, and near East Amana. The largest amount has been taken from the quarry at West Amana. Many of the buildings of the villagers belonging to the Amana Society are of this stone, and occasionally it has been used in other places in the county. It is quite soft when taken from the quarry, but hardens on exposure into a fairly durable building stone, especially when used above ground. It tends to disintegrate when used below ground. Its effect in buildings is not particularly pleasing, owing to the discoloration of the iron. Bowlders of the Iowan drift have been used to some extent for building purposes, but they are comparatively scarce, even in parts of the county overspread with Iowan till.

Clay Products

Iowa county has an inexhaustible supply of the best material for brick, tile, and crockery. The alluvial and upland loessial clays are unexcelled for this purpose. Several brick and tile plants have been established in the county and for the most part are doing a good business.

Mr. J. W. Wagner has a well equipped plant two miles south of Marengo. He employs from fifteen to twenty men. He has four kilns with a total capacity of 340,000 bricks. The upper five feet of the loess works best, being more plastic. The unleached deeper portion is "short". A mixture of the surface clay with the deeper layers increases plasticity. Mr. Wagner proposes to install a machine for removing the pebbles from bowlder clay, and mixing this with the loess clay.

Lewis and Lewis, located two miles southeast of Williamsburg, have an excellent equipment for the manufacture of brick and tile. Steam is used in drying, thus extending the working year. The clay used is a secondary deposit from the Kansan till and loess. This clay possesses high plasticity, and would be improved with an admixture of sand, if such were available. The product is of excellent quality. Practically the whole output is used locally. Smith Brothers of North English have four kilns and run an extensive business, making brick and tile. H. A. Cheney of Millersburg has one kiln in operation making brick.

Coal

With the exception of the outlier of the Des Moines sandstone along the Iowa river in Amana township, all the rocks that lie beneath the surface in Iowa county are older than the Coal Measures. No rocks older than the Coal Measures have ever been known to yield workable coal. Iowa county lies entirely beyond the region of the Coal Measures and there is no evidence that coal exists anywhere in the deposits of the county.

Meteorites

Although not a purely geological subject, it is proper to refer to the Amana meteorite of 1875. This wonderful meteorite was seen, in its fall, over an area reaching from St. Louis to St. Paul, and from Chicago to Omaha, and produced a profound sensation by its unusual brilliancy. Before reaching the earth it parted into two bodies, with loud detonation. The larger of the two bodies passed on over Iowa county and was believed to have fallen in Benton county, but was never found. The smaller portion fell in fragments over the region south of the Amana villages, townships 80-81 North, ranges IX-X West. The meteorites collected from this field weigh, together, according to Hinrichs, from whose account the facts are taken, nearly a quarter of a ton, and constitute one of the most remarkable collections of cosmical matter in the world. These meteorites have been generally distributed through the great museums of this country and Europe.

ACKNOWLEDGMENTS

The writer would acknowledge with thankfulness the aid received in his work in Iowa county from many of its citizens. A number of well drillers, including Mr. M. B. Wright of Marengo, Thomas Gittens of Williamsburg, and F. L. Pounds of Millersburg, were painstaking and obliging in giving information concerning the wells of the county. Dr. Charles F. Noe of Amana, Dr. William Moershal of Homestead and others of the Amana Society gave valuable and much appreciated assistance. Mr. Conrad Schadt, the druggist of Amana, compiled the list of plants published in connection with this report. And especially Dr. Calvin, Director of the Survey, has been ready with help and suggestions at all times. The photographs are by Dr. Calvin.

FLORA OF IOWA COUNTY

A list of plants found growing wild in Iowa county, Iowa; by *William Moerschal and Conrad Schadt, pharmacists, Amana, Iowa. Compiled by C. Schadt.

Orders or families and nomenclature are based upon Gray's Manual, 5th edition.

Ranunculaceae.	Crowfoot Family.
Clematis Viorna	Leather-flower
Clematis Virginiana	Common Virgins' Bower
Anemone Pennsylvanica	Pennsylvanian Anemone
Anemone nemorosa	Wind-flower. Wood Anemone
Hepatica triloba	Round-lobed Hepatica. Liver-leaf

*Deceased.

Hepatica acutiloba	Sharp-lobed Hepatica
Thalictrum anemonoides	Rue-anemone
Thalictrum purpurascens	Purplish Meadow-rue
Ranunculus abortivus	Small flowered Crowfoot
Ranunculus fascicularis	Early Crowfoot
Ranunculus repens	Creeping Crowfoot
Ranunculus acris	Buttercups
Caltha palustris	Marsh Marigold
Aquilegia Canadensis	Wild Columbine
Menispermaceae.	**Moonseed Family.**
Menispermum Canadense	Canadian Moonseed
Berberidaceae.	**Barberry Family.**
Caulophyllum thalictroides	Blue Cohosh
Podophyllum peltatum	May-apple
Nympheaceae.	**Water-Lily Family.**
Nelumbium luteum	Yellow Nelumbo
Papaveraceae.	**Poppy Family.**
Chelidonium majus	Celandine
Sanguinaria Canadensis	Blood-root
Fumariaceae.	**Fumitory Family.**
Dicentra cucullaria	Dutchman's Breeches
Cruciferae.	**Mustard Family.**
Nasturtium palustre	Marsh Cress
Nasturtium Armoracia (Escaped from gardens)	Horseradish
Brassica Sinapistrum	Charlock
Capsella Bursa-pastoris	Shepherd's Purse
Thlaspi arvense	Field Pennycress
Capparidaceae.	**Caper Family.**
Cleome pungens	Cleome
Violaceae.	**Violet Family.**
Viola cucullata	Common Blue Violet
Viola pubescens	Downy Yellow Violet
Hypericaceae.	**St. John's-Wort Family.**
Hypericum pyramidatum	Great St. John's-wort

Caryophyllaceae.	**Pink Family.**
Stellaria media	Common Chickweed
Portulacaceae.	**Purslane Family.**
Portulaca oleracea	Common Purslane
Claytonia Virginica	Narrow-leaved Spring Beauty
Malvaceae.	**Mallow Family.**
Abutilon Avicennae	Velvet Leaf Indian Mallow
Hibiscus militaris	Halbert-leaved Rose Mallow
Tiliaceae.	**Linden Family.**
Tilia Americana	Basswood. Whitewood
Geraniaceae.	**Geranium Family.**
Geranium maculatum	Wild Cranesbill
Impatiens fulva	Spotted Touch-me-not
Oxalis violacea	Violet Wood-sorrel
Oxalis stricta	Yellow Wood-sorrel
Oxalis corniculata	Yellow Wood-sorrel
Rutaceae.	**Rue Family.**
Zanthoxylum Americanum	Northern Prickly Ash
Anacardiaceae.	**Cashew Family.**
Rhus glabra	Smooth Sumach
Rhus Toxicodendron	Poison Ivy, Poison Oak
Rhus radicans	Climbing Ivy. Poison Ivy
Vitaceae.	**Vine Family.**
Vitis cordifolia	Winter or Frost Grape
Ampelopsis quinquefolia	American Ivy. Virginia Creeper
Rhamnaceae.	**Buckthorn Family.**
Ceanothus Americanus	New Jersey Tea
Celastraceae.	**Staff-Tree Family.**
Celastrus scandens	Wax-work. Climbing Bitter-sweet
Euonymus atropurpureus	Burning-bush. Wahoo

Sapindaceae.	Soapberry Family.
Acer saccharinum (rare)	Sugar or Rock Maple
Acer dasycarpum	Silver Maple
Acer rubrum	Red or Swamp Maple
Negundo aceroides	Box Elder. Ash-leaved Maple
Polygalaceae.	**Milkwort Family.**
Polygala sanguinea	Milkwort
Polygala Senega	Seneca Snakeroot
Leguminosae.	**Pulse Family.**
Trifolium arvense	Rabbit-foot or Stone Clover
Trifolium pratense	Red Clover
Trifolium repens	White Clover
Psoralea melilotoides	Psoralea
Petalostemon violaceus	Purple Prairie Clover
Petalostemon candidus	White Prairie Clover
Amorpha fruticosa	False Indigo
Amorpha canescens	Lead Plant
Robinia pseudacacia	False Acacia. Common Locust Tree
Astragalus canadensis	Milk Vetch
Desmodium acuminatum	Tick Trefoil
Desmodium humifusum	Tick Trefoil
Lathyrus pratensis	Vetchling. Everlasting Pea
Apios tuberosa	Ground Nut
Phaseolus diversifolius	Wild Bean
Baptisia leucantha	White False Indigo
Baptisia leucophaea	Yellow False Indigo
Cassia Marilandica	Wild Senna
Gleditschia triacanthos	Honey Locust. Three-thorned Acacia
Rosaceae.	**Rose Family.**
Prunus Americana	Wild Yellow or Red Plum
Prunus Pennsylvanica	Wild Red Cherry
Prunus Virginiana	Choke Cherry
Prunus serotina	Wild Black Cherry
Spirea salicifolia	Common Meadow-sweet
Spirea lobata	Queen of the Prairie

Geum album	Avens
Potentilla Norvegica	Five-finger
Fragaria vesca	Wild Strawberry
Rubus villosus	Common or High Blackberry
Rubus Canadensis	Low Blackberry. Dewberry
Rosa blanda	Early Wild Rose
Rosa lucida	Dwarf Wild Rose
Crataegus coccinea	Scarlet-fruited Thorn
Crataegus oxyacantha	English Hawthorn
Crataegus tomentosa	Black or Pear Thorn
Pyrus coronaria	American Crab Apple
Saxifragaceae.	**Saxifrage Family.**
Heuchera hispida	Alum Root
Crassulaceae.	**Orpine Family.**
Penthorum sedoides	Ditch Stone-crop
Sedum acre	Mossy Stone-crop
Onagraceae.	**Evening Primrose Family.**
Oenothera biennis	Common Evening Primrose
Lythraceae.	**Loosestrife Family.**
Lythrum alatum	Loosestrife
Cucurbitaceae.	**Gourd Family.**
Echinocystis lobata	Wild Balsam-apple
Umbelliferae.	**Parsley Family.**
Sanicula Canadensis	Black Snakeroot
Eryngium yuccaefolium	Button Snakeroot
Thaspium aureum	Meadow Parsnip
Cryptotaenia Canadensis	Honewort
Osmorhiza longistylis	Smoother Sweet Cicely
Eulophus Americanus	Eulophus
Araliaceae.	**Ginseng Family.**
Aralia racemosa	Spikenard
Aralia nudicaulis	Wild Sarsaparilla
Aralia quinquefolia (very rare)	Ginseng

Cornaceae.	Dogwood Family.
Cornus sericea	Silky Cornel. Killikinnik
Cornus asperifolia	Rough-leaved Dogwood
Caprifoliaceae.	**Honeysuckle Family.**
Lonicera sempervirens	Trumpet Honeysuckle
Triosteum perfoliatum	Fever-wort. Horse Gentian
Sambucus Canadensis	Common Elder
Viburnum Lentago	Sheepberry
Viburnum prunifolium	Black Haw
Viburnum Opulus	Cranberry Tree
Rubiaceae.	**Madder Family.**
Galium Aparine	Cleavers. Goose Grass
Galium triflorum	Sweet-scented Bedstraw
Cephalanthus occidentalis (rare)	Button-bush
Compositae.	**Composite Family.**
Liatris scariosa	Blazing Star. Button Snake-root
Liatris spicata	Blazing Star. Button Snake-root
Liatris pycnostachya	Blazing Star. Button Snake-root
Liatris paniculata	Blazing Star. Button Snake-root
Kuhnia eupatoroides	Kuhnia
Eupatorium purpureum	Joe-Pye Weed
Eupatorium perfoliatum	Thoroughwort. Boneset
Eupatorium ageratoides	White Snakeroot
Tussilago farfara (Escaped from gardens)	Coltsfoot
Sericocarpus tortifolius	White-topped Aster
Aster dumosus	Aster
Aster multiflorus	Aster
Aster Novae-Angliae	Aster
Aster sagittifolius	Aster
Aster ericoides	
Erigeron Canadense	Horse-weed. Button-weed

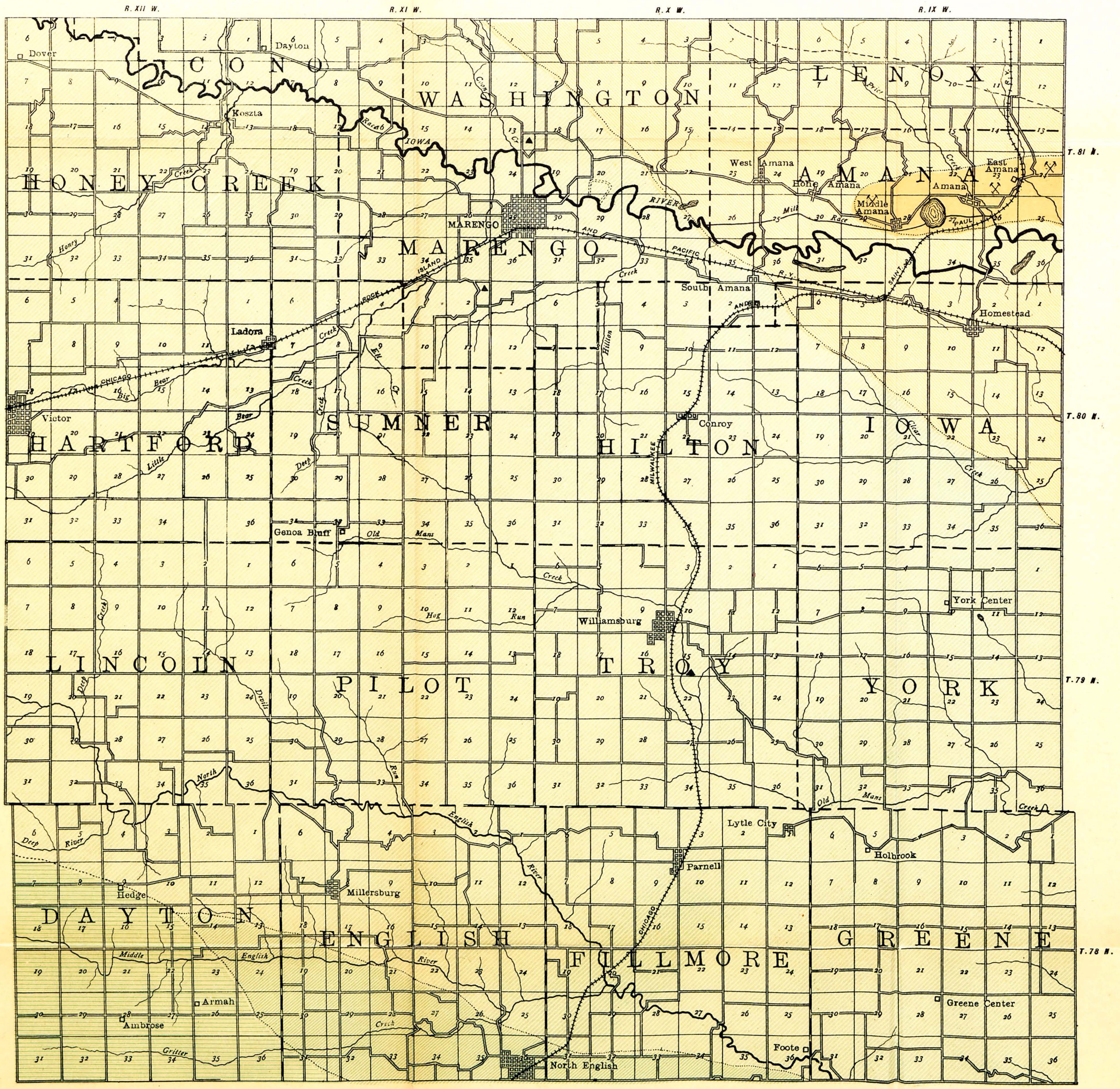
Erigeron philadelphicum	Common Fleabane
Boltonia glastifolia	Boltonia
Solidago Missouriensis	Golden-rod
Solidago rigida	Golden-rod
Inula Helenium (Escaped from gardens)	Elecampane
Silphium laciniatum	Compass-plant
Silphium perfoliatum	Cup-plant
Silphium integrifolium	Rosin-plant
Parthenium integrifolium	Parthenium
Ambrosia trifida	Great Ragweed
Ambrosia artemisiaefolia	Roman Wormwood
Xanthium strumarium	Common Cocklebur
Heliopsis laevis	Ox-eye
Echinacea purpurea	Purple Cone-flower
Rudbeckia hirta	Cone-flower
Rudbeckia triloba	Cone-flower
Lepachys pinnata	Cone-flower
Helianthus annuus	Common Sunflower
Helianthus grosse-serratus	Sunflower
Helianthus laetiflorus	Sunflower
Coreopsis tripteris	Tickseed
Bidens frondosa	Common Beggar-ticks
Bidens connata	Swamp Beggar-ticks
Dysodia chrysanthemoides	Fetid Marigold
Helenium autumnale	Sneeze-weed
Maruta Cotula	Common May-weed
Achillea millefolia	Milfoil. Common Yarrow
Leucanthemum vulgare	Ox-eye or White Daisy
Tanacetum vulgare (Escaped from gardens)	Common Tansy
Artemisia Ludoviciana	Western Mugwort
Antennaria plantaginifolia	Plaintain-leaved Everlasting
Cacalia tuberosa	Tuberous Indian Plantain
Cacalia atriplicifolia	Pale Indian Plantain
Senecio aureus	Golden Ragwort
Cirsium discolor	Common or Plumed Thistle
Lappa officinalis	Common Burdock

Cichorium Intybus	Succory or Cichory
Hieracium venosum	Rattlesnake-weed
Nabalus asper	Rattlesnake-root
Nabalus albus	White Lettuce
Taraxacum dens-leonis	Common Dandelion
Lactuca Canadensis	Wild Lettuce
Sonchus asper	Spiny-leaved Sow-thistle
Sonchus oleraceus	Common Sow-thistle
Lobeliaceae.	**Lobelia Family.**
Lobelia cardinalis	Cardinal-flower
Lobelia syphilitica	Great Lobelia
Lobelia inflata	Indian Tobacco
Campanulaceae.	**Bellflower Family.**
Campanula rotundifolia	Harebell
Campanula Americana	Tall Bellflower
Specularia perfoliata	Venus's Looking-glass
Ericaceae.	**Heath Family.**
Pyrola elliptica	Shin-leaf
Monotropa uniflora (rare)	Indian Pipe
Plantaginaceae.	Plantain Family
Plantago major	Common Plantain
Plantago lanceolata (Escaped from gardens)	Ribgrass. English Plantain
Primulaceae.	**Primrose Family.**
Dodecatheon Meadia	American Cowslip. Shooting Star
Bignoniaceae.	Bignonia Family.
Tecoma radicans (cultivated)	Trumpet Creeper
Catalpa (cultivated)	Catalpa
Scrophulariaceae.	Figwort Family.
Verbascum Thapsus	Common Mullein
Scrophularia nodosa	Figwort
Chelone glabra	Turtle Head. Balmony
Pentstemon digitalis	Beard's-tongue. Pentstemon

Veronica Virginica	Culver's Physic
Veronica peregrina	Neckweed. Purslane. Speedwell
Gerardia purpurea	Purple Gerardia
Gerardia tenuifolia	Slender Gerardia
Castilleia coccinea	Scarlet Painted-cup
Pedicularis Canadensis	Common Lousewort
Melampyrum Americanum	Cow-wheat
Ilysanthes gratioloides	False Pimpernell
Verbenaceae.	**Vervain Family.**
Verbena hastata	Blue Vervain
Verbena urticaefolia	Nettle-leaved or White Vervain
Verbena bracteosa	Prostrate Vervain
Phryma leptostachya	Lopseed
Labiatae.	**Mint Family.**
Mentha viridis	Spearmint
Mentha piperita	Peppermint
Lycopus Virginicus	Bugle-weed
Pycnanthemum lirifolium	Mountain Mint
Pycnanthemum lanceolatum	Mountain Mint
Monarda fistulosa	Wild Bergamot
Lophantus nepetoides	Giant Hyssop
Nepeta Cataria	Catnip
Brunella vulgaris	Common Self-heal or Heal-all
Scutellaria lateriflora	Mad-dog Skullcap
Stachys palustris	Hedge-nettle
Lamium amplexicaule	Dead-nettle
Leonurus Cardiaca	Common Motherwort
Borraginaceae.	**Borage Family.**
Lithospermum hirtum	Hairy Puccoon
Mertensia Virginica	Virginian Cowslip or Lungwort
Echinospermum Lappula	Common Stickweed
Hydrophyllaceae.	**Waterleaf Family.**
Hydrophyllum Virginicum	Waterleaf
Ellisia nyctelea	Ellisia

Polemoniaceae.	**Polemonium Family.**
Polemonium reptans	Polemonium
Phlox pilosa	Wild Phlox
Convolvulaceae.	**Convolvulus Family.**
Ipomoea purpurea	Common Morning Glory
Calystegia sepium	Hedge Bindweed
Cuscuta glomerata	Dodder
Solanaceae.	**Nightshade Family.**
Solanum nigrum	Common Nightshade
Physalis pubescens	Ground Cherry
Datura Stramonium	Common Stramonium. Thorn Apple
Gentianaceae.	**Gentian Family.**
Gentiana Andrewsii	Closed Gentian
Gentiana Saponaria	Soapwort Gentian
Gentiana puberula	Gentian
Apocynaceae.	**Dogbane Family.**
Apocynum androsaemifolium	Spreading Dogbane
Apocynum cannabium	Indian Hemp
Asclepiadaceae.	**Milkweed Family.**
Asclepias Cornuti	Common Milkweed
Asclepias incarnata	Swamp Milkweed
Asclepias tuberosa	Butterfly-weed
Acerates longifolia	Green Milkweed
Oleaceae.	**Olive Family.**
Fraxinus Americana	White Ash
Fraxinus sambucifolia	Black or Water Ash
Aristolochiaceae.	**Birthwort Family.**
Asarum Canadense	Wild Ginger. Asarabacca
Phytolaccaceae.	**Pokeweed Family.**
Phytolacca decandra	Common Poke. Garget
Chenopodiaceae.	**Goosefoot Family.**
Chenopodium album	Lambs-quarters. Pigweed
Amaranthaceae.	**Amaranth Family.**
Amaranthus retroflexus	Pigweed. Green Amaranth

Polygonaceae.	**Buckwheat Family.**
Polygonum Virginianum	
Polygonum Convolvulus	Black Bindweed
Polygonum Hydropiper	Common Smartweed
Polygonum aviculare	Knot Grass. Doorweed
Polygonum dumetorum	Climbing False Buckwheat
Fagopyrum esculentum	Common Buckwheat
Rumex orbiculatus	Great Water-dock
Rumex Brittanica	Pale Dock
Rumex verticillatus	Swamp Dock
Rumex crispus	Curled Dock
Euphorbiaceae.	**Spurge Family.**
Euphorbia maculata	Spurge
Euphorbia corollata	Spurge
Acalypha Virginica	Three-seeded Mercury
Urticaceae.	**Nettle Family.**
Ulmus fulva	Slippery or Red Elm
Ulmus Americana	American or White Elm
Celtis occidentalis	Hackberry
Morus rubra	Red Mulberry
Laportea Canadensis	Wood-nettle
Cannabis sativa	Common Hemp
Humulus Lupulus	Common Hop
Platanaceae.	**Plane-Tree Family.**
Platanus occidentalis	American Plane. Sycamore
Juglandaceae.	**Walnut Family.**
Juglans nigra	Black Walnut
Juglans cinerea	Butternut
Carya alba	Shellbark Hickory
Carya amara	Bitternut or Swamp Hickory
Cupuliferae.	**Oak Family.**
Quercus alba	White Oak
Quercus macrocarpa	Bur Oak
Quercus rubra	Red Oak
Corylus Americana	Hazel-nut



IOWA LITHO. CO.

DRAWN BY F.C. TATE

IOWA GEOLOGICAL SURVEY

GEOLOGICAL MAP OF IOWA COUNTY, IOWA.

BY

S. W. STOOKEY

1910

Scale $\frac{1}{125000}$

1 ½ 0 1 2 3 4 5 Miles.

1 ½ 0 1 2 3 4 5 Kilometers

LEGEND

GEOLOGICAL FORMATIONS

PENNSYLVANIAN
- DES MOINES

MISSISSIPPIAN
- SAINT LOUIS
- OSAGE
- KINDERHOOK

MIDDLE DEVONIAN
- CEDAR VALLEY

THE MARGIN BETWEEN THE IOWAN AND THE KANSAN DRIFTS IS INDICATED BY THE BROKEN LINE ACROSS LENOX TOWNSHIP.

INDUSTRIES

QUARRIES

CLAY WORKS

Betulaceae.	**Birch Family.**
Betula papyracea	Paper or Canoe-birch
Alnus incana	Speckled Alder
Salicaceae.	**Willow Family.**
Salix humilis	Prairie Willow
Salix cordata	Heart-leaved Willow
Salix nigra	Black Willow
Populus monilifera	Cottonwood
Populus dilatata (Cultivated, but at present almost wholly died out.)	Lombardy Poplar
***Coniferae* (all cultivated).**	**Pine Family.**
Pinus strobus	White Pine
Pinus sylvestris	Scotch Pine
Pinus Austriaca	Austrian Pine
Abies excelsa	Norway Spruce
Abies balsamea	Common Balsam Fir
Larix Europaea	European Larch
Thuya occidentalis	Arbor Vitae or White Cedar
Juniperus Virginiana	Red Cedar
Araceae.	**Arum Family.**
Arisaema triphyllum	Indian Turnip
Arisaema Dracontium	Dragon Arum. Green Dragon
Symplocarpus foetidus	Skunk Cabbage
Lemnaceae.	**Duckweed Family.**
Lemna (species not defined)	Duckweed
Typhaceae.	**Cat-Tail Family.**
Typha latifolia	Common Cat-tail
Sparganium eurycarpum	Bur-reed
Alismaceae.	**Water-Plantain Family.**
Alisma Plantago	Water-plantain
Sagittaria variabilis	Common Arrow-head
Sagittaria heterophylla	Arrow-head
Orchidaceae.	**Orchis Family.**
Orchis spectabilis (rare)	Showy Orchis
Habenaria leucophaea	Rein-orchis
Cypripedium spectabile	Showy Lady's Slipper

Amaryllidaceae.	**Amaryllis Family.**
Hypoxys erecta	Star-grass
Iridaceae.	**Iris Family.**
Iris versicolor	Common Blue Flag
Sisyrinchium Bermudiana	Blue-eyed Grass
Dioscoreaceae.	**Yam Family.**
Dioscorea villosa	Wild Yam-root
Smilaceae.	**Smilax Family.**
Smilax hispida	Greenbriar
Smilax herbacea	Carrion-flower
Liliaceae.	**Lily Family.**
Trillium nivale	Dwarf White Lily
Zygadenus glaberrimus	Zygadene
Uvularia grandiflora	Bellwort
Smilacina racemosa	False Spikenard
Smilacina stellata	False Solomon's Seal
Smilacina bifolia	False Solomon's Seal
Polygonatum biflorum	Smaller Solomon's Seal
Polygonatum giganteum	Great Solomon's Seal
Asparagus officinalis (Escaped from gardens)	Garden Asparagus
Lilium Philadelphicum	Wild Orange-red Lily
Lilium Canadense	Wild Yellow Lily
Erythronium albidum	White Dog-tooth Violet
Pontederiaceae.	**Pickerel-weed Family.**
Pontederia cordata	Pickerel-weed
Commelynaceae.	**Spiderwort Family.**
Tradescantia Virginica	Common Spiderwort
Gramineae.	**Grass Family.**
Zizania aquatica	Indian Rice. Water Oats
Poa pratensis	Kentucky Bluegrass
Triticum repens	Couch or Quick-grass
Hordeum jubatum	Squirrel-tail Grass
Cenchrus tribuloides	Bur-grass
Polypodiaceae.	**True Ferns.**
Adianthum pedatum	Maidenhair

GEOLOGY OF WAYNE COUNTY

BY

MELVIN F. AREY

GEOLOGY OF WAYNE COUNTY

BY MELVIN F. AREY

CONTENTS

GEOLOGY OF WAYNE COUNTY

INTRODUCTION

LOCATION AND AREA.

Wayne, fifth from the east of the counties bordering upon Missouri, is next east of Decatur county, south of Lucas and west of Appanoose. The three upper tiers of civil townships are everywhere conterminous with the congressional townships. The four in the south tier are fractional, the three eastern townships of this tier lacking more than twelve sections and the fourth lacking a little less than twelve, owing to the fact that the boundary line runs a little south of west rather than upon a parallel of latitude. The county contains about 525 square miles. Agriculture is the chief industry, though the mining of coal engages no inconsiderable portion of the activity of its citizens.

PREVIOUS GEOLOGICAL WORK.

This county has received comparatively little attention from the geologists except as a coal producing region. White* has the northeastern limit of the Upper Coal Measures enter the county at the middle of its northern boundary, whence it proceeds to Centerville. Later investigations place this boundary of the Missouri stage, the more recent equivalent of the Upper Coal Measures, farther west, though its exact location is still somewhat uncertain. In discussing the practicability of prospecting for certain coal beds known to outcrop in Davis county and vicinity, White recommends sinking a shaft in the valley of Medicine river in case of successful results reached in the valley of the Chariton river, recommendations which are yet to be carried out, so far as the writer can learn.† In volume II of the present series of Reports‡ several pages are devoted to the coal outcrops and mines of the county. Hinds, in his report on the Coal Deposits of Iowa,§ has described the coal bearing

*Geol. of Iowa, White, Vol. I, p. 242, 1870.
†Ibid. p. 261.
‡Keyes: Iowa Geol. Surv., Vol. II, pp. 402-406.
§Iowa Geol. Surv., Vol. XIX, pp. 254-261. 1908.

strata and the mines of Wayne county. Incidental allusions occur in other volumes, but nothing that promises to give material aid in solving any of the numerous problems of geology has thus far been found.

PHYSIOGRAPHY

Topography

The surface of this county is a plateau having an elevation of a little over one thousand feet. Kansan drift originally thickly blanketed the older formations practically everywhere leaving a surface with comparatively little perceptible variation in elevation. Today much of this surface has suffered little change from erosion through the long interval since the disappearance of the ice sheet, though the material itself has weathered notably to some depth. While this plateau has been deeply and complexly dissected by the running waters, in two localities only has the underlying rock been exposed. It is true the streams are small, having their sources within the bounds of the county, with the slight exception of the Chariton river which barely cuts the northeast corner of the county. Yet the South Fork of the Chariton has excavated a valley more than a hundred feet deep through the major part of its course, finding the rock only in the last mile of its passage, in section 36 of Wright township.

Though erosion has proceeded until the ramifications of the main waterways have advanced well into the dendritic stage, yet only near the confluence of the larger branches have they succeeded in reducing the elevation of the interstream ridges. Every township has several areas of from one to several sections the original surface of which has never been materially modified. Varying little from one another except in size and outline, a journey over them would be very monotonous were it not for the absorption of the traveler's interest by the stacks of hay, thickly standing shocks of harvested grain, or other evidences of nature's bountiful response to the labors of the husbandman. These level tracts, however, are slowly but surely being encroached upon on all sides by the headward erosion of the numerous streamlets that in times of melting snows or heavy rains swell into raging torrents, the effectiveness of their erosive

Plate XX. Upper view—Rugged Kansan topography, east one-half section 7, Grand River township.
Lower view—Flat Kansan type of drift areas common in the county. Southeast quarter section 1, Grand River township.

P. [206]
(V. 20)

power being greatly encouraged by the cultivation of the soil, leaving its surface bare of vegetation at the very time when these little streams are most active, since through a large part of the year they are wholly without water. If trees were allowed to grow along the sides of these intermittent waterways their ravages would be checked very materially, the effects of wind erosion would be reduced and the beauty of the landscape would be improved as well. In these times of quickening in-

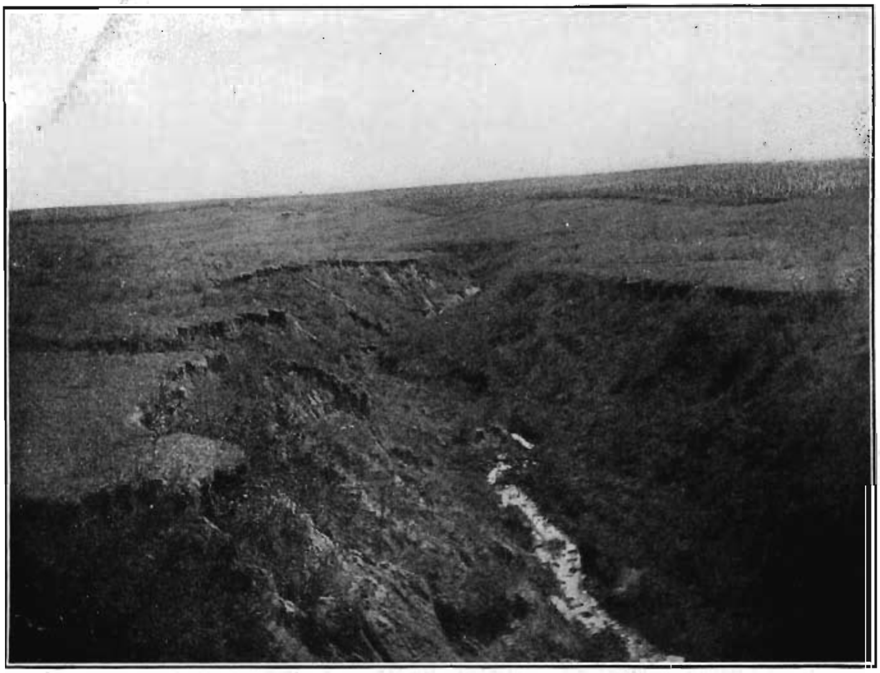


Figure 16. Encroachment upon the unmodified drift topography by headward erosion of small intermittent streams. Grand River township.

terest in practical forestry and the immanence of a wood and lumber famine, a little care in the selection of the kinds of trees would further enhance the utility of such a course.

Three phases of topography here present themselves: one is the flat interstream areas just described, another is the flat bottom lands of the larger streams while the third includes the intervening territory, which consists of a succession of ridges and valleys, small relatively in the immediate neighborhood of the flat areas and gradually becoming steeper-sided and of greater elevation and depression as the larger streams are approached. This phase, occupies, perhaps, the larger extent of the county. The flat bottom lands constitute the least area, being almost a negligible quantity compared with the others, and confined mainly to the valleys of the South Fork and its larger tributaries. The naturally wooded tracts are the bottom lands of the larger creeks and the rugged lands adjacent to them.

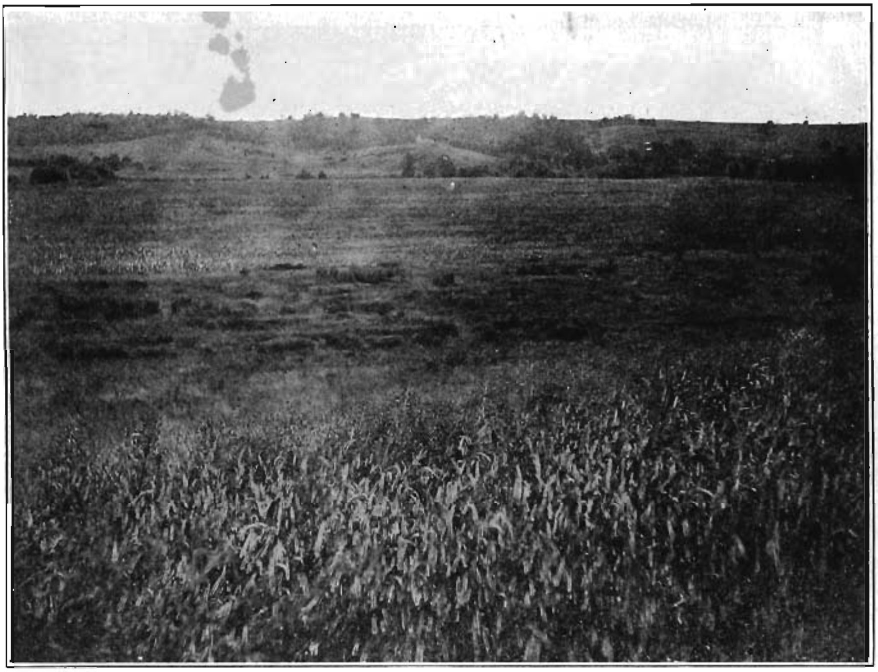


Figure 17. Flat bottom lands on Caleb creek, section 6, Grand River township.

There is little tangible evidence that preglacial topography has left any impress upon the present, if we except the slopes of the Chariton. Its channel doubtless is that of a pre-Kansan stream and it is not unlikely that the course of the South Fork in the main is over the buried channel of a tributary of the ancient Chariton, though it has not yet reached the bed of the former stream excepting in section 36 of Wright township. It is unlikely that so firm a rock as is here exposed has been cut away through a thickness of at least twenty feet in addition to at least a hundred feet of till in post-Kansan time while nowhere above this point has erosion reached the rock surface. The present divide between the basin of the South Fork and that of the south flowing streams was left as a slight swell in the plateau surface, partly determined perhaps by the preglacial valley of the South Fork, though the records of the few prospect holes that we have secured would not indicate that there is much difference in the altitude of the subjacent rocks of the uplands and of the lowlands.

It is said above that the present topography is in part the result of erosion. The flat bottom lands are to some extent the product of aggradation. The smaller V-shaped valleys in their lower courses have been aggraded till they, too, have a flat bottom, though of restricted extent, the thickness of the deposit being ten or fifteen feet, sometimes. The material is mainly a heavy clayey silt, the recent wash from the neighboring hillsides, portions of the Kansan till one remove further towards its final destination, the sea bed. The bed of the stream of today is cut into this deposit and not infrequently through and beyond it, the excavated silt having been carried one and in some instances several removes further on its way.

From Gannett's Dictionary of Altitudes, fourth edition, 1906, we may compile the following table of altitudes for points in Wayne county:

TABLE OF ELEVATIONS.

STATION	AUTHORITY	FEET
Allerton	C., R. I. & P. Ry	1130
Benton	C., B. & Q. R. R	1059
Cambria	K. & W. R. R	1100
Clio	C., R. I. & P. Ry	1117
Corydon	K. & W. R. R	1105
Harvard	C., R. I. & P. Ry	1087
Humeston	C., R. I. & P. Ry	1104
Kniffin	C., R. I. & P. Ry	1086
Lineville, Mo	C., R. I. & P. Ry	1094
Promise City	K. & W. R. R	1065
Sewall	C., M. & St. P. Ry	1106
Seymour	C., M. & St. P. Ry	1074

Drainage

The Chariton river, though itself practically extra-limital, controls the drainage of quite two-thirds of the county. The other third has no master stream, its water courses being merely the initial branches of small rivers that are tributary to the Missouri and have a southerly course. The largest of the latter streams has a length within the county of less than fifteen miles. Reckoned from the east, they are Locust, Fowler and Walnut creeks, Big, Middle and West Forks of Medicine river, Caleb and Steele creeks. These streams have little individuality except in trivial details. Caleb and Steele creeks, with a southwesterly course, make their way into Decatur county before discharging into the south flowing Weldon. For the most part they have the deep V-shaped valleys common to the upper courses of the streams of the Kansan drift regions. Caleb creek, the largest of these, has quite a wide alluvial bottom, well up into the county. They are all post-glacial, consequent streams, undoubtedly.

All along the north border a series of still smaller streams flow northward, tributaries of the Chariton. The South Fork of the Chariton is preëminently the master stream of the county, receiving the run-off waters of two-fifths of the county's area, though in common with all the others its sources are all within the borders of the county. Rising in Warren township, southwest of Allerton, its course is due north to a point in section 4, Benton township, whence its course is easterly, crossing the east line of the county in section 36, Wright township. Throughout its easterly course it has an alluvial bottom more than a mile in width in some places. Farther south Walnut, Cooper and Shoal creeks, smaller tributaries of the Chariton with easterly courses, drain portions of South Fork and Walnut townships.

It will be recognized that there are two swells in the drift mass constituting the surface of the county, which serve as divides; one passing east and west entirely across the upper tier of townhips in a sinuous line, turning the waters of the minor tributaries of the Chariton northward and those of the South Fork southward. The other and stronger begins, in common with the first mentioned, in Richmond township and proceeds at first southeasterly though mainly southward, for some fifteen miles, then sharply turning winds its way eastward nearly to Seymour whence it runs southeasterly to the border. From the position of these divides the run-off waters are turned to every point of the compass. There is nothing about them, however, to distinguish them from the many others that separate the minor drainage basins, save their length and the fact that they give bounds to the basin of the master stream, the South Fork, excepting a small area of the eastern border north and south of Seymour which is included within their limits but is drained by direct tributaries of the Chariton.

STRATIGRAPHY

With one exception, of little importance beyond the fact that it is an exception, the Pleistocene alone appears as a superficial deposit within the limits of the county. Knowledge of the underlying formations must be sought, therefore, from the mines, prospect holes and deep wells that have penetrated the drift and entered the older beds somewhat. Outcrops in the adjoining counties also give some clue to the probable conditions in Wayne. The following table gives the relations of the various formations as they may be gathered from the above mentioned sources:

SYNOPTICAL TABLE.

GROUP	SYSTEM	SERIES	STAGE	FORMATION
Cenozoic	Quaternary	Recent	———?	Alluvium
		Pleistocene	———?	Loess
			———?	Gumbo
			Kansan	Bowlder till
			Aftonian	Gravel, peat, silt
			Nebraskan?*	Dark bowlder clay
Paleozoic	Carboniferous	Pennsylvanian	Missouri	Bethany?
			Des Moines	Pleasanton Appanoose

*As a substitute for the non-geographical terms, pre-Kansan and sub-Aftonian, which have been used to designate the earliest sheet of drift in Iowa and states adjacent, Shimek proposes the name, Nebraskan. See Bulletin of the Geological Society of America, volume 20, page 408; published December, 1909. See also, SCIENCE, new series, volume XXXI, page 75, January 14, 1910.

CARBONIFEROUS SYSTEM

Of all the systems of the Paleozoic group in Iowa that are immediately overlain by the almost universally prevalent Pleistocene, the Carboniferous is by far the largest in area and of the greatest economic importance. Beginning on the northern border of the state with a width of eighteen or twenty miles, it rapidly extends eastward as its boundary is traced towards the south, reaching the Mississippi a little north of the mouth of the Iowa river. On the south border of the state it stretches from the Mississippi to the Missouri. Most of this extensive area is buried beneath heavy deposits of drift, sometimes reaching well nigh the maximum thickness of four hundred feet. Outcroppings are confined mainly to the banks of the deeply eroded channels of the larger streams and the lower courses of their tributaries. In Wayne county such exposures are limited to the scant mile of the course of the Chariton river and to a small tributary of it in the northeast corner of Wright township and to a half dozen miles or so along the South Fork of the Chariton and its tributary, the Little Walnut, in the northeast corner of South Fork and the southeast corner of Wright townships.

Of the two great divisions of the Carboniferous, the Lower has no practical significance in Wayne county beyond the fact that it lies below the beds in which there are any possibilities of finding coal, so that, if it is ever reached by the drill, further prospecting at the point where the drill is located, is absolutely unnecessary. But, as the later overlying deposits have never been penetrated as yet, and from all experiences and reasonable estimates in nearby counties, there are no undiscovered probabilities of profitable coal beds below these already known to exist, even this fact has little of economic interest. Bain,* with little reliable data and in the face of serious difficulties in determining just when the base has been reached owing to probable, but little understood, changes in the character of the uppermost rock of the Saint Louis stage, estimates that the base

*Iowa Geol. Survey, Vol. V, p. 376. Later developments have shown that the Saint Louis lies higher than this—from 350 to 500 feet below the surface—in central and western Appanoose and eastern Wayne counties. See also reports on Decatur, Wayne and Appanoose counties in volume XIX of this series of reports.

of the Coal Measures at Centerville is within about 600 feet of the surface. There is little likelihood that it is any less anywhere in Wayne county, but rather it is probable that the dip of the Lower Carboniferous strata continues towards the southwest, thus increasing their distance from the surface across the county from east to west. Moreover in the western part the beds of the Lower Coal Measures probably are succeeded by the over-lapping strata of the Missouri stage.

Pennsylvanian Series

DES MOINES STAGE

Appanoose Formation.

The outcroppings mentioned above belong to the Des Moines stage and with the evidences derived from deep wells, prospect holes and coal mines, establish the fact that the Pleistocene of nearly the entire county has immediately beneath it material belonging to the Des Moines stage. The terrane consists of sands, sandstone and shales more or less coherent, together with coal and limestones, all of which are usually quite variable as to thickness of beds, order of relationship and physical and chemical characteristics, though some of them maintain their identity over considerable areas, thus enabling the stratigrapher to determine with a reasonable degree of assurance the correct relationships of the more inconstant beds. In some localities the drift has never been penetrated fully and the underlying formation has been determined only by inference, but such are the grounds for the inference that it may be regarded as a fairly safe one.

The following section by Keyes* on Little Walker creek in the northeast corner of Wright township gives the character of the exposed beds in that locality:

	FEET	INCHES
7. Drift	7	
6, Limestone, blue, fossiliferous, thick bedded	1	8
5. Shale, bituminous, fissile	1	4
4. Coal	1	5
3. Clay parting		2
2. Coal		9
1. Fire clay, gray, impure	2	

*Iowa Geol. Surv., Vol. II, p. 402.

The only other outcroppings in the county of Paleozoic material of any kind occur in the southeast corner of Wright township. The most important of these may be seen in a small quarry just east of the wagon bridge over Little Walnut creek in the south half of section 36, Wright township, and at the crossing of the South Fork of the Chariton river a little farther east. The quarry has merely broken into the level exposure to meet the very limited demand for stone for foundation walls, for which purpose it is said to be durable and otherwise very satisfactory. Loose stone lay heaped promiscuously in the quarry, concealing what little face it may have had, but from examination of the stone, it appears that the beds are irregular and from six to twelve inches thick. The rock at the quarry is hard, compact, bluish gray, brittle and with a conchoidal fracture, readily suggesting the lithographic type of the Cedar Valley limestone. At the South Fork crossing the rock has been used for the abutments of the bridge. The rock as exposed slopes from the river bed up into the road, a vertical distance of fifteen feet or more. It is yellowish brown and softer than the rock at the quarry owing to earthy impurities.

The remarkable thing about it is the unusual thickness of the deposit, as the limestones of the Des Moines stage are rarely more than three feet in thickness. There are no clay partings, though along the irregular horizontal division planes the limestone sometimes grades down into almost a shaly condition. The two phases of the rock maintain their distinctions very well. The conditions under which they were formed must have been very uniform and exceptionally extended in time. It would be of interest to know something more of the horizontal extent of this limestone. Its great thickness led to the supposition that it might be the Bethany limestone of the Missouri stage but this is disproved both by the stratigraphic and paleontologic conditions. The Joe Hayhurst mine, three-quarters of a mile to the northwest, has a depth of thirty feet. Its surface is unquestionably more than thirty feet above these outcrops. The mine of E. T. Jared, Jr., in the south half of section 26, has a total depth of only twenty-eight feet. The Simms mine, in the very northeast corner of section 1, South Fork township, is sixty feet deep, but it is well up towards the prairie level, which in this locality is more than 100 feet above the bridge. Stratigraphically therefore, this limestone seems to lie below the coal bed that has been worked in the neighborhood.

Lees has suggested that it represents the "bottom rock" of these and neighboring mines. It does not appear that this rock has been penetrated in any of these localities and it is very probable that his suggestion correctly accounts for its stratigraphic relations. That it belongs to the Des Moines stage is assured from the fact that a specimen of *Spirifer rocky-montanus* Marcou, was found in the rock at the bridge, a brachiopod that is not found in the Missouri stage. The only other identifiable fossils discovered were *Seminula subtilita* Hall, *Dielasma bovidens,* and a spine of Archæocidaris sp.

Appanoose Beds.

Bain found in Appanoose county and extending over into Wayne county a well related group of strata forming a distinct substage of the Des Moines stage to which he gave the name Appanoose beds because of their widespread occurrence in that county. The most characteristic features of these beds are the Mystic coal seam and certain limestone bands which maintain a fairly definite and uniform sequence throughout the exposed portion of the area covered by them. From his study of numerous borings, shaft records, and exposures, he constructed a generalized section, a copy of which is here given:*

		FEET	INCHES
17.	Limestone, gray, subcrystalline, known among the miners as "floating rock"	2 to 4	
16.	Shale, argillaceous, color variable	12 to 30	
15.	Limestone, heavy ledges, the "fifty-foot limestone"	4 to 10	
14.	Shale, argillaceous, blue and red in color	14	
13.	Shale, arenaceous, frequently forming a well defined sandstone	8	
12.	Shale, argillaceous, blue to gray	10	
11.	Limestone, somewhat variable in thickness, known as the "seventeen-foot limestone" or "little rock"	1 to 3	
10.	Shale, sometimes gray, frequently bituminous and pyritiferous	7	

*Iowa Geol. Surv., Vol. V, pp. 382-383.

9.	Limestone, sometimes gray, and coarsely subscystalline; sometimes fine-grained, bituminous and grading into the shales above and below; known as the "cap-rock"	2 to 4	
8.	Shale, usually bituminous and known as "slate"; occasionally in part soft and clay-like, then known as "clod"; at times heavy and homogeneous, non-fissile, in which form it is known as "black bat"	1 to 3	
7.	Coal, upper bench, usually		8 to 10
6.	Clay parting, "mud band"		2 to 3
5.	Coal, lower bench, usually		8 to 10
4.	Clay parting, "the dutchman"		½
3.	Coal, frequently not so pure		2 to 3
2.	Fire clay	1 to 6	
1.	Limestone, "bottom rock"	3	6

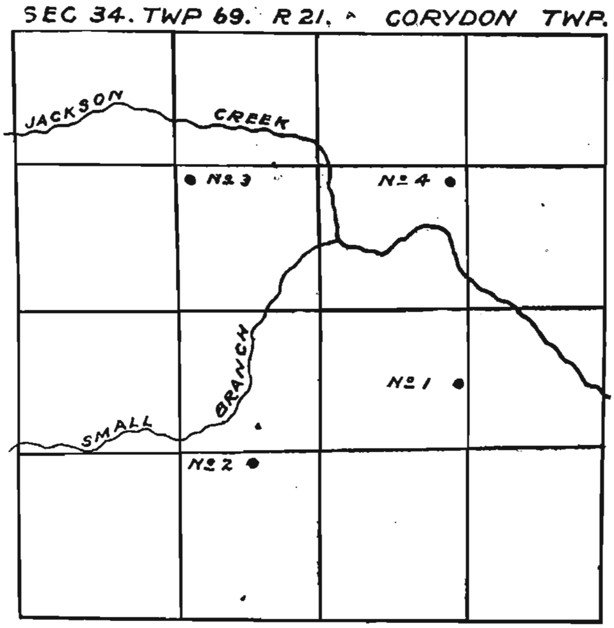


Figure 18. Plan showing location of Posten prospect holes.

The western border of these beds cannot be determined as yet with any degree of exactness owing to the fact that exploration into the Paleozoic formations in the west half of the county has been very seldom made and even when such explorations have been made definite records are not accessible. Mr. R. C. Posten has reported the results secured from three prospect holes drilled by him in section 34, township 69 north, range 21 west. Numbers 3 and 4 were on the creek bottom and at about the same level and number 2, which was on a small branch was some fifty feet higher at the surface than the others.

PROSPECT HOLE NUMBER 2.

(Number 1 not accessible.)

Southeast quarter of the southwest quarter of section 34.

	FEET	INCHES
Surface, not characterized	25	
Sand and gravel	20	
Gray drift (144 feet, 8 inches total drift)	99	8
Gray shale	9	7
Red sand rock	1	4
Gray shale		6
Red sand rock		8
Light gray shale	3	6
"Soap" shale	23	11
Gray sand rock		8
Gray shale	3	6
"Soap" shale	2	
Red shale	1	
Light gray shale	15	6
Gray sand rock	1	4
Sand shale	3	8
Sand rock		6
Gray shale	6	4
Cap rock (limestone)	3	6
Gray shale	5	4
Light sand shale	19	6
Gray shale	23	7?
(1) Coal (at 270 feet, 7 inches)	1	5
Dirty coal		8
Gray shale	15	
Dark shale	4	
(2) Coal (at 291 feet, 8 inches)	1	2
Light shale	2	6
Rock, hard, hydraulic	3	6
Dark shale	4	6
Black slate	2	5
Gray shale	8	4
(3) Coal (at 314 feet, 1 inch)		9
Light shale	4	
Gray sand rock	1	2
Light sand shale	10	4
White rock	1	6
Gray shale	4	
Lime rock		8
Light shale	1	1?
Dark shale	3	
Dark sand rock		9
Dark shale	2	

(4) Coal (at 343 feet, 4 inches)		8
Clay parting		9
Coal		5
Dark shale, (sulphur)	6	6
Fire clay	7	2
Light sand shale	4	
Light sand rock	4	
Gray shale		10
Green shale		2
Lime rock		8
Light shale	1	5
Total	369	11

PROSPECT HOLE NUMBER 3.

(Southeast quarter of the northwest quarter of section 34.)

	FEET	INCHES
Surface	20	
Sand and gravel	15	
Gray drift and sand (total drift, 131 feet)	96	
"Soap" shale	5	6
Dark shale	3	6
Coal (No. 1), (at 140 feet)		3
"Soap" shale	16	9
Sand shale	6	
Fossil limestone	3	5
Light sand shale	16	
Gray shale	7	9
Black slate	2	
Gray shale	1	10
Coal (No. 2)		2
Fire clay	4	2
Hard rock, hydraulic	3	
Light sand shale	13	3
Light sand rock	2	
Dark shale	4	6
Light shale	4	
Light sand shale	22	
Gray shale	21	
Coal (No. 3)	1	3
Clay parting		1.5
Dirty coal		3
Coal		3
Light shale	1	
Gray sand rock	6	
Gray shale	13	
Dark shale	2	1
Coal (No. 4)	1	6
Dirty coal		2
Light shale	3	

Dark hydraulic rock	4	6
Dark shale	7	
Black slate	2	4
Coal (No. 5)	1	3
Light shale	1	
Hydraulic rock	2	6
Light sand shale	10	
Light shale	7	4
Dark shale	1	
Cap rock		8
Dark shale	2	
White top		8
Dark sand shale		8
Coal (No. 6)	1	
Dirty coal	1	11
Light shale	2	
Light sand shale	2	9
Gray sand rock	2	8
Light shale	1	6
Dark shale	2	
Black shale	1	2
Rotten coal (No. 7)		6
Dirty coal	2	1
Light shale	1	
Lime rock		10
Lime shale	4	1
Total	361	1

PROSPECT HOLE NUMBER 4.

Southwest quarter of the northeast quarter of section 34.)

	FEET	INCHES
Surface	18	
Sand and gravel	2	
Gray drift	68	
Water bearing sand	18	
Gray shale	32	
Black shale		6
Gray shale	1	6
"Soap" shale	53	3
Yellow clay shale	3	11
Black shale		3
Gray sand shale	2	7
Gray sand rock		4
Limestone, bastard	3	
Light shale	2	
Gray shale	6	1
Limestone	1	8
Light shale		6

Brown shale	1	
Dark shale	1	5
Brown rock		4
Light shale	1	
Light sandstone	8	9
Light shale	3	
Red clay shale	4	4
Light gray shale	5	4
Dark shale	1	
Gray shale	2	
Gray sandstone	5	
Gray sand shale	2	4
Gray shale	9	3
Red flint rock		4
Gray shale	11	
Dark shale		3
Coal (No. 1)		4
Coal, brown		8
Light sand shale	3	
Gray sand shale	4	
Gray sandstone	19	4
Dark shale	1	5
Coal (No. 2)	1	2
Dirty coal		8
Light shale	4	10
Lime shale	1	
Fossil limestone	1	8
Light gray shale	1	2
Dark shale	5	2
Gray sand rock		5
Gray shale		7
Black slate	1	
Coal (No. 3)	2	1
Fire clay	3	
Light sand shale	9	2
Hard gray sand rock	1	11
Sandstone	1	4
Light sand shale	7	2
Dark shale	3	8
Dark sand rock	1	3
Dark shale	3	2
Dirty coal (No. 4)		8
Light shale	2	
Dark shale, sulphur	5	4
Light sand	5	9
Sand rock	9	
Total	362	11

Comparison of these sections is interesting, for no side of the triangle formed by the location of these prospect holes is over a half mile long, yet each differs markedly from the others. There is fairly good correspondence between four of the coal seams, and in Number 4 the horizon of coal seams 1 and 2 of Number 3 is marked by a black shale or a black slate, but the number, sequence and thickness of the overlying, intermediate and subjacent beds are highly variable.

A comparison of these sections with Bain's generalized section in Appanoose county is interesting also. The most prominent differences are to be found in the number of coal beds, in the great prominence of arenaceous matter, either as sandstones or arenaceous shales, and in a corresponding lessening of calcareous deposits, the limestone beds being thinner and fewer in number, though in some instances they are represented by calcareous shales. These changes have somewhat obscured the evidence of the persistence of the Mystic seam in this locality, but a careful comparison and study of the sequence and character of the beds, makes it seem probable that bed 3 of Numbers 2 and 4 and bed 6 of Number 3, represent this seam. The presence of another coal seam below it is something of an anomaly to be accounted for by the fact that the Wayne county deposits were laid down near the border of the area where conditions were subject to change to an unusual degree. This view also accounts for the inferior quality of the coal in some of the thin veins as well as for the increased arenaceous and diminished calcareous constituents of many of the beds.

Pleasanton Shales.

Bain* found in Morgan township in the southeast corner of Decatur county certain shales immediately below the base of the Bethany limestone. These shales are more or less arenaceous and are sometimes associated with a limestone also usually arenaceous, which he believed to represent the top of the Des Moines. He thought them likely to prove equivalent to the Pleasanton shales of Kansas and in the interests of simplicity

*Iowa Geol. Surv., Vol. VIII, pp. 269-271.

of nomenclature he appropriated the name of the Kansas formation and tentatively applied it to the above mentioned shales in Decatur county.

In section 14, Richman township, Wayne county, the following beds were passed through as reported by McElhany Brothers, coal prospectors at Humeston.

		FEET
8.	Drift deposit	403
7.	Ferruginous shale	3
6.	Gray and yellow shale	4
5.	Dark blue argillaceous shale	11
4.	Variegated arenaceous shale with indented bands	7
3.	Gray sandstone	4
2.	Blue sand shale with sandstone partings	17
1.	Blue sandstone alternating with thin layers of blue, hard and impure limestone	55
	Total	504

This section, especially in the middle and lower beds, exhibits the characteristic lithological features of the so-called Pleasanton beds in Decatur county, being notably arenaceous and associated with sandstones and arenaceous limestones. The exceptional thickness is due to the lower sandstone beds which are themselves of unusual thickness.

These same beds may be recognized in Number 2 of the Posten prospect holes in Corydon township and possibly in the uppermost members of Numbers 3 and 4. There is no reason to question Bain's judgment that the drift of the western portion of the county is underlain immediately with these shales, but such is the great thickness of the drift, it is difficult to regard them as contributing in any degree to the prevalent superficial topography of this portion of the county, especially when it is taken into consideration that similar topography is not uncommon even as far east as Davis county. These topmost beds of the Des Moines manifest themselves along its border in Madison, Dallas, Guthrie and perhaps, Webster counties, but always exhibiting variations in the lithological character and the thickness of the individual beds, as well as in the thickness of the entire formation. Indeed in many localities exact discrimination between them and the related beds below is very difficult, if not quite impossible.

MISSOURI STAGE.

Owing to the great thickness of the drift, the absence of large streams that could cut through it and the fact that a sufficient water supply has been secured thus far without penetrating the drift, there is no available evidence that rocks of the Missouri stage underlie any part of the county's area, yet from the range of the border of that stage in counties north and west, it is not unlikely that the border line passes through the northern members of the western tier of townships.

QUATERNARY SYSTEM

Pleistocene Series

With two relatively unimportant exceptions in Wright township the entire county is overspread to a depth ranging from forty to more than 400 feet with material belonging to the Pleistocene. The Pleistocene of Iowa is made up of the morainic material of several distinct ice sheets and a number of secondary deposits bearing various names according to their positions and mode of formation.

NEBRASKAN STAGE.

This oldest of the ice sheets is often known in the state as the sub-Aftonian or pre-Kansan. It naturally follows from its basal position in the series, that it is rarely exposed except artificially, but in a few counties, along with overlying beds of other members of the Pleistocene, it has been revealed in railroad cuts in such a way as to leave no doubt of its true character and distinct nature. In other counties its existence has been made known only in sinking deep wells or in boring prospect holes and the like. In still others the evidence of it is so scanty that doubts may well be entertained that a correct interpretation of the phenomena under consideration would not ascribe them to the Kansan stage. Wayne county may well be classed here, for while the Nebraskan has its best expression in the southern counties, as a rule, this county has no natural exposures and few deep wells and the available records of borings through the drift give little ground for definite conclusions.

The old well at the Humeston creamery affords the following section approximately:

		Feet
12.	Surface	2 to 3
11.	Whitish clay, darker below	22 to 25
10.	Yellowish brown sandy clay	12
9.	Red sand	1
8.	Yellowish brown sandy clay	32
7.	Blue clay with trace of sand	34
6.	Yellow clay with fine gravel	35
5.	Blue clay	25
4.	White sand and gravel	3
3.	Blue clay and large gravel	30
2.	Blue mud	198
1.	Water bearing sand	8
	Total	406

From the section already given of a prospect hole in section 14, located only about a mile east of this well, it may be inferred that the water bearing sand in which the well ends is at the base of the drift. The blue mud may be Nebraskan and Number 4 may be Aftonian, though nothing given here except its position would indicate it. Allowing the surmise to be correct, the thickness of the Nebraskan is unusual for this neighborhood, but Macbride* reports its occurrence in Cherokee county with the surprising thickness of more than 500 feet, the Kansan on the other hand being very thin.

AFTONIAN INTERGLACIAL STAGE.

In the section given under the previous topic, Number 4 is referred hypothetically to the Aftonian. Numerous instances are reported currently of twigs, bogs and other vegetal remains and of black earth bands below the blue clay and in connection with sand or gravel aquifers. Inasmuch as the wells end in these water bearing sands nothing is known of the underlying beds. Mr. Alexander Mardis relates that in sinking a coal shaft at Corydon many pieces of wood of considerable size were found, real logs in some instances. These were met with at the base of the drift.

KANSAN STAGE.

After the Aftonian interval, the Kansan ice sheet made its way from the Keewatin center, ever widening its front and spreading over a broad expanse of country, including nearly the

*Geol. Surv. of Iowa, Vol. XII, p. 320.

whole area of Iowa. Upon its retreat it left a ground moraine usually of great thickness and having distinctive characteristics now well known and readily recognized by every student of the Pleistocene. Its components, as might be expected from the manner of its production, consist of fragments of the country rocks over which it swept with irresistible force. The greater amount of these fragments was ground into rock flour. In addition there are present the products of the Nebraskan glacial activities which often had been modified by the agencies which were active during the Aftonian interval. All these have been intermingled and blended in every conceivable manner and degree, and yet, different as it must prove to be upon close examination in different localities, whether near or remote, this material always preserves its general appearance and character. Two general phases are recognized: the normal unweathered basal portion, and the superficial phase, distinct enough when the two are noted at points separated vertically by a band of indistinct demarcation a foot or more in thickness. The difference has been produced by weathering agencies through the very long interval that has elapsed since the Kansan ice sheet laid down its burden, when it began its retreat northward. The changes were wrought chiefly by oxidation, leaching and removal of various mineral salts by plant growth. The material of the unweathered zone is of a dark blue color and is very dense and readily separable into square blocks owing to its finely jointed structure. In the superficial zone the color ranges through the yellow and red browns, owing to the oxidation of its iron constituents. It has lost much of its compactness also, and its granitoid pebbles and bowlders show a tendency to crumble and waste.

The few cases in which the thickness of the drift could be secured are here given. The Chicago, Rock Island and Pacific railroad well just over the state line at Lineville ends in loose stone at a depth of eighty feet, but other wells in the vicinity having a depth of fifty feet end in the drift. The prospect holes in Corydon township already given in detail show the drift there to be 106, 131 and 144 feet deep, the difference being due mainly to the difference in surface elevation. Mr. Alexander Mardis reports 350 feet of drift before reaching a clay shale in a drill hole near the center of the southeast quarter of the northwest quarter of section 19, township 69, range 21 west, though three-fourths of a mile northeast, Mr. J. S. Whittaker reports it to be but 131 feet thick. A prospect hole near Humeston gives 403 feet of drift.

Rock was reached at 140 feet in a drill hole in the southwest quarter of section 22, Union township, the location being on a hillside, not far from the top. In the northeast quarter of section 14, Jackson township, the drift is sixty-three feet deep at an elevation some forty feet below the maximum for that vicinity. At the coal mine in the southwest quarter of section 23, Wright township, it is forty-five to fifty feet thick in a depression somewhat as in the last named instance. In section 36, Wright township, it is about 100 feet thick. The prospect hole already referred to east of Humeston is 403 feet deep and is entirely in drift. The sharp contrast in the two quotations at and near Corydon indicates the possibility of the existence of a buried channel there, but in the absence of other data nothing more could be determined. The shallowest drift occurs in the northeast and southwest corners of the county, while it is thickest in the northwest.

SECONDARY DRIFT FORMS.

Gravels and Bowlders.

Besides the sands and gravels that occur in sheets, streaks and pockets in the till and also the beds of these materials in the Des Moines and Missouri stages, occasional outcroppings in the road cuts were seen that readily suggest the Buchanan gravels so common in many of the more northern counties, particularly those within the Iowan drift area. On the hill in the road north of the Caleb creek bridge in section 31, Jefferson township, and also on a hill slope farther south in Grand River township such gravel outcrops occur. They are red brown in color, show marked indications of weathering and have similar relations to the Kansan till with the Buchanan gravels. Similar outcrops, though less ferruginous, were seen in Jackson township. In the southeast quarter of section 35, Wright township, two to three feet of gravel of this nature underlies the loess, which here is quite thin.

It is more than probable that some, if not all of these sand and gravel sheets, are residual in origin. Calvin* in his report on Page county describes similar beds, which he accounts for very satisfactorily as being the product of erosion where currents of sheet-water too weak to transport the coarser constituents of the till had removed the finer portions and thus caused an accumulation of gravel. It is difficult, however, to account for the thicker beds of Wayne county in this way, unless it be added that stronger local currents here and there moved such accumulations for a short distance and dropped them upon a slackening of the current in comparatively thick deposits.

Pebbles, cobbles and bowlders are comparatively scarce as seen in the road cuts. Bowlders are rarely seen in the fields. The largest was noted in section 24, Benton township. It had been partly uncovered in excavating the roadway and was six feet in diameter, though it had been broken up somewhat, being a weak sandstone. The distribution of bowlders was apparently very uniform over the county.

GUMBO.

Gumbo is a term often used in Missouri, Nebraska and in many of the southern counties of Iowa. Its application is somewhat varied, but this is warranted in great part on account of the variability of the material itself. It occurs overlying Kansan till and most frequently beneath the loess, but Udden notes it naturally exposed in some of the creek valleys of Pottawattamie county. Graduating as it often does into the loess above it and resembling it in many particulars it has been regarded by some as a form of loess, but sometimes it as certainly graduates into the bowlder clay below and in intermediate forms it maintains a distinctive character that justifies giving it a name and characterization of its own. Its color varies from a dark blue through the red and yellow browns to a drab. It consists of a dense, sticky and very impervious clay with scattered pebbles and coarse sand grains in the lower part. It is nonfossiliferous and well leached, though Bain finds small lime balls to be quite abundant in it. The exceptional thickness of forty feet

*Geo. Surv. of Iowa, Vol. XI, pp. 442-444.

has been given, but more commonly it does not exceed ten feet.

While its origin is still quite problematical, there is a marked tendency to consider it an aqueous product formed under different conditions and thus giving rise to the different phases under which it appears to-day. Udden* says "Probably it is mostly an old loess, which has been clogged up by interstitial deposition of fine ferruginous material through the agency of ground water. Perhaps it is in part a fluviatile deposit, made at a time of semi-stagnant drainage, or possibly it is of varied origin, being in some places a surface wash, or a disintegration product derived from the underlying bowlder clay, and at other places a modified upland loess, or a river silt." The open-minded attitude taken by this author upon the question of the origin of gumbo is undoubtedly the wisest until fuller details have been secured.

In Wayne county gumbo occurs over considerable areas of the flat-Kansan that are slightly basin-shaped, where its presence in wet seasons works more or less disaster to the growing crops by reason of its impervious nature, a condition which artificial drainage by open ditch canals or tiling would probably relieve.

LOESS.

In common with much of the Kansan drift area in southern Iowa, Wayne county has its uplands overspread to a large extent with a fine clayey silt which in this county is of a light gray color. It does not seem to be very thick anywhere, varying from a few inches to about two feet. Along the eastern sections of Walnut and South Fork townships, sometimes both it and the gumbo are wanting, the yellow Kansan till making the surface. At times the loess appears here, but gumbo fails to intervene. Usually gumbo immediately underlies the loess. Modified by plant action and tillage it constitutes the soil of much of the county. The black loam so characteristic of the Iowan drift region is seldom seen upon the uplands of the county.

A few sections made by the road cuts are here given. On the hillside west of the South Fork of the Chariton between sections 21 and 16, Benton township, is seen:

*Iowa Geol. Surv., Vol. XI, p. 258.

		Feet	Inches
4.	Loess, light gray		8
3.	Clay, reddish brown, grading below into No. 2	2	
2.	Clay, yellowish	2	
1.	Clay, light brown with lime spats and balls, streaked, jointed and containing near the base, gravel and a few pebbles and cobbles, among which greenstone, quartz and the granitoids, were dominant		8

Numbers 2 and 3 are gumbo, but number 1 was believed to be Kansan till, though not quite typical in some of its features.

North of Lineville a roadside cut shows:

		Feet	Inches
3.	Loess, light gray		6 to 8
2.	Clay, red-brown, plastic	2 to 3	
1.	Clay, light colored, mottled and streaked with iron and containing lime balls	3	

Number 2 is gumbo and so, possibly, is number 1. By reason of the grading of the gumbo into the till it becomes difficult to draw the line sharply between the two materials. The upper part of number 1 is much like gumbo while the lower part is much more like the till. Number 1 of the first section presents something of the same difficulty.

A more anomalous section occurs in section 32, Jefferson township, just north of the Caleb creek bridge.

		Feet
3.	Soil, fine, gray, somewhat gravelly	1
2.	A stiff, dark gray joint clay (gumbo)	1
1.	A stiff, light gray clay with some sand and gravel	2

Recent Series

ALLUVIUM.

Rich alluvial deposits cover the flood plain of the South Fork of the Chariton and extend a short distance up its larger tributaries. Alluvium is also found along Caleb creek and a few other streams. Along the eastern half of the course of the South Fork, these plains are from one to two miles wide, but elsewhere they are usually quite restricted. Most of the drainage of the county is accomplished by small post-glacial streams that have as yet merely cut V-shaped valleys that make deposits of any kind impossible.

ECONOMIC GEOLOGY

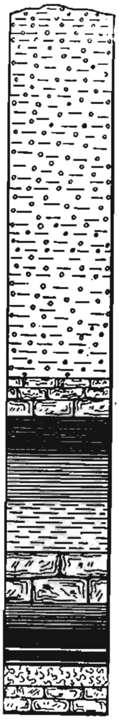
Soils

The chief natural source of wealth in Wayne county in the future as in the past lies in its soils. Loess, alluvium, gumbo and modified Kansan till constitute the principal kinds. Fortunately gumbo, the least desirable of these, is known mainly as a subsoil. Though in places it is all too thin, the most widespread of these soils is loess and happily, it is one of the best. The alluvium, too, ranks high for many purposes, but owing to its location it is subject to serious flooding in wet seasons. Where the loess is thin, the impervious nature of the gumbo is a detriment both in wet and dry seasons, holding the water upon the surface in wet seasons and preventing free capillarity in dry times. The former evil may undoubtedly be remedied by judicious drainage and where the gumbo is thin, tillage will tend to mingle better elements with it and thus make it more pervious. The till is perhaps more variable in quality than any of the others, and for this reason needs to be especially studied by the agriculturist, that he may get the best results from it, but upon the whole it is entitled to rank high in possible productivity. While the immediately available resources of Wayne county soils are gratifying, it is the opinion of the writer that scientific farming has many pleasant surprises in store for the land holders.

Coal

Next in value to the soils of Wayne county are its deposits of coal, which are found at various points in the eastern half of the district. There is little reason to doubt that the famous Mystic vein in workable conditions underlies a large part of this area, but profitable mining has been developed as yet in Wright, Walnut and Jackson townships only.

Along the Chariton river drift mining has been engaged in to some extent for a number of years. In sections 23, 26, 35 and 36, Wright township, a good quality of coal is mined to supply local demands, but owing to lack of good transportation facilities extensive operations cannot be engaged in profitably.



FEET	INCHES	
28		11. Drift.
3		10. Limestone, gray, thinly bedded.
3		9. Shale, firm, bituminous.
3	5	8. Shale, clayey, dark drab.
4		7. Shale, light gray to blue.
4		6. Limestone ("cap rock").
1		5. Shale, drab, clayey "clod"
	10	4. Shale, black, fissile.
2	6	3. Coal.
1	6	2. Fire clay, impure, gray.
2		1. Limestone, gray, fossiliferous.

Figure 19. Section of old Frye shaft, Confidence.

In the southwest quarter of section 23, Mr. Lewis Frye has worked a twenty-eight inch vein for five years. Two to four inches of clay forms a parting about midway of the vein. Six or eight inches of slate make a good roof. Coal is found at a depth of 105 feet. Not far away John Kersey and John Hayhurst work a similar vein. The output of each of these mines for the year 1908-9 was about 45,000 bushels.

FEET	INCHES	
1		7. Shale, bituminous, fissile.
1	8	6. Coal.
	2	5. Clay parting.
	7	4. Coal.
	½	3. Clayey parting, containing much pyrite.
	1	2. Coal.
1		1. Fire clay, impure.

Figure 20. Coal seam in Frye mine Confidence. After Hinds.

In the south half of section 26 at a depth of twenty-eight feet the same vein has been worked by E. T. Jared, Jr. The output of the Joe Hayhurst mine, in the center of section 35, is about 25,000 bushels. The vein is found at a depth of thirty feet. The Sipes mine, seventy-five feet deep, yields about 30,000 bushels annually. The conditions of all these and of some neighboring mines, some of which are worked only at intervals, are much the same. The seam maintains a uniform thickness of twenty-eight inches with very great persistency. The differences of depth are due to surface elevation. In the Simms mine, in the extreme northeast corner of South Fork township, the vein is reported to be thirty inches thick and at a depth of sixty feet.

In the southwest half of section 23, Jackson township, there is a coal shaft 165 feet deep, with a twenty-six inch vein and a good roof. Mr. W. R. Slack, the owner, reports an output of eighty bushels per day.

In the northeast quarter of section 14, same township, Thomas Wood operates a mine with a twenty-five inch seam, at a depth of 135 feet. The roof is said to be poor. Seven to ten tons per day is reported to be the output, the demand being local merely.

By far the greater part of the coal mined in Wayne county is taken out by the two mines of the Numa Block Coal Company at Seymour. Mine No. 2 is situated on the north side of the Chicago, Milwaukee and Saint Paul railway, one mile east of the Milwaukee depot at Seymour (southwest quarter of the northeast quarter of section 13). This mine, known as the "Big Jim," has produced more coal during recent years than any other in the Appanoose-Wayne coal field. Working full time it can easily produce 100,000 tons per year. It is equipped with an Ottumwa first-motion hoisting engine, steam dirt dump, Ottumwa box-car loader, and self-dumping cages. The remainder of the equipment is good. The shaft is 202 feet in depth. Mine No. 3, called the "Sunshine" mine, is in the southeastern part of Seymour about one-half mile from the Rock Island station. It loads a considerable output on the Chicago, Rock Island and Pacific railway. The shaft is 240 feet deep, showing that the strong southwesterly dip seen in the mines is continued between Nos. 2 and 3. The lower part of the section in this district, as given by Keyes, is:

FEET	INCHES	
1	10	8. Limestone, gray, fossiliferous (exposed).
	6	7. Clay, drab, shaly ("clod)"
	10	6. Shale, bituminous, fissile.
1	4	5. Coal.
	2	4. Clay parting.
	9	3. Coal, with an occasional thin clay parting.
1	3	2. Fire clay.
1	10	1. Limestone, thick bedded, gray.

Figure 21. Part of Seymour shaft, Seymour.

In the northeast quarter of the southwest quarter of section 29, Walnut township, is the Winger mine. The shaft is 145 feet in depth. Hoisting is done by a small single engine. The limestone "cap rock" occasionally rests directly on the coal; elsewhere "slate" intervenes as shown in figure 22.

FEET	INCHES	
3		6. Shale, black, fissile, grading into 5 below.
1	2	5. Coal.
	2	4. Clay parting.
	8	3. Coal.
2	6	2. Fire clay.
3		1. Limestone, gray.

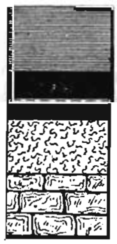


Figure 22. Bed of Winger mine, Harvard.

A number of other mines in different localities are reported to have been abandoned or to be worked at irregular intervals as they supply local demands only.

Numerous prospect holes have been put down. In some instances no coal was found, either because they were situated outside of the Des Moines area or because they were not carried to a sufficient depth. In many cases a good vein of coal has been reported to be found, but for various reasons it has not been worked as yet. Too much water, poor roofs, or too great depth are the commoner reasons given. Towards the western edge of the Des Moines stage the Mystic seam appears to become more variable and other veins appear. The Posten sections already given illustrate this. In one of these as many as seven coal seams are found.

Mr. Alexander Mardis found a thirty-one inch vein at a depth of 321 feet in the northeast portion of the city of Corydon. In sinking a shaft, just before reaching the rock surface, a flood of water caused abandonment of further effort. This strong aquifer was the Aftonian doubtless, as numerous evidences of vegetation were found immediately above it.

Mr. O. C. Davidson some time ago had a prospect hole put down near New York, Union township. It is 200 feet deep and a good vein of coal is reported to have been found by Mr. Davidson, but details could not be secured.

Coal is reported to be found in Missouri three or four miles southwest of Lineville, but no active mining operations were discovered. Two thin seams of coal are reported in a prospect hole not far from the Mineral Spring about two miles southwest of Lineville. Along a "branch" southeast of the mineral spring near Dan Reagan's a very hard, thick bedded brown limestone some six feet thick outcrops. It overlies twelve to fourteen feet of blue argillaceous shale, locally known as soapstone. Somewhere beneath this a drift mine is said to have been operated. From inquiries made it is not thought that it is a very important outcrop. A prospect hole in the southwest quarter of section 21, Grand River township, 154 feet deep, failed to reveal any traces of coal.

Clays

Loess quite often proves to be a satisfactory material for brick making for common use. In the west border of Corydon Mr. Alexander Mardis has a brick plant where all the common brick used in that town are manufactured. Two or three inches of surface are removed and about eighteen inches of loess remain suitable for the purpose. Handmade brick of a good red color are made in quantity to meet the local demand and also to supply neighboring towns to some extent. The same material is used at Allerton, Lineville and Crawfordsville. The soft mud process is employed in all cases. The clays of the Des Moines stage would make excellent material for brick and tile in some cases, no doubt, but the demand at present does not warrant the expenditures necessary to secure them, owing to the heavy covering of Pleistocene.

Water Supplies

Good water is usually secured in abundance from wells, dug, bored or drilled, ending usually in the drift, but in a few cases going to a sandy or gravelly aquifer just at the base of the drift and in a few instances ending in the older formation. At Seymour wells average from twenty-five to thirty feet in depth. At Corydon they are from twenty-six to thirty feet. At Humeston the average is twenty feet. About New York dug or bored wells average sixty feet. At Lineville dug wells average twenty to thirty feet. All were of this kind until a few years ago, when boring became common and some wells went to the depth of sixty feet, ending in the drift, however. The railroad well there is eighty feet deep, ending in rock, but the water is mineral to such an extent as to be of no value to the railroad company. The well just east of the public square is thirty-two feet deep and furnishes an abundance of water.

A well drilled in a deep valley two or three miles southwest of Lineville across the Iowa border reached limestone at twenty-seven feet. Shale, "soapstone" and sandstone are also reported but the driller was unable to give the details of the order or thickness of the various beds. The waters are strongly mineral and medicinal and a sanitarium is maintained there. The instances given are typical and illustrative for all parts of the county.

Mr. J. S. Whittaker informs me that fifty years ago water was scarcely obtainable from wells at any reasonable depth. Water therefore was run into dug wells from the roofs and such were called overshot wells. But these wells, forty-five to sixty feet deep, gradually acquired water by seepage until now it stands in them to within ten or fifteen feet of the surface. This change is due, perhaps, to the cultivation of the soil by which it has been rendered more pervious through the breaking up of gumbo and mixing in more pervious materials, such as loess and till, and thus allowing a higher per cent of the rainfall to become ground water.

Springs

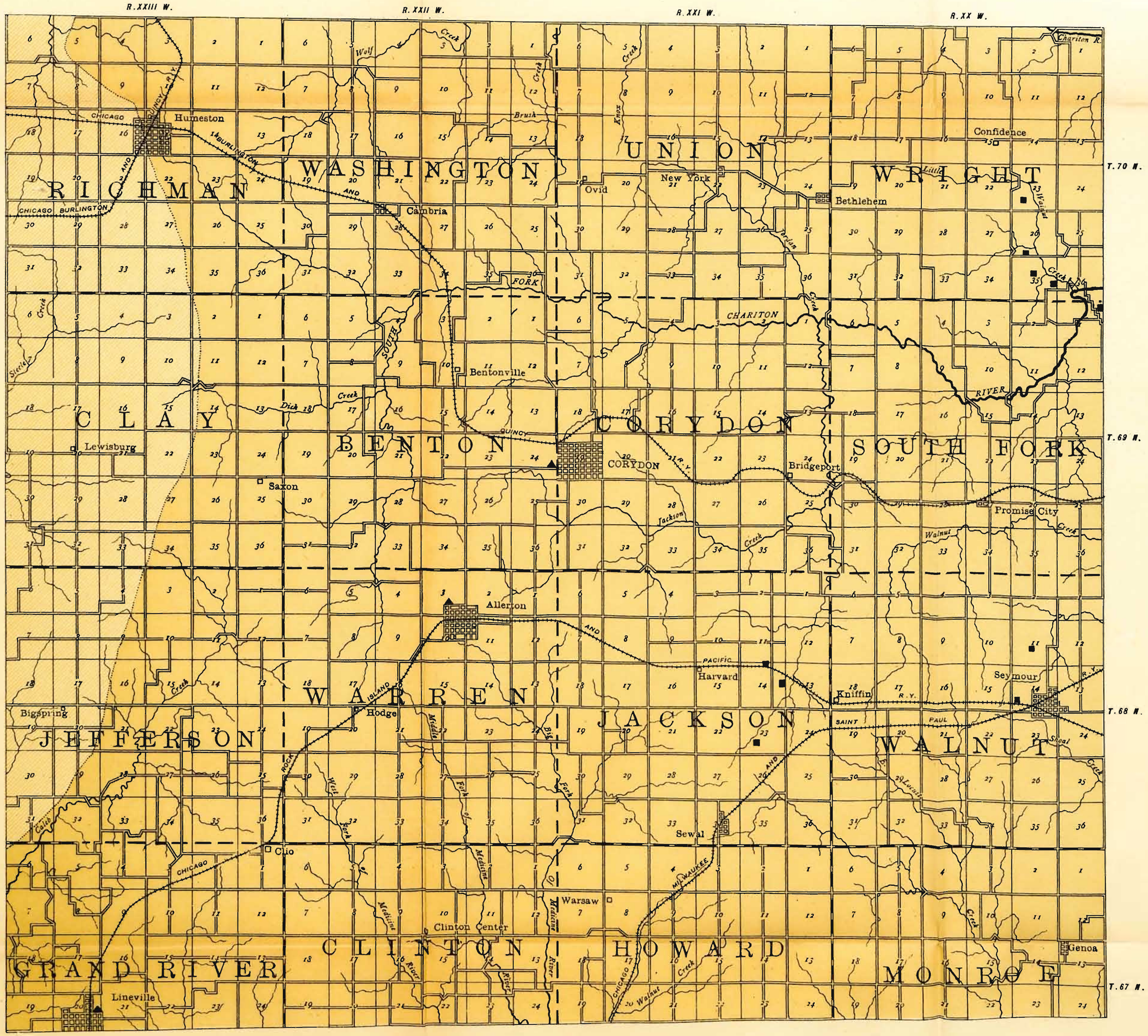
Springs are rarely found anywhere in the county, but in the neighborhood of Humeston "made springs," as they are called, have been formed by piercing the foot or more of impervious clay underlying small bogs. A water bearing sand is thus reached and a perennial spring or shallow artesian well is the result. On section 22, Richman township, near the line of section 21, a constant flow filling an inch and a quarter pipe has been secured. Others are located on sections 18 and 19.

White* gives a history of "salt springs" in Iowa. Of the twelve reputed salt springs given in a list supplied by Col. C. C. Carpenter at the time when he was Register of the State Land Office, one was located in section 1, township 70, range 22, Wayne county. Mr. J. S. Whittaker, one of the earliest settlers of the county, and one who has an intimate acquaintance over all parts of the county, finds no trace of a spring of any kind in that or neighboring sections. Long time residents of that immediate neighborhood know nothing of such a spring. Some of the springs in the list were real springs and maintain a briny taste to this day, but it will have to be conceded that the one in Wayne county was mythical from the first.

ACKNOWLEDGMENTS

The writer here wishes to express his grateful appreciation of the many courtesies extended to him in the prosecution of his work. He feels under special obligation to R. C. Posten, Esq., J. S. Whittaker, Esq., and Hon. Alexander Mardis, of Corydon, and Mr. Austin of the Lineville Tribune, who have given much valuable information and have otherwise shown a generous interest in the furtherance of the work.

*Geol. of Iowa, Vol. II, p. 335. 1870.



IOWA GEOLOGICAL SURVEY

GEOLOGICAL MAP OF WAYNE COUNTY, IOWA.

BY

M. F. AREY.
1910

Scale $\frac{1}{125000}$

1 ½ 0 1 2 3 4 5 Miles.

1 ½ 0 1 2 3 4 5 Kilometers

LEGEND
GEOLOGICAL FORMATIONS

PENNSYLVANIAN
MISSOURI

DES MOINES

INDUSTRIES

COAL MINES ■

CLAY WORKS ▲

QUARRIES ⚒

IOWA LITHO. CO.

DRAWN BY F. C. TATE

GEOLOGY OF POWESHIEK COUNTY

BY

S. W. STOOKEY

GEOLOGY OF POWESHIEK COUNTY

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CONTENTS

GEOLOGY OF POWESHIEK COUNTY

INTRODUCTION

LOCATION AND AREA.

Poweshiek county lies southeast of the center of the State of Iowa. It is in the fourth tier from the south and is the fourth county west from the Mississippi river. To the north lies Tama county, to the east Iowa, Mahaska and Keokuk border it on the south, and Jasper forms its west boundary. From the center of the area to the Mississippi river is about one hundred miles, and Des Moines is fifty miles to the west. It is included in the area described by McGee in his Pleistocene History of Northeastern Iowa. The name is that of a famous Fox or Musquakee chief, this county having formed part of the territory occupied by that tribe of the aborigines before the white man took possession.

The area under consideration embraces townships 78 to 81 north, and ranges 13 to 16 west of the 5th principal meridian. It contains sixteen congressional townships and 576 square miles, or 369,360 acres.

HISTORY.

The first settlement of Poweshiek county was made in 1843 by Richard B. Ogden, followed next year by D. Satchel and Richard Cheesman. In 1848 the county was organized, the first county commissioners being Jacob Yeager, Martin Snyder and Richard B. Ogden. In 1854 colonists from the eastern states under the leadership of the Rev. J. B. Grinnell of New York, after careful investigation of various localities, selected as a most suitable place for settlement the tract of land embraced in township 80, range 16 west, in this county. The city of Grinnell and Iowa College are the historic results, and this selection out of the splendid domain of government lands then open to settlement, speaks in eloquent terms of the beauty of landscape, the richness of soil, the abundant water supply and the general healthfulness and desirability that have always characterized this highly favored spot.

PREVIOUS GEOLOGICAL WORK.

The report of James Hall, 1858, makes some reference to Poweshiek county. Attention is called to the lack of exposures of the indurated rocks except along the North Skunk river; to the Subcarboniferous limestones probably extending from Tama and Marshall counties through Poweshiek; to the rock quarry at Walker's Mill on the North Skunk river.

McGee in his Pleistocene History of Northeastern Iowa makes a number of references to this county. He refers to its topography, to the predominance of sandstones in the Coal Measure strata, to a deformation of the strata southwest of Grinnell, and to the asymmetric character of the stream valleys.

Under the present survey Keyes has treated at some length the subject of the coal of the county,* Beyer and Williams† the clay industries, and Norton‡ the Grinnell Artesian Well Number 1. The lack of rock exposures has of course made it a comparatively uninteresting field for the geologist and accounts for the small amount of work done and the paucity of its literature.

PHYSIOGRAPHY

Topography

The present topographic features of Poweshiek county are expressed in an original plain gently sloping to the east and south. Into this original plain the streams have cut their valleys and a mature drainage system has been established. Remnants of the original plain are still to be seen in the comparatively level divides between the larger streams.

Almost the entire surface of the county is covered with a thick mantle of drift, the Kansan drift sheet, everywhere present except in a few places in the southwestern part of the county

*Iowa Geological Survey, Vol. II, pp. 300-304. 1893.
†Iowa Geological Survey, Vol. XIV, p. 477. 1903.
‡Iowa Geological Survey, Vol. VI, pp. 287-292. 1896.

where stream action has laid bare the underlying indurated rocks. Over a considerable part of the county the drift is covered by a veneer of loess. The larger stream valleys are partially filled with alluvium which likewise obscures the glacial drift. Generally throughout the county the roadways expose the yellow or brown bowlder clay of the Kansan till, and in many fields the plow finds evidences of the same material forming the basis of the surface soil.

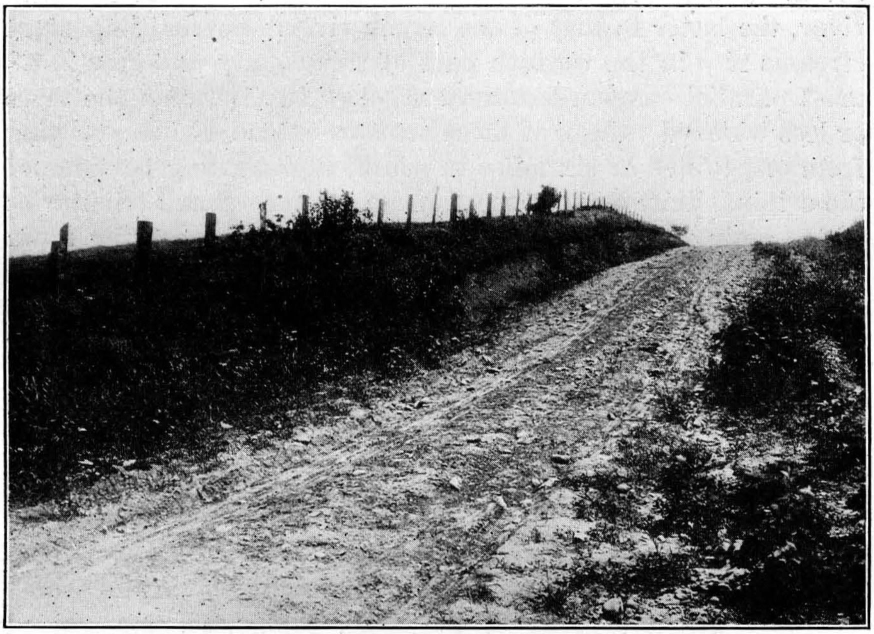


Figure 23. Road showing weathered Kansan drift without loess. Along the north line of section 6, Grinnell township. Typical of many stretches of road in Poweshiek county.

The Kansan glacier in its final retreat evidently left this region a relatively level plain. As the mighty ice-cap made its way down from the north over the country, it doubtless completely changed the features of the ante-Pleistocene surface. The streamways and valleys of that old eroded land surface must have been filled and its ridges and rocky ledges more or less completely overwhelmed and destroyed by the repeated advances and retreats of the ice sheet. Over the whole region was spread to a depth reaching in many places several hundred feet the heterogeneous material of the Kansan drift and when the ice sheet finally retreated it left a comparatively level surface. In this drift surface the present topographic features are very largely expressed, and they have been produced largely by the ordinary work of water erosion.

As indicated by the direction of the streams, the slope of the northern and eastern two-thirds of the surface of the county is almost east, while the southwestern third is a little east of south. The former belongs to the drainage system of the Iowa river, the latter to that of the Skunk river. Several important streams rise in the western part of this county and flow in almost parallel eastward courses through it. Between the more or less widened valleys of these streams extend divides, varying from one to five or six miles in width, representing portions of the original drift plain of the Kansan glacier. Small tributaries of the main streams head back in these divides, breaking up in dendritic fashion into very complex systems of ravines and gullies. Gradually under the operation of the erosive agencies these initial gullies are working their way farther and farther back into the divides, enlarging the area of the valleys and diminishing the area of the uninvaded upland.

Throughout the county there is the almost endless repetition of this type of topography. East and west roads that skirt these uplands present a succession of hill and dale, that is exceedingly trying to the traveller. Now the road runs over the crest of a ridge which is a spur of the upland plain, on the top of which will be found a capping of the drab, pebbleless, fine-grained loess. The next hill may not rise so high, showing no trace of loess, the brown, weathered bowlder clay of the Kansan till forming the roadbed. A series of successively lower hills will be passed over by the road, and finally a transversely running streamlet will be reached. Traced by the eye in one direction the valley of the streamlet will be seen to widen as it advances toward the major eastwardly flowing stream; in the other direction it may be seen to divide and subdivide into innumerable minor valleys that run back into the upland plain. The slopes of the hills are rounded, and the ravines are V-shaped. It is a region well advanced toward maturity of drainage and topography.

One may indeed select his road in such a way as to traverse the county largely on the divides, and thus avoid in large measure the irregularities just mentioned. Such a road is the one running from Grinnell in a southeastward direction to the middle line of the county, thence eastward on the south line of Malcom, Bear Creek and Warren townships to the border of the county. Another upland road is that from Montezuma to Deep

Figure 24. Loessless area in northwest quarter of section 6, Grinnell township.

River; another one mile southeastwardly from Ewart, thence east to the county line. The Iowa Central railroad, which enters the county in Chester township northwest of Grinnell, has selected a route along inter-stream divides for one of its branches, that through Jacobs, Ewart and Montezuma. From the car window the traveller over this line may easily believe that he is passing over a portion of the characteristically level Iowan drift plain instead of the usually hilly Kansan.

These level areas formed the typical treeless savannas or prairies of the days before the settler transformed the country with plow, grove and homestead. They form today the most ideal farms. The wealth of humus accumulated during the long period when countless annual growths of vegetable matter were returned to the soil is not washed and carried away by rain and stream as is the case in the more hilly parts of the county. Here the labor of the agriculturist is carried on with a minimum of energy and a maximum of result. Probably no soil in the world is capable of yielding a larger reward for the labor expended than that of the comparatively level uplands of Poweshiek county.

The larger streams meander through well developed flood plains. Several of these streams rise in the western part of the county and form excellent illustrations of the phases of stream development. The Grinnell plain is being gradually encroached upon by gullies and ravines which, uniting to form ever enlarging runs, finally become Little Bear creek and North English river. These streams are thus gradually working back into the divide and lengthening their courses, while their valleys ever widen and encroach upon the inter-stream divides.

The abundant wash from the plains and the materials eroded from the gullies and ravines of the stream heads, as well as that from the valley slopes farther down, have been spread over progressively widening flood plains. As these plains expand the streams increase their meanders. This may be well seen along the Chicago and Northwestern railroad which runs across the east tier of townships in this county, and has located its stations, Carnforth, Guernsey and Deep River at the crossings of Bear creek, North English river and Deep river, respectively. At these stations good views are obtained of these stream valleys where they are best developed. The Chicago, Rock Island and Pacific railroad has utilized as a roadbed the flood plain of Bear creek and Little Bear creek through the western part of Iowa county and through Poweshiek almost to Grinnell.

There is a gentle slope of the northeastern two-thirds of the county toward the east as indicated by the courses of the streams. According to the elevation of points on the upland plain near the western and the eastern borders of the county, as Grinnell on the west and Hartwick on the east, the average gradient is not more than two and a half to three feet to the mile. Measured along the stream valleys, however, the fall is much greater, showing the progressive downcutting of these streams into the plain. The average fall of Little Bear creek from Malcom, near the center of the county, to Carnforth, near the eastern border, is eight feet per mile; while from the Grinnell plain in which this stream heads, to Malcom, a distance of less than ten miles, the fall is 119 feet. At the crossing of the Northwestern and Rock Island railroads on the flood plain of Bear creek, in Warren township, the stream bed is 150 feet below the upland plain at Hartwick four miles north.

The work of North English river in excavating and widening its valley is nearly as great as that of Bear creek. Jacobs is a station on the Iowa Central railroad in the west central part of the county, situated on the upland plain, and near the heads of North English river. Its elevation according to the profiles of the Iowa Central railway is 971 feet. Guernsey, situated on the flood plain of that river two miles from the east border of the county, is 137 feet lower.

A similar comparison may be made for Deep river in the case of Montezuma, a point five miles from the south border of the county and exactly in the midline from east to west, and Deep River, a point on the flood plain of the stream of the same name, and situated seven miles due east of Montezuma. The elevation of the upland plain at Montezuma is 948 feet and the flood plain at Deep River 862 feet, a difference of eighty-six feet.

The southwestern third of the county presents some topographic contrasts, and many similarities to the area already described. The line of separation is determined by the divide between the Iowa river drainage basin, to which most of the county belongs, and that of the Skunk river. As already noted the Iowa Central railroad has utilized this comparatively level remnant of the original Kansan plain for its road bed. The highest points in the county are along the crest of this divide. At Gilman in Marshall county, one mile from the county line, the elevation is 1,090 feet; other points along this crest are:

Grinnell, 1,011 feet; Jacobs, 971 feet; Ewart, 963 feet; Montezuma, 948 feet; Barnes City, 910 feet. An average slope toward the southeast along this divide of about four feet to the mile is indicated by these figures.

The region to the southwest of this divide belongs to the basin of the North Skunk river. It includes all of Sugar Creek and Union townships, the larger part of Washington and portions of Pleasant and Jackson. Over this area very little of the original Kansan plain remains. The whole presents a thoroughly dissected plain. The slope is toward the southeast, and toward the master stream of the area, the North Skunk river, which crosses the southwest corner of the county, cutting off the southwest third of Sugar Creek township. Here and there on the crests of hills the capping of loess indicates a remnant of the original plain, but almost everywhere the roadways show the brown, weathered, oxidized bowlder clay of the Kansan till at the surface. An exception to this is seen in the bluffs along the North Skunk river, where the loess may generally be found of considerable thickness.

A feature of the stream valleys throughout the county, which has been noted by various geologists as characteristic of the streams of the Kansan drift area in Iowa, is their lack of symmetry. McGee refers to the streams of Poweshiek and Iowa counties as typical examples of these asymmetrical valleys. His comparison of the area of these eastwardly flowing streams to a series of tilted plains with the northern margin raised and the surface gently sloping to the south, to meet the northern raised edge of the next plain, which in turn slopes southward, and so on throughout the area, fairly describes the appearance presented. The stream bed in such a case is along the base of the scarp of the supposed tilted plain. The slope of the valley to the south of the stream is short and comparatively steep. The tributaries from the south are few in number and insignificant in size. Looking up this southern slope from the flood plain or stream bed one gets the impression of irregular bluffs of varying height. In the opposite direction the slope is gradual and more or less regular to the crest of the divide. The tributaries from the north are more frequent and of considerable size, draining as they do the comparatively large area of the extended northern slope. Admirable illustrations of this peculiarity are found in all the larger streams of the county. In the case of Bear creek in its course throughout Bear Creek township to its junction with Little Bear creek there is not a tributary from the south, while at least four flow in from the north.

The supposition of a series of tilted plains elongated in an east and west direction, as suggested by McGee, might be admissible in an area whose surface topography is determined by indurated rock strata. Faulting or folding of such strata might easily produce an effect of this sort. But in a region such as this whose topographic features are expressed in the drift and are almost exclusively the result of erosive agencies, such an explanation seems scarcely tenable.

Professor Calvin suggests an explanation based upon the principles of erosion and stream action. "This surface in the region under discussion was drained by a number of parallel streams, each flowing toward the east. As soon as these streams cut channels of any considerable depth, the two sides of each channel were differently affected by the agents of erosion. The northward facing surfaces suffered less than the opposite side of the channel from the alternations of freezing and thawing, and consequently the effects of erosion in early winter and spring. They were less affected by the droughts of summer, which tended to check the growth of vegetation and render the surface more pulverulent and more easily attacked by the dashing rain storms. The result was that as the channel was deepened the north side of the valley receded more rapidly than the south, the slopes soon became gradual, the small lateral streams on the north cut back into the highlands with greater facility and greater speed, robbing the secondary streams developed on the south side of the drainage area to the north; and so as a result of normal causes each drainage basin became unsymmetrical, and was converted into a sloping plain with the main drainage streams along its southern margin."*

*Geology of Johnson County, Vol. VII, Ann. Rep. Iowa Geol. Survey.

TABLE OF ELEVATIONS.

Taken from Gannett's Dictionary of Altitudes, 4th Edition, 1906.

LOCALITY	AUTHORITY	FEET
Carnforth	C., R. I. & P. Ry	808
Carnforth	C. & N. W. Ry	832
Brooklyn	C., R. I. & P. Ry	848
Malcom	C., R. I. & P. Ry	892
Newberg (Jasper Co.)	I. C. Ry	1029
Grinnell	I. C. Ry	1011
Grinnell	Weather Bureau	1023
Jacobs	I. C. Ry	971
Searsboro	I. C. Ry	806
New Sharon (Mahaska Co.)	I. C. Ry	859
Ewart	I. C. Ry	963
Montezuma	I. C. Ry	948
Barnes	B., C. R. & N. Ry	910
Hartwick	C. & N. W. Ry	955
Guernsey	C. & N. W. Ry	834
Deep River	C. & N. W. Ry	862
Tilton	C. & N. W. Ry	845

Drainage

As already indicated in the foregoing discussion Poweshiek county forms a part of two drainage basins, viz., that of the Iowa river and that of the Skunk river. The northern and eastern two-thirds of the county belong to the Iowa river system, and the southwestern third to the Skunk. The whole county presents an area of nearly mature drainage, but no large river flows through it. The North Skunk flowing across the southwest corner, is the largest, but its total length within the county is not great, the linear distance from the points of its entrance and its exit being not more than five or six miles.

No less than six important tributaries of the Iowa river head in the divide that separates the Iowa basin from that of the Skunk. These flow in an easterly course. Walnut creek flows through the northern tier of townships and drains the eastern part of Chester township and approximately the northern two-thirds of Sheridan, Madison and Jefferson. It follows the law of these streams in having its longer and more numerous tributaries from the north, and having the southern slope of its valley comparatively short and steep. Several of the tributaries of Bear creek, the next stream to the south, approach to within a mile of the stream channel of the Walnut. It leaves the county in section 1, Jefferson township, near the northeast corner of the county.

Bear creek is one of the most important streams of the county. It heads in the divide just beyond the northwest border of the county, and flows entirely through it, draining a considerable part of the two northern tiers of townships. Through Malcom, Bear Creek and Warren townships, its channel is from seventy-five to 150 feet below the upland divide to the north and south. It flows through a widened valley and through the greater part of its course meanders through a flood plain of from one-half mile to a mile in width. It receives no tributaries of consequence from the south (except the eastwardly flowing Little Bear creek) but several from the north, the largest of which is Rock creek.

Little Bear creek heads in Grinnell township, flows through Malcom and Bear Creek townships and joins Bear creek near the center of Warren township. The Chicago, Rock Island and Pacific railway has advantageously utilized its comparatively level valley for a road bed, as it has that of Bear creek eastward to Marengo in Iowa county.

North English river heads in the region south of Grinnell, flows southeast across the northeast corner of Washington township, thence east through Pleasant, Scott and Lincoln townships. With the exception of Bear creek it has a longer course within the county than any other stream. Its flood plain is well developed, especially in the eastern half of its course within the county, and it flows through Scott and Lincoln townships in a valley from fifty to 100 feet lower than the upland plain.

Deep river rises in the southeastern part of Pleasant township, and flows through the southern part of Scott, thence across the northern part of Deep River.

South English river with its tributaries drains the larger part of Jackson and Deep River townships.

The drainage basin of the Skunk river includes the western part of Grinnell township, the southwestern three-quarters of Washington, the southwestern third of Pleasant, the western third of Jackson, and all of Sugar Creek and Union. Sugar creek, West creek, Buck creek and Moon creek, with their numerous secondary and tertiary branches, have cut up this part of the country into a labyrinth of hills and ridges, so that it is the roughest part of the county, and the most thoroughly drained.

STRATIGRAPHY

In Iowa the oldest Paleozoic rocks outcrop along the streams in the extreme northeastern part of the state; those of successively younger age forming a series of terranes running in a northwest-southeast direction across the state. There is a gentle dip of these successive rock systems toward the southwest, so that in general each formation as it meets the eastern margin of the next younger dips beneath it and continues to be found in deep well sections throughout the state to the southwest. In this way the Cambrian, the Ordovician, the Silurian, the Devonian and the Carboniferous systems of rocks form a series of terranes of varying width over which one passes in succession as he travels across the state from the northeast to the southwest.

The rocks that appear at the surface in Poweshiek county all belong to two groups, widely separated in geologic time, the Pleistocene and the Carboniferous, the former lying unconformably upon the latter. Almost the entire area is covered by a mantle of loose uncemented material of considerable variety, representing chiefly Pleistocene deposits and these are spread over the indurated rock to a depth varying from nothing to three hundred feet or more.

The indurated rocks appear at the surface at only a few points along the North Skunk river, which has excavated more deeply than any other stream in the county, and here has reached the sandstones, shales, coal and lime rock of Carboniferous age. At every other point the hard rocks are buried deeply beneath the mantle of drift, loess and alluvium. Even here the part of the Paleozoic section exposed is comparatively insignificant considered from the standpoint of thickness and length of geologic time represented. Knowledge of the indurated rocks in other parts of the county is matter of inference from the study of borings that have been made for wells or in the search for coal, and from the general relations of the geological formations in regions adjacent to this county. The following table exhibits the major groups of the geological record and their subdivisions that are represented in Poweshiek county:

TABLE OF FORMATIONS.

GROUP	SYSTEM	SERIES	STAGE	FORMATION
Cenozoic	Quaternary	Recent		Alluvium Humus Sands, silts, etc.
		Pleistocene	Iowan	Loess
			Kansan	Drift
Paleozoic	Carboniferous	Pennsylvanian	Des Moines	Shales Sandstone Coal
		Mississippian	Saint Louis	Pella beds
				Verdi beds
			Kinderhook	Shale Limestone

Deep wells sunk through these strata show their thickness, depth and general relations. Three such wells have been sunk at Grinnell. The studies of Professor Norton give interesting and important results bearing upon the geological section in this region.* The following table summarizes his results:

FORMATION	THICKNESS	DEPTH	ELEVATION ABOVE TIDE
Pleistocene	212	212	618
Mississippian and Kinderhook*	358	570	458
Devonian	370	940	88
Silurian	260	1,200	—172
Maquoketa	120	1,320	—292
Galena-Trenton*	380	1,700	—672
Saint Peter	40	1,740	—712
Upper Oneota (?)*	262	2,002	—974
New Richmond (?) at	....	2,002	.....

*In place of the terms indicated by the asterisk the following are used in more recent publications of the Iowa Geological Survey: The Kinderhook is included in the Mississippian; for Galena-Trenton Galena-Platteville is substituted; for Upper Oneota Shakopee, and for Lower Magnesian the geographic name Prairie du Chien is used.

A comparison of these results of Professor Norton's study with the record of well number 3 at Grinnell shows the general similarity in thickness and depth of the formations as follows:

FORMATION	THICKNESS	DEPTH
Pleistocene	209	209
Mississippian and Kinderhook*	358	567
Devonian	348	915
Silurian	264	1,179
Maquoketa	156	1,335
Galena-Trenton*	364	1,699
Saint Peter	32	1,731
Lower Magnesian*	290	2,021

*Iowa Geol. Surv., "Artesian Wells of Iowa," Vol. VI, pp. 291.

CARBONIFEROUS SYSTEM

Mississippian Series

KINDERHOOK STAGE.

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

The Grinnell wells show a body of limestone and shale more than 350 feet in thickness next below the drift that is regarded as chiefly representing this stage. Wells in the vicinity of Brooklyn penetrate similar deposits. In the northwest quarter of section 12, Bear Creek township, the Talbott and Thompson well shows the following as reported by W. W. Shannon of Brooklyn:

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

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

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

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

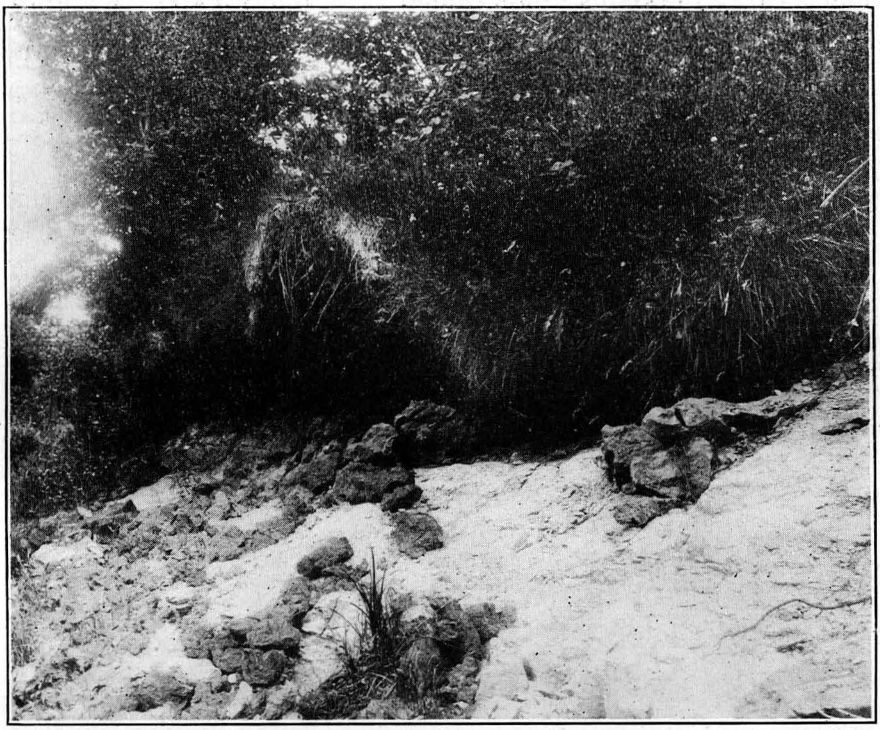


Figure 25. Exposure of Pella beds, Saint Louis limestone, in the south bank of the Skunk river, section 35, Sugar Creek township. The darker, loose masses belong to the overlying Des Moines stage of the Upper Carboniferous or Pennsylvanian series.

SAINT LOUIS STAGE.

Rocks of the Saint Louis stage are exposed at several points along the North Skunk river in the southwest portion of the county. In the southeast quarter of the northwest quarter of section 35, Sugar Creek township, the river has exposed a section as follows:

6. Drift.
5. Sandstone, shaly, partly exposed.
4. Talus.
3. Sandstone, ferruginous, shaly, 6 inches.
2. Limestone and marl, fossiliferous, 7 feet.
1. Limestone at water's edge and bed of stream, compact, fossiliferous.

Numbers 1 and 2 represent the upper part of the Saint Louis, known as the Pella beds. Numbers 3 and 5 are Des Moines. The contact between the Des Moines and the underlying Pella beds is well seen. Both the lime rock at the water's edge and the marls carry the Saint Louis fauna. The following species were noted:

Figure 26. Exposure of Pella beds, Saint Louis stage, overlain by sandstones and shales of the Des Moines stage. South bank of the Skunk river, section 35, Sugar Creek township.

1. *Zaphrentis pellaensis* Worthen.
2. A Monticuliporoid bryozoan.
3. *Schuchertella keokuk* Hall or *S. crenistriatus* Phillips.
4. *Productus marginicinctus* Hall.
5. *Productus ovatus* Hall.
6. *Pugnax ottumwa* White.
7. *Terebratula turgida* Hall.
8. *Spirifer keokuk* Hall.
9. *Athyris subquadrata* Hall.
10. *Allerisma marionensis* White.

Spirifer keokuk is more common in the upper part of the formation, while *Productus ovatus* and *Pugnax ottumwa* are found only lower down in the limestone at the bed of the river.

In the northwest quarter of the southwest quarter of section 36, Sugar Creek township, in the east bank of the river near the Stillwell bridge, eight feet of rather heavily bedded, compact limestone is exposed. It represents the middle phase of the

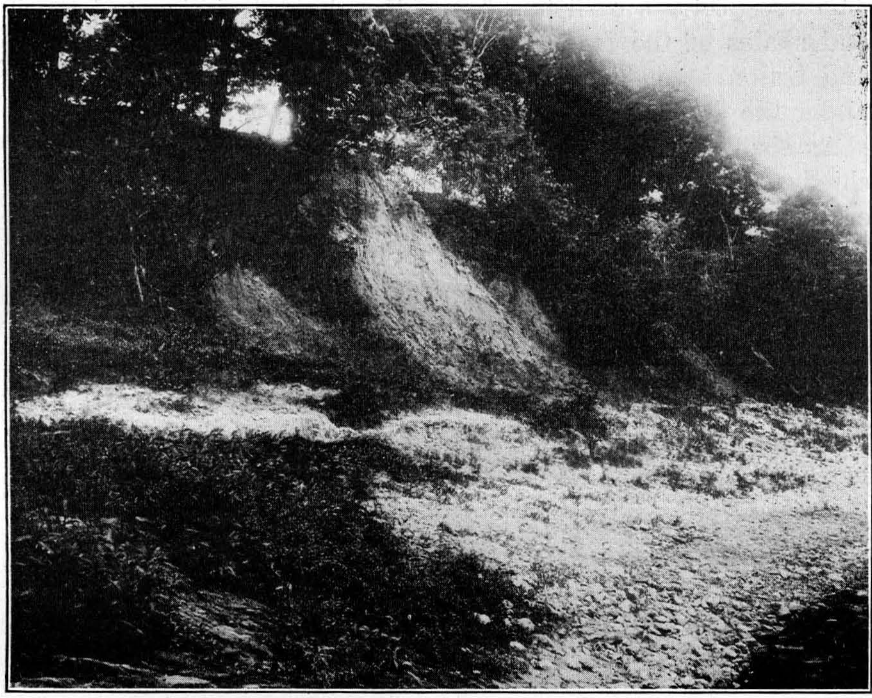


Figure 27. Exposure of Verdi beds, Saint Louis limestone, in left bank of the Skunk river, northwest quarter of section 36, Sugar Creek township.

Saint Louis stage, known from the typical exposure at Verdi in Washington county, as the Verdi beds. No fossils were noticed. Above the limestone exposure the drift is intermingled with fragments of limestone indicating the extension of these beds upward. Elsewhere, as in Washington county, the Verdi beds are characteristically brecciated, and in Keokuk county they alternate with beds of sandstone. The phase represented here is the compact cherty form of the limestone which to the southeast is found associated with sandstone.

Pennsylvanian Series

DES MOINES STAGE.

Deposits of the Des Moines stage form the country rock over approximately the southwestern third of the county. They are exposed at several points along the North Skunk river and its tributary, Buck creek, but elsewhere are deeply buried by drift. The prospector's drill has found the characteristic sandstones and shales of the formation at various places in Sugar Creek and Union townships and well makers report similar deposits under the drift in Washington and Jackson townships.

As elsewhere the rocks of this stage in Poweshiek county are chiefly sandstones, shales and coal. There is but little to indicate their thickness except the few outcrops along the North Skunk river, where some thirty feet of Coal Measure sandstones and shales are exposed. They are doubtless comparatively thin everywhere in this county, and grow thinner toward the margin. The outcrop in the south bank of the North Skunk river in Sugar Creek township (northwest quarter of the southwest quarter of section 36) shows the following:

		FEET	INCHES
10.	Drift	8	
9.	Shale		6
8.	Coal		10
7.	Limestone	1	
6.	Shale, bituminous	18	
5.	Coal	1	
4.	Fire clay	2	
3.	Shale, variegated	7	
2.	Sandstone, brown	2	
1.	Limestone	6	

Of this section 1 is Saint Louis and 2 to 9 are Des Moines. This is the site of one of the early mining enterprises of the county.

The Coal Measure strata in southern Iowa were deposited on the eroded surface of the Saint Louis limestones. Preceding the Carboniferous period the interior region, of which Iowa is a part, was a land surface, and in this particular area the Saint Louis limestones formed the country rock. The agencies of erosion had done their work and a very irregular surface with hills, valleys, ridges and streamways was the result.

The Carboniferous period was ushered in by a widespread depression of the interior of the continent and the encroachment of the sea upon the old eroded Saint Louis surface in such a way as to form shallow estuaries and salt water marshes. The climatic conditions were such as to produce a luxuriant growth of vegetation in these marshes, the accumulated remains of which formed the coal. The shales and sandstones associated with the coal seams represent shore deposits, which under gradual changes of elevation were laid down upon the accumulations of vegetable matter.

Toward the close of the Carboniferous period that part of the interior of the continent in which Iowa is comprised rose high above the sea and became a permanent land surface never again to be submerged beneath the sea. During the extremely long period represented by the closing stage of the Paleozoic, the whole of the Mesozoic, and the earlier part of the Cenozoic, our area was a land surface, subject to the same processes of change that are in operation today. The rocks were disintegrated into soils, while water as rain, snow, ice, surface wash, springs and streams carried on its characteristic work. The progressive changes by which a drainage system establishes itself, matures and passes into old age were repeated again and again during these long periods of time. At first the streamways began to cut valleys and drain the surface. These simple streams developed by working back farther and farther from the sea into the interior. Tributaries were formed and increased in size and number until complex drainage systems were formed. Valleys were widened, ever encroaching upon the inter-stream areas and more and more completely draining them. Finally the divides disappeared, peneplains were formed, the rivers became sluggish and meandering, the cycle was complete.

The re-elevation of the region would start stream action anew, and the cycle of changes would be repeated. Thus were the upper Paleozoic accumulations gradually disintegrated and carried into the Mesozoic seas. To what extent this process went on the vast length of time involved and the extremely uneven character of the ante-Pleistocene surface bear abundant testimony.

At various places to the east and southeast of the Des Moines terrane, as far as the Mississippi river, are outliers of this formation. Evidently it originally covered Iowa as far at least as the Mississippi and may have been continuous with the Coal Measures of Illinois. These patches of the Des Moines sandstone escaped the agencies of erosion which carried away every vestige of the formation around them.

QUATERNARY SYSTEM

Pleistocene Series

The deposits of Poweshiek county that are later than the Coal Measure sandstones and shales belong to the Pleistocene and recent epochs of the Cenozoic era. They consist of glacial drift, alluvium and loess. They overlie the indurated rocks to a depth varying from a few inches to several hundred feet.

Nebraskan Stage: There are no surface exposures of till in this county older than the Kansan. The Nebraskan, the oldest known drift sheet in Iowa, is exposed at the surface at comparatively few points in the state. An old soil and forest bed at the top of this sheet and other lines of evidence indicate an interglacial stage, the Aftonian. Well sections in Poweshiek county seem to show this old forest bed and beneath it a bowlder clay which may be Nebraskan. The well on the Holmes farm south of Brooklyn, as reported by Mr. W. W. Shannon is as follows:

	FEET
4. Yellow and blue bowlder clay	325
3. Much soil with wood	10
2. Blue bowlder clay	40
1. Sandstone (water)	1.5

The Jones well (southeast quarter of section 19, township 81, range 14 west) is reported by Mr. Shannon as follows:

	FEET
4. Yellow and blue bowlder clay	375
3. Forest bed, plenty of ill-smelling water	16
2. Blue bowlder clay	20
1. Sandstone (water)	

In these sections number 1 is Coal Measure sandstone, number 2 Nebraskan (?) drift, number 3 Aftonian (?), number 4 Kansan.

Kansan Drift: The Kansan till is spread over practically the whole of the county. Generally it has a thickness of several hundred feet. Its characteristics are in general the same here as elsewhere in Iowa. It is typically a stiff blue clay containing rock fragments or bowlders of very great variety. Under oxidation and weathering it changes in color to yellow or brown, or where there is considerable iron, to a red color. It presents various phases and conditions. It often contains inclusions of sand and gravel which form important aquifers. In general it is unstratified but in places gives distinct evidence of the sorting effect of water.

The Kansan drift is exposed generally along the roadways and in railroad cuts. Excellent exposures are found in the cuts of the Iowa Central railroad north of Searsboro, where the relations of the loess to the drift may be seen. Between the Kansan drift and the capping of loess is found a line of bowlders, showing that the Kansan surface was eroded and the finer materials removed by wind and water before the loess was deposited.

Loess: This fine dust-like, drab colored material is laid down quite generally in Poweshiek county as a covering to the Kansan drift. It varies in thickness from nothing to twenty-five or more feet. It is thicker along the streams and thins out on the divides. The peculiar lime concretions known as loess-Kindchen are abundant in places.

Recent Series

ALLUVIUM.

This is of recent origin and is found along the principal streams. As the valleys have been widened, the materials eroded from the uplands and valley slopes have been distributed over the bottoms to form alluvial flood plains.

SOILS

Soils are made up of the products of rock decay mingled with more or less vegetable matter or humus. The soils of Poweshiek county are largely derived from the Kansan drift, which itself is rock debris from widely different sources, ground up and worked over in various ways and distributed by the great ice mill and later by aqueous agencies.

The productiveness of any soil depends not only upon its composition, but also upon its physical properties. The drift by its origin forms an ideal soil basis. It contains in abundance a very great variety of rock ingredients finely comminuted and commingled. When the final retreat of the last ice sheet took place, forms of plant life gradually obtained possession of the vast waste of comparatively level, undrained land, and vegetation in ever-increasing variety and luxuriance began to clothe the surface. The annual growth of vegetable tissues, whether in lake, marsh or bog, or on well drained surface, was left in a partially decayed condition to accumulate from year to year. These accumulations became peat or the dark carbonaceous mud of lakes, or the humus of drier lands. The ever changing conditions of erosion redistributed these accumulations, mingling with them new elements eroded from the drift and the result was the rich soils so characteristic of the Kansan drift plain of which Poweshiek county forms a part.

Drift Soils: The upland soils of Poweshiek county have generally the Kansan clays as a basis. In places where erosion has been excessive, the bowlders lie at the surface and the larger ones must be removed from the fields by hand. Generally, however, there is a sufficient accumulation of humus and material of æolian origin at the surface so that the plow does not come in contact with the bowlders.

All that is necessary to perpetuate these upland drift soils in all their productiveness is to return sufficient humus to them to compensate for that which is removed by cropping, and to utilize the clovers and other leguminous plants for their well-known power of storing in the soil nitrogen compounds in available form for plant food. Rich as these soils were when first broken up as virgin prairie, there is no reason why, by proper tillage and management, they may not be made more and more productive.

Loess Soils: This æolian deposit varies considerably in chemical composition in its different phases and in different localities, but it is always rich in the elements of plant food. In its best condition, it is porous and very productive. It forms the soil on the uplands, especially along the streams. It is characteristic of the rougher, more broken parts of the county. For this reason it is often subject to excessive erosion and the problem is to keep it supplied with sufficient humus. It is fortunately well adapted to the growth of clover, and by the proper rotation of this with other crops, the fertility and proper physical condition of this valuable soil may be maintained. The forested parts of the country were originally confined to the loess-covered hilly areas along the streams and there seems a peculiar adaptation of this soil to forest growth and for this reason to the growing of fruit trees. Some of the finest orchards in the county are found where the loess is deepest.

In many of the more hilly parts where the original timber has been removed, the reforesting of the loess hills would give a larger future reward than any other use that could be made of them. On these hills, erosion is so excessive as to make farming unprofitable and their roughness makes it extremely laborious. If they were planted to forest trees or allowed to become forest covered in nature's way, under proper management they would soon become very profitable. Every encouragement should be given to the conservation of the woodlands that remain, and to the reforestation of areas so subject to erosion as to make their value for tillage doubtful.

Alluvial Soils: These deposits are chiefly in the flood plains of the streams. They consist of the material that has been carried down from the uplands and spread over the valley floors. They are generally rich, warm, well underdrained and highly productive.

ECONOMIC PRODUCTS

Coal

The eastern margin of the coal area crosses this county, approximately the southwestern third of it being covered with Coal Measure deposits. It is possible that outliers of the same formation may exist beyond this border within the limits of the county. Notwithstanding the fact that Poweshiek is thus in part within the coal area, it cannot be considered a coal producing county. In fact, almost no coal has been mined within its limits for many years.

Along Buck creek in Union township, some coal was formerly mined, but the seam, which was a foot in thickness at the outcrop, thinned rapidly and was soon exhausted.

On the south side of the North Skunk river (northwest quarter of the southwest quarter of section 36, Sugar Creek township) is the old Petit mine. This mine was at one time fairly productive and supplied the local demand. The vein was sixteen inches in thickness. No coal has been taken from this drift for a number of years. Recently an unsuccessful attempt has been made to locate a second seam several rods up the draw from the Petit drift. It is very doubtful if such a second seam exists at this point.

Prospecting has been carried on west and south of Searsboro where thin seams of coal were found, but not promising enough to warrant further effort. A more thorough exploiting of the region with the drill which is sure to be made in the future may reveal profitable seams of coal within the county.

	FEET	INCHES
3. Shale, bituminous, (exposed).	2	
2. Coal.		8
1. Fire clay (exposed).		4

Figure 28. Coal at Smith and Barrowman mine, Searsboro.

Clay Products

An inexhaustible supply of material for brick and tile exists everywhere within the county. Clays derived from the Kansan drift are common on the lowlands and are of fine quality. Certain phases of the loess afford an excellent material for certain grades of brick and tile. Large supplies of shale may be had at the site of the old Petit mine on the North Skunk river, and along Buck creek.

The Grinnell Brick and Tile Company of Grinnell has a well equipped plant for the manufacture of brick and tile. The loess used here is of the blue phase and more than usually plastic. It makes an excellent product.

Mr. B. J. Broadston, of Montezuma, manufactures brick and tile of good quality. He uses the soft mud method. His plant is equipped with a "Bensing" cutting machine and has a capacity of 30,000 brick per day. He has four down-draft kilns.

Mr. Peter Meyer has a small plant for the manufacture of brick and tile near Stillwell in Sugar Creek township.

Water Supply

Throughout the county the water supply is largely from wells in the drift, usually a local sand or gravel bed being the immediate aquifer. Several wells reported from memory by Mr. W. W. Shannon have their supply in the Des Moines sandstone, and a few others in the Saint Louis limestone.

Three deep wells have been sunk at Grinnell from which the city is supplied. The depth of these wells is a little over 2,000 feet. Professor Norton* is authority for the facts here presented, his study being based on well No. 1. The depth is 2,003 feet, the head of water above tide 798 feet and the elevation of the curb 1,028 feet above tide.

The diameters of the bore are as follows: Ten inches to 208 feet, six inches to 408 feet, five inches to 1,185 feet and four inches to 2,003 feet. Ten-inch casing occupies the ten-inch bore, 450 feet of five-inch casing is located at a depth of from 408 feet to 958 feet, covering the shales of the Mississippian and Devonian, and forty feet of four-inch casing from 1,145 feet to 1,185 feet from the surface.

Water was first found at 212 feet, at the top of the Saint Louis limestone, strongly mineral, almost yellow in color, and rising to within ninety feet of the surface. The inflow of this water could not be checked for a long time, but before the well was completed it was entirely shut off. The second water was found at 1,530 feet from the surface in the Trenton. A third flow was encountered in the Saint Peter at 1,700 feet. This was a strong vein, and "as the drill penetrated the sandstone a roaring noise was heard, and the drillings were washed away by the strong current of water." The water in the tube, which had remained at about 100 feet below the surface, immediately sunk, and this was no doubt the cause of the roaring noise reported. After some time the water returned to nearly the same level. The head of the Saint Peter and Trenton water is in this region ap-

*Artesian wells of Iowa, Vol. VI, pp. 287-292. Iowa Geol. Survey.

parently about 928 feet, but this high level is probably due to a filling of the well with the higher waters faster than it could be drawn off through the lower outlet. More or less water was found all the way from 1,700 feet to 2,003 feet, and on completion of the well the head was found to be 230 feet from the surface.

ANALYSES

The quality of the water at different depths was carefully tested during the progress of the boring. Four separate analyses were made. Number 1 is of the combined water of the first, the second and third flows. Number 2 is of the second and third flows, the first being shut off. These are both by Professor L. W. Andrews, of Iowa City, and were made when the well had reached a depth of 1,770 feet, when water was first pumped from the well. Number 3 and number 4, by Mr. Luther Verbeck, of Grinnell, represent the constitution of the combined waters of all flows, except the first, to their respective depths of 1,940 feet and 2,003 feet.

COMPOUND	NO. 1	NO. 2	NO. 3	NO. 4
Calcium carbonate	9.70	9.60	5.89	7.00
Calcium sulphate	45.25	41.25	42.55	41.10
Magnesium sulphate	41.60	41.00	24.60	30.00
Sodium sulphate	24.75	23.35	24.60	30.00
Sodium chloride	0.05	0.05	0.50	0.87
Iron	....	....	0.17	....
Silica	....	....	0.65	....
Silica, iron and alumina	....	....	....	0.70
Total dissolved solids	121.35	115.25	....	....
Total suspended solids	14.55	2.85	....	....
Total solids	135.90	118.10	112.30	120.75
Hardness	78°	74.1°	41°	44°

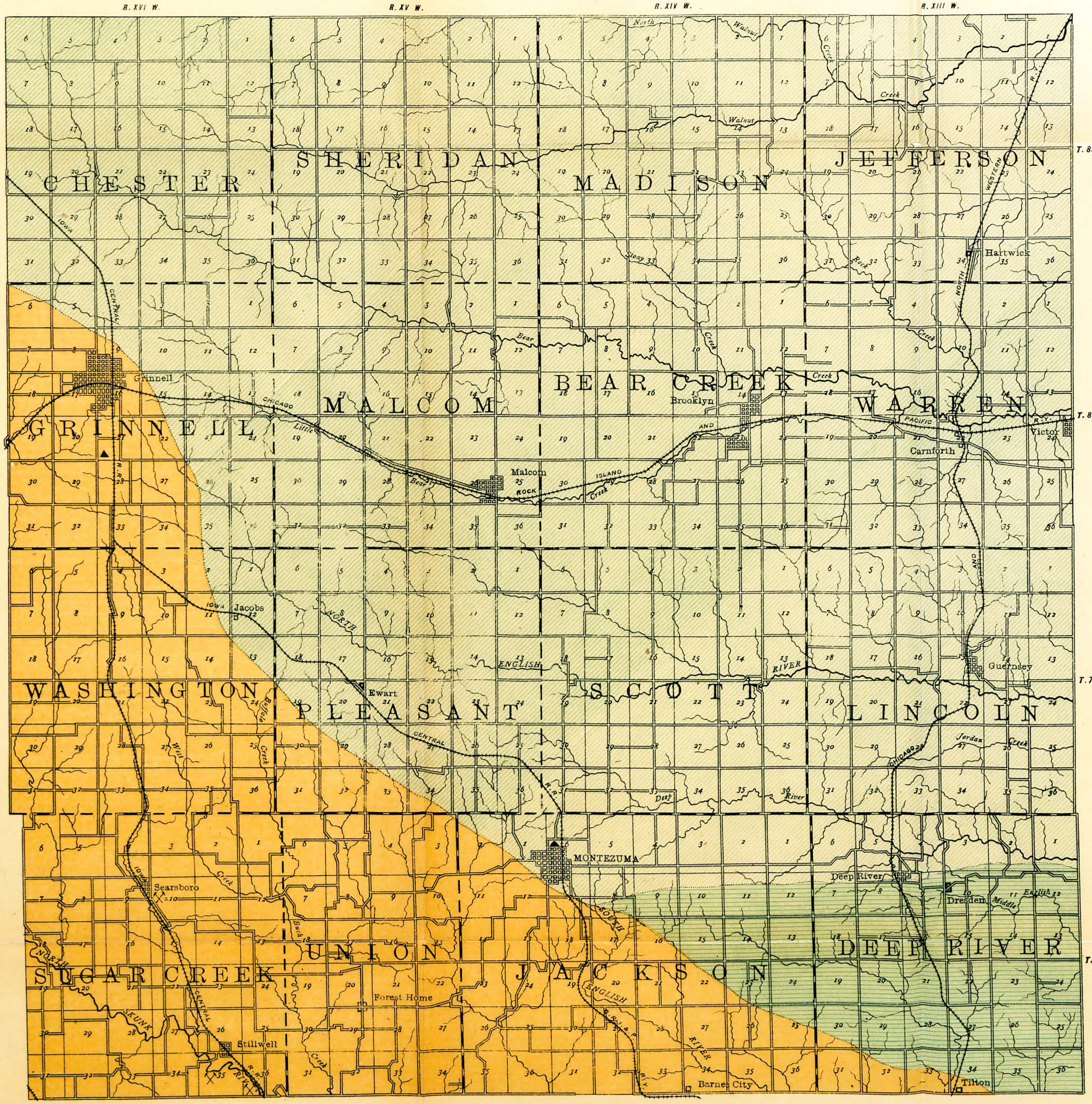
The similarity of the first two analyses is certainly surprising, if the strong mineral water present in the water of number 1 were really excluded from the water of number 2; and the same may be said of the uniformity in the amount of calcium sulphate in all the waters and of sodium sulphate in the first three.

The water is said to be universally liked and very generally used. Physicians report that there has been a marked decrease in zymotic diseases since its introduction, and that it seems to be beneficial in cases of chronic rheumatism. It is at first laxative and diuretic to those unaccustomed to its use, but the diuretic effect ceases and the laxative effect is changed to constipation. Patients with chronic diarrhoea can not take it at all. It is one of the strongest selenitic waters in the state.

RECORD OF STRATA.

		THICKNESS	DEPTH
41.	Soil, loess and drift	212	212
40.	Limestone, rather soft, buff, in chips mixed with sand and small pebbles of northern drift	8	220
39.	Shale, dark gray, fissile, with fragments of impure chert, in light drab argillo-calcareous powder	20	240
38.	Limestone, cherty, arenaceous, argillaceous; after washing is seen to contain many minute crystals of selenite		270
37.	Limestone, gray, as fine sand in argillo-calcareous powder		315
36.	Limestone, cherty, and shale, as chips in argillo-calcareous powder	125	365
35.	Shale and limestone, soft, fissile, dark drab; in powder with a few minute fragments of limestone and considerable chert	35	400
34.	Shale, blue, calcareous, in powder concreted into readily friable masses containing microscopic particles of quartz		415
33.	Shale, hard, green-gray, with compact, light yellow, calcareous, siliceous fragments; siliceous in the form of angular grains of transparent quartz, mostly from .054 to .09 mm. in size, but many much smaller		435
32.	Shale, fine-grained, calcareous, greenish		440
31.	Shale, brownish drab		450
30.	Shale, light blue-gray, somewhat calcareous, two samples		550
29.	Shale, as No. 31		570
28½	Limestone, fine-grained (report A. J. Jones) at		570
28.	Shale, light blue-gray, seleniferous, calcareous, with a few particles of limestone		600
27.	Shale, light drab and bluish, somewhat calcareous, with a little finely divided quartzose residue after washing, five samples	400	800
26.	Limestone, light yellow-gray, granular, subcrystalline, briskly effervescent in cold dilute HCl, with much shale	10	810
25.	Shale and limestone, in light blue-gray argillaceous powder containing a few fragments of limestone		825

	THICKNESS	DEPTH
24. Shale, light blue and green-gray, somewhat calcareous, seven samples, last at 900......		940
23. Limestone, magnesian, medium dark gray, earthy, argillaceous		949
22. Limestone, magnesian, or dolomite, with considerable hard, finely arenaceous, greenish shale		969
21. Shale, light gray, argillo-calcareous...........		990
20. Limestone, highly cherty.....................		1,012
19. Limestone, white, soft........................		1,065
18. Limestone, highly cherty, two samples........		1,130
17. Limestone, cherty		1,175
16. Dolomite or magnesian limestone, light buff, in fine sand		1,200
15. Shale, light drab, calcareous..................		1,260
14. Shale, light brown, pyritiferous, two samples, last at 1,280..............................		1,320
13. Magnesian limestone or dolomite, buff; residue cherty and microscopically arenaceous.......		1,380
12. Shale, brown, darker than No. 14............		1,400
11. Magnesian limestone or dolomite, ferruginous, in dark buff powder; residuary quartzose particles .018 to .18 mm. in diameter, four samples		1,475
10. Unknown		1,610
9. Limestone, magnesian, cherty, light yellow, in powder		1,630
8. Limestone, light gray, fossiliferous, in flaky chips		1,640
7. Shale, green, non-calcareous, "fossiliferous"..		1,655
6. Limestone, magnesian, in buff powder.........		1,700
5. Sandstone, calciferous, quartzose particles from .018 to .18 mm. in diameter; particles of white dolomite mingled with the quartz in the drilling		1,706
4. Sandstone, white, grains rounded and smooth, usual size about .55 mm., maximum seen .92 mm. in diameter		1,740
3. Sandstone, light reddish buff, fine grains, mostly broken, many stained with film of ferric oxide, size .18 to .28 mm. in diameter		1,740
2. Unknown		2,002
1. Sandstone, highly calciferous, or limestone, arenaceous; sand grains angular with some rounded and up to 1 mm. in diameter, matrix of dolomite, white; at....................		2,002



IOWA GEOLOGICAL SURVEY

GEOLOGICAL MAP OF POWESHIEK COUNTY, IOWA.

BY

S. W. STOOKEY
1910

Scale 1/125000

LEGEND
GEOLOGICAL FORMATIONS

PENNSYLVANIAN
DES MOINES

MISSISSIPPIAN
SAINT LOUIS
KINDERHOOK

INDUSTRIES
CLAY WORKS ▲
QUARRIES ⚒

IOWA LITHO. CO.

DRAWN BY F. C. TATE

ACKNOWLEDGMENTS

I found the most ready coöperation on the part of a large number of citizens of Poweshiek county in gathering the data for this report. The officials of the Grinnell municipality furnished copies of the deep well records. Mr. Rayburn of Grinnell facilitated the work in various ways. Mr. W. W. Shannon and other well-makers freely furnished information at their command. Professor Hendrixson gave valuable suggestions. Especially is grateful acknowledgment due the Director of the Survey for his help in the field work, for the photographs illustrating the report and for the identification of the species of the Saint Louis fauna.

GEOLOGY OF HARRISON AND MONONA COUNTIES

BY

B. SHIMEK

ERRATA

P. 309—First line at top, read XXIV in place of XXXI.

P. 349—Plate XXVIII, Figure 2.—The inscription for Figure 2 (B), reads as if the calcareous plates had been folded after formation. They were evidently formed on a folded surface.

P. 395—Sixth line from top, read 30 in place of 31.

P. 415—Tenth line from bottom; read XXXV in place of XXV.

P. 466—Fourteenth line from bottom, read 47 instead of 49.

P. 475—Seventeenth line from bottom, after "first grove" insert: (See Plate XXXV, Figure I.).

P. 484—Tenth line from bottom, substitute H. A. Kinney for M. S. Kinney.

GEOLOGY OF HARRISON AND MONONA COUNTIES

BY B. SHIMEK

CONTENTS

GEOLOGY OF HARRISON AND MONONA COUNTIES

INTRODUCTION

LOCATION AND AREA.

Harrison and Monona counties border on the Missouri river, the latter being in the middle east and west tier of counties and the former lying immediately south of it. They adjoin Woodbury county on the north, Crawford and Shelby on the east, and Pottawattamie on the south. Both are irregular in outline, the Missouri river forming their western boundaries, and the east line of Harrison county is broken because the southernmost tier of townships lies south of the correction line.

Harrison county, which was named for President William Henry Harrison, has a superficial area which is a variable quantity on account of the shifting of the Missouri river. It was reported in 1875* as "nearly 660 square miles," and in 1888 on the basis of the "latest measurements" as about 697 square miles.† Its present area is probably nearly 690 square miles, of which less than one-fourth is occupied by the Missouri river bottom-lands.

Monona county is said to have been named from Monona, Clayton county, the name having been suggested by the member of the General Assembly from Clayton. Its area is also variable, and for the same reason. It was reported in Andreas' Atlas‡ as about 680 square miles, but it is now probably about 690 square miles, of which nearly two-fifths is occupied by the Missouri river alluvial plain.

PREVIOUS GEOLOGICAL WORK.

Though recent investigations show that this region possesses features of great interest it has not been looked upon with favor by geologists in the past, in part because it was assumed that the

*Andreas' Atlas of Iowa, p. 410.
†J. H. Smith, History of Harrison County, p. 20.
‡Op. cit., p. 409.

great mantle of loess on the uplands obscures all other features, and in part because the neighboring counties of Woodbury and Pottawattamie had been quite fully studied, and the intermediate region seemed to give little promise of new developments.

The first scientific expedition to visit this territory was that of Lewis and Clark in 1804,—44 years before the first white settler came to Harrison county, and 48 years before the settlement of Monona county. The expedition spent seven days, from August 5th to 11th inclusive, along the Missouri river within our limits, and three camps were located in what is now Harrison county, and four in what is now Monona county.*

On April 20, 1820, Thomas Say, who was a member of the Long Expedition,† which had spent the winter almost opposite the south line of Harrison county, ascended Boyer creek in a row boat with a small party to ascertain where it discharges from the bluffs.‡

In 1870 St. John made a brief report on the surface features and geology of these counties;§ in 1894 Keyes published a brief discussion of the possibility of the occurrence of coal in Harrison county,** probably based on St. John's report; in 1896 Bain made a brief report on the geology of Woodwarth's (or Woodward's) glen in the northern part of Monona county;†† in 1899 Todd noticed certain Pleistocene and surface features of Harrison county;‡‡ in 1901 the writer reported a *Pyramidula* from the loess of Monona county,§§ later discussed and illustrated the sand-dunes of Harrison county,*** noted certain loess features of the vicinity of Missouri Valley,**** and illus-

*See History of the Expedition under the command of Lewis and Clark, republished by Elliott Coues, 1893, Vol. I, pp. 67-72.

†Account of an Expedition from Pittsburgh to the Rocky Mountains——, under command of Major S. H. Long, U. S. Top. Eng. Compiled by Edwin James, 3 vols., 1823.

‡Op. cit., Vol. II, pp. 67-69. They reached the bluffs in the evening, and on the following day walked up the river, evidently to the present site of Logan, for Say records that "at the distance of about five miles, the high grounds closely bounded the creek, and the valley which below is extensive and fertile, disappears." No other point would answer to this description. There can be no question as to the identity of the stream as the Boyer is correctly represented on the map which accompanies the report. Say subsequently described mammals, birds, reptiles, insects and mollusks from the general region, and some of them are specifically credited to "Boyer creek."

§In White's Report on the Geological Survey of the State of Iowa, Vol. II, pp. 175-186.

**Rep. Iowa Geological Survey, Vol. II, pp. 436-437.

††Rep. Iowa Geological Survey, Vol. V, p. 280.

‡‡Bull. U. S. Geol. Survey, No. 158, plate I, and pp. 88, 98, 140, 144, 147, 149 and 151.

§§Bull. Lab. of Natural Hist., State University of Iowa, Vol. V, p. 143.

***Op. cit., Vol. V, part IV, 1904, p. 374, plate XIV, fig. 2.

****Proc. Iowa Academy of Sciences, Vol. XIV, 1908, pp. 243 and 245.

trated the bluff topography and sand-dunes of Harrison county;* and in 1907 Beyer and Williams discussed the Carboniferous of Harrison county and again described the Logan section.**

Preliminary reports on the results of the present survey were also made by Calvin and the writer in papers cited in connection with the discussion of the Aftonian.

PHYSIOGRAPHY

Topography

The topography of Harrison and Monona counties exhibits three distinct features. The greater part of the surface of both counties presents a rolling loess-Kansan contour which is interrupted by a series of valleys of the streams tributary to the Missouri, extending from northeast to southwest and varying in width from one-half to nearly three miles. Over the greater part of this upland area the surface is not too rough for successful cultivation excepting in a few rather restricted inland localities, which probably date their greater roughness from Kansan time, or even earlier.

The most striking examples of these rough areas in Harrison county are found in the northeastern part of La Grange township; the eastern part of Jefferson township and the western part of Cass (Six Mile grove); near the center of Jefferson township (Elk grove); in the southeastern part of Boyer township and the southwestern part of Douglas township (Twelve Mile grove); the region immediately north and west of Logan; Bigler's Grove in Magnolia and Boyer townships; the region northwest of Magnolia (Raglan's grove) in Raglan township; a large part of Allen township; and in a number of less sharply defined areas in Monona county of which the most striking are in the eastern part of Sioux township; the western part of Kennebec township; and the territory northeast of Grant Center. All these latter areas are deeply cut by narrow branching valleys above which the rugged slopes rise very abruptly. It is also a noteworthy fact that these rough areas are marked by the largest native groves of hard-wood trees.

*Op. cit., Vol. XV, 1909, plate III, fig. 2, and plate V, fig. 2.
**Rep. Iowa Geol. Survey, Vol. XVII, pp. 495-496.

The loess bluffs border the Missouri valley throughout its extent in these counties, and are interrupted only by the tributary valleys, which they frequently follow for some distance, especially on the north and west sides. Similar bluffs appear on the opposite side of the valleys wherever a turn in the valley exposes them to the south and west, but usually on the southeast sides of the tributary valleys the bluffs are lower and less abrupt.*

These loess bluffs and ridges form the most striking feature of the topography of this region. They are most prominent along the immediate border of the great valley, gradually descending to the east and finally blending with the rolling loess-Kansan surface. They present their most striking faces toward the great valley of the Missouri, however, and the abrupt slopes rise in sharp contrast from two to three hundred feet above the great flat alluvial plain (see plate XXI, figure 1, and plate XXXI, figure 2) which has been constructed by the restless river whose history is so interestingly written in the geology of the region. In the spring when abundant rains have bathed the rugged slopes an almost uniform green suffuses them; in early summer they are brilliant with loco weed and other flowers; but when summer has advanced, when the rains have ceased and the blistering winds and scorching sun have robbed the southwesterly prairie slopes of their moisture, the sheltered groves and the exposed prairie surfaces stand out in sharp contrast, visible for many miles and setting out with striking effect and unmistakable precision the varied features of this singular topography. The bluffs facing the valley are usually abrupt, though the basal part of the slope is frequently rendered less precipitous by a remnant of a bench which may be traced along almost their entire length. (See plate XXI, figure 1, plate XXIX, figure 1, and plate XXXI, figure 2.) Frequently the bluffs are formed by the abrupt sides of sharp ridges which are parallel with the valley and in that case they are continuous; or they are formed by the ends of a succession of ridges lying

*See plate XXII. The bluffs at Pisgah (figure 1) are on the left side of the valley, but their line is here so bent that they face the southwest. They resemble the type which is common on the opposite side of the valley.

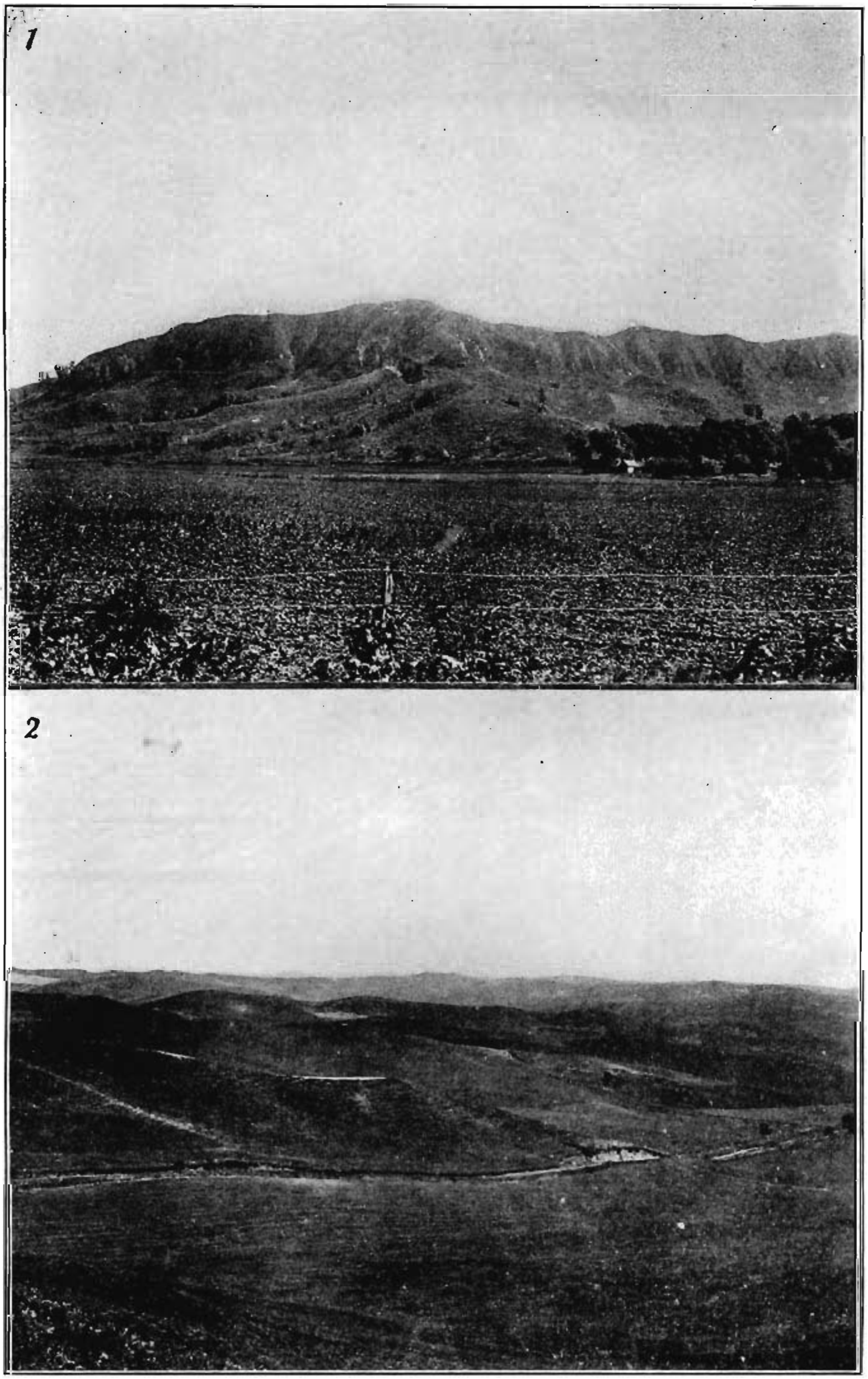


Plate XXI.—Topography in northern Harrison county. (1) Murray Hill, looking northeast (p. 280). (2) Inland topography, looking east from summit of (1) (p 287).

p. [282]
(V.20)

nearly at right angles to the valley and which present an interrupted serrate contour reminding one of distant views of some of the Sierras of the west.

During the day these bluffs may burn in the heat of the midday sun, they may be swept by the hot blasts of summer winds, or hidden in the whirling clouds of yellow dust which are carried up from the bars of the great river; but in the stillness of early morning, and again when the peace and quiet which portend the close of day have settled upon them, they are both restful and inspiring when looked upon from the valley; and there is no grander view in the great Mississippi-Missouri valley than that which is presented under such circumstances from their summits,—on the one hand over the broad valley and on the other across the billowy expanse of the inland loess ridges which appear like the giant swell of a stormy sea which has been suddenly fixed. (See plate XXI, figures 1 and 2.)

This maze of sharp ridges separated by deep valleys has usually been regarded as a result of erosion. White specifically referred to it in these terms,* and this view of their origin has been very generally accepted. It will be shown, however, in the discussion of the loess that the sharpest features of this topography owe their peculiarities to constructional agencies combined with erosion, the former building up the ridges, the latter degrading the valleys. Not infrequently the slopes facing the valley are almost vertical, presenting clear exposures of loess as a result of great slides or faults, which are not unusual during very wet seasons. The oldest settlers report that in the spring of 1859, following an unusually wet year, great masses of the bluff material slipped in this manner. Mr. J. B. P. Day, one of the oldest settlers of Monona county, specifically reports that the principal abrupt exposures along the west side of the Maple valley between Castana and Turin were formed in this manner at that time.

The familiar "cat-steps" which form so conspicuous a feature of the most abrupt loess slopes represent similar action on a smaller scale. It has been sometimes thought that these steps are formed by grazing cattle, but they appear on all the sharper

*Report of the Geological Survey of Iowa, Vol. II, 1870, p. 178.

loess ridges, especially where exposed to the south and west, and the numerous narrow ledges which characterize this type of topography seem to be the result of successive faulting of masses of the loess, and the cattle have simply taken advantage of the natural paths so provided. It should be especially noted that these ''cat-steps'' and the very abrupt slopes upon which alone they occur are not ordinarily found on the bluffs bordering the valleys of the larger tributaries of the Missouri on the southeast. It is only where a projecting ridge or a bend in the line of bluffs on this side of the valleys forms an exposure to the south and southwest that we find the slopes marked by the cat-steps which are so frequent on the opposite sides of the valleys. This is strikingly illustrated along the east side of the Soldier in Harrion county in sections 13 and 26, township 81 north, range 44 west, and along the Little Sioux river in Monona county in sections 11 and 14, township 85 north, range 44 west. (See also plate XXII, figure 1.) Cat-steps are almost uniformly present along the main line of the bluffs facing the Missouri river (see plate XXXI, figure 2, and plate XXXIII, figure 1), and for several miles along the tributaries back from the main valley they are also prominent on the west side. They are also more or less well developed on inland loess ridges with a similar southerly exposure. (See plate XXXIV, figure 1.)

These loess bluffs rise to a height of from one hundred and fifty to a little more than three hundred feet above the alluvial plain and present the most unique topography of the entire Mississippi valley; and whether viewed in midsummer with their unequal covering of vegetation, or in the fall when they are tinted a rusty red by the covering of dry blue-joint grass, or in winter when with their mantle of snow they present the aspect of a series of huge snow drifts, they are of unusual interest to the physiographer, the geologist and the botanist, and they will some day be more fully appreciated even by those who are seeking merely material interests.

As already noted these loess bluffs pass eastward into typical rolling Kansan through a series of ridges constantly decreasing

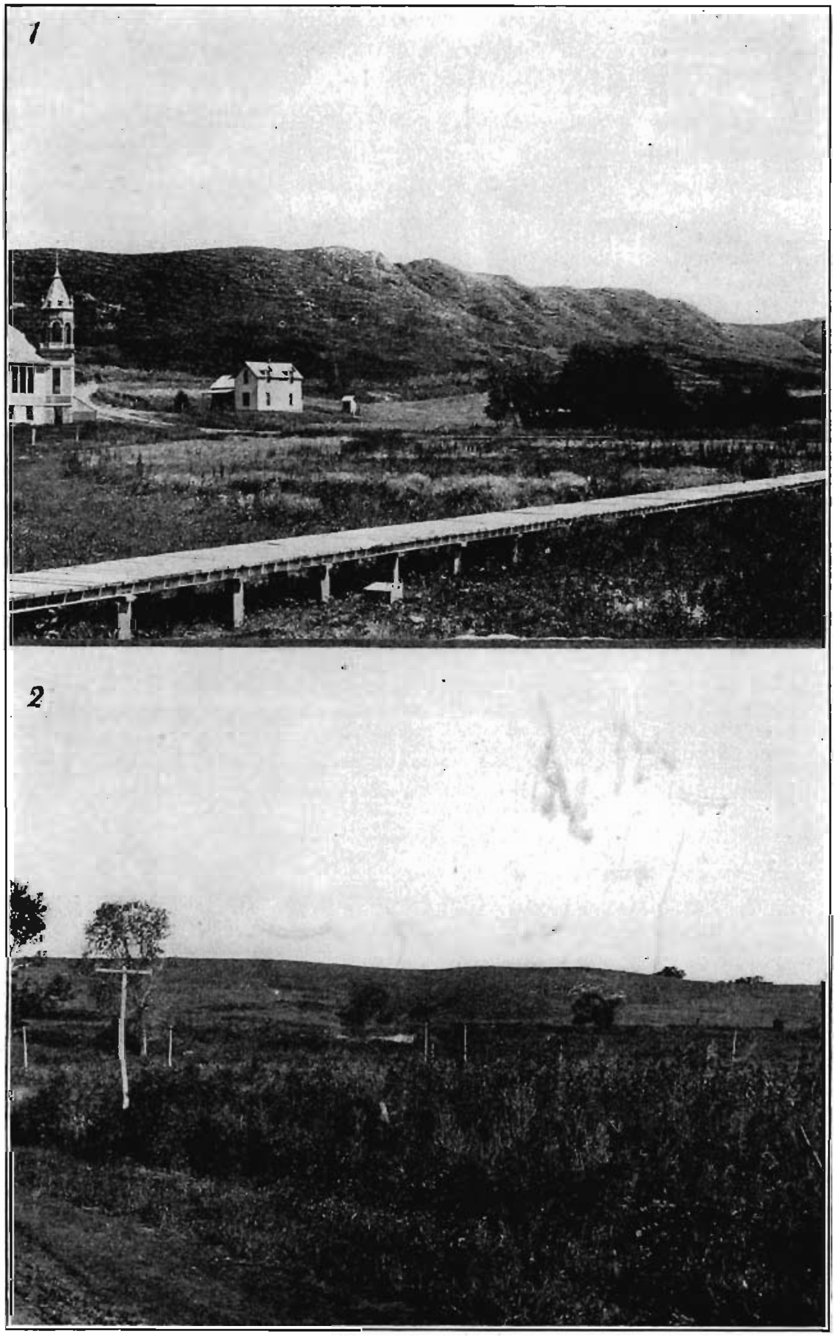


Plate XXII.—Bluffs of tributary valleys. (1) Loess bluffs with cat-steps exposed to southwest. Pisgah, along Soldier (p. 280). (2) Rounded bluffs along the Boyer, south of Cox pit (p. 280).

p. [286]
(V.20)

in abruptness and altitude, the transition usually being complete within two or three miles; though in some cases, as in Raglan, Jackson and Allen townships in Harrison county, and in Sioux, Belvidere and Kennebec townships in Monona county, they extend inland for several miles. The succession of bare sharp ridges and deep valleys form a picture of unusual interest when viewed from the highest points. A bit of this topography is illustrated in plate XXI, figure 2, which represents a view looking east from Murray Hill along the boundary between Little Sioux and Jackson townships in Harrison county.

The third of the great topographic regions includes the alluvial plains of the Missouri river and its larger tributaries. The main Missouri alluvial plain varies in width from about five miles near the southern boundary of Harrison county to about eighteen miles in the northern part of Monona county. The Missouri plain slopes to the south, the fall in Monona and Harrison counties being a total of about seventy feet, but there is also a slope of five to six feet from the banks of the Missouri to the flat at the base of the bluffs. It is this fact which accounts for the presence of ponds and small lakes along this edge of the alluvial plain. It also places one of the greatest obstacles in the way of the great drainage projects in which the people of this section are so vitally interested. The difficulty of securing an outlet under such circumstances is obvious.

The tributary streams, like the Little Sioux, Soldier, etc., have likewise formed natural levees which rise from four to five feet above the outlying flats in that portion of the great valley which is subject to frequent overflows, thus exposing these flats to more disastrous floods, and rendering their drainage more difficult after the floods have subsided.

The alluvial plain extends inland along all the larger tributaries of the Missouri, forming flat bottom lands varying, as noted, from one-half to three miles in width. These bottom lands are narrowed in many cases by the encroachment of more or less distinctly developed benches which form a striking feature of the tributary valleys. These benches are narrow or obsolete along the bluffs bordering the great valley, but in the lateral valleys they are conspicuous, and form not only the best farming territory, but a safe and convenient location for many of the towns.

The most conspicuous of these benches are located as follows:

IN HARRISON COUNTY.

Along the Boyer.—At Dunlap, on both sides of the river, varying in altitude from forty to fifty feet above the river bottom. Dunlap is located on the east bench.

At Woodbine, the town being located on the west bench, which rises thirty-five to forty feet above the valley. On the east side the bench is also conspicuous, especially above Woodbine, and is cut by Picayune creek.

Opposite Willets Siding a prominent bench narrows the valley to about one-half mile. This bench reaches a width of more than a mile, and extends along the east side of the valley for more than two miles.

Opposite Logan a bench more than four miles long extends along the east side of the river, and the business part of Logan is situated on the corresponding bench on the west side, which rises sixty to seventy-five feet above the valley. The ridge bordering this bench on the west rises from ninety to 120 feet higher.

Along the west side of the Boyer between Logan and Missouri Valley several smaller benches may be seen.

Along the Willow.—Along the Willow numerous smaller benches appear, perhaps the largest being located in section 27, township 80 north, range 43 west, on the west side.

Along the Soldier.—In sections 14 and 15 on the west side of the valley, and in 22 and 27 on the east side, township 81 north, range 44 west, distinct benches, which are more or less broken, form a prominent feature.

In sections 1 and 12 of the same township, northeast of Pisgah, benches appear on both sides of the stream.

IN MONONA COUNTY.

Along the Soldier.—Between Preparation and Moorhead a bench which reaches fully a mile in width, extends along the east side of the valley for more than three miles. Moorhead is partly located on a narrow bench on the west side.

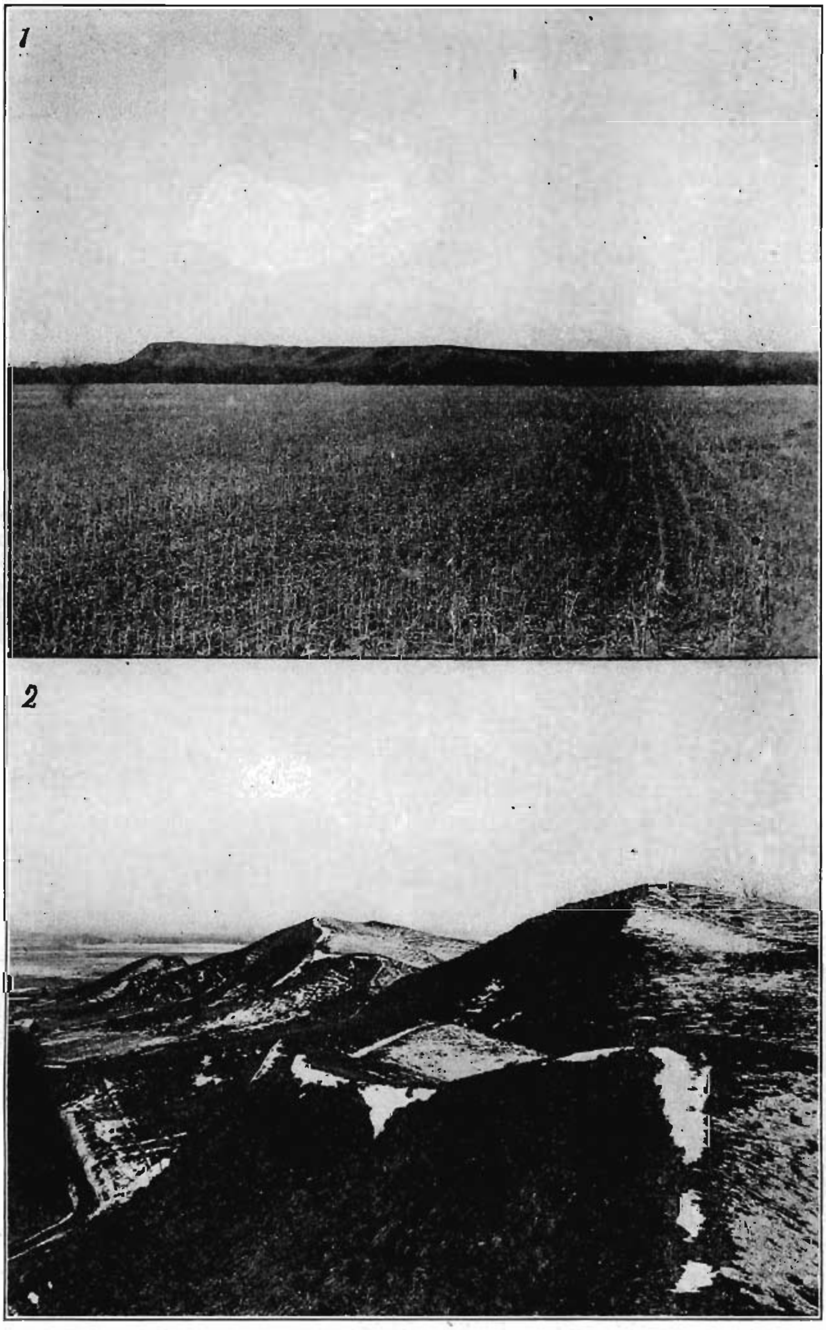


Plate XXIII.—Topography near Turin. (1) Belvidere bench, looking north (p. 291). (2) Loess ridges north of Turin, looking south. Snow on highest points.

Another of about the same size extends south from Soldier, on the east side. The town of Soldier is located on a smaller bench on the west side.

Between Soldier and Ute smaller, interrupted benches appear on both sides of the river.

Along the Maple.—The finest of these benches, the Belvidere bench, extends along the southeast side of the Maple opposite Turin, for more than three miles. (See plate XXIII, figure 1.) Its upper surface is quite level, and lies about 120 to 130 feet above the valley, rising toward its western extremity, however, to a height of 170 feet and then abruptly descending to the valley. This additional elevation is evidently due to the greater accumulation of loess along the edge lying nearest to the Missouri valley.

Castana also stands on a prominent bench which rises from ninety to 140 feet above the valley. Its finest portion extends northeast from Castana. On the west side a narrow bench extends southward from Castana for about two miles.

Between Castana and Mapleton interrupted benches also appear, especially on the east side of the river.

Mapleton is located on a bench which rises thirty to forty feet above the valley on the east side, and extends southward, gradually descending to the lower level of the valley.

Along the Little Sioux.—The benches along the Little Sioux are not prominent within the county, and appear chiefly on the east side.

In all these cases the hills rise above these benches quite abruptly on the west side, often showing cat-steps, while on the east side the rise is more gradual, and the hills are less rugged.

These benches have sometimes been mistaken for river-terraces,* but they are evidently a remnant of an old drift plain, their stratigraphic structure being the same as that of all the uplands, as is shown in well-sections and exposures. In sections they show Missouri limestone, Nebraskan drift, Aftonian sand and gravel, Kansan drift, Loveland joint clay, post-Kansan loess, and a yellow loess which sometimes shows an imperfect division

*They were specifically referred to as "high terraces of silt" by J. E. Todd, Bulletin U. S. Geol. Sur., No. 158, 1899, p. 140. St. John also describes them as terraces, in White's Report on the Geol. Sur. of Iowa, Vol. II, 1870, pp. 178-179, and 185-186.

into two parts. The structure of these benches is shown in the Peckenpaugh well, and section, the Griffin well, and the various wells on benches which are discussed in connection with the Aftonian.

LIST OF ELEVATIONS.

Taken from Gannett's Dictionary of Altitudes.

HARRISON COUNTY.

LOCALITY	AUTHORITY	ELEVATION
Dunlap	C. & N. W. R. R.	1,097
Logan	Ill. C. R. R.	1,033
Missouri Valley	C. & N. W. R. R.	1,006
Modale	C. & N. W. R. R.	1,016
Mondamin	C. & N. W. R. R.	1,025
Persia	C., M. & St. P. R. R.	1,167
River Sioux	C. & N. W. R. R.	1,042
Rode	Ill. C. R. R.	1,007
Woodbine	C. & N. W. R. R.	1,058
Woodbine	Ill. C. R. R.	1,069

Missouri river opposite California Junction, low water, 986, high water, 1,007.

MONONA COUNTY.

LOCALITY	AUTHORITY	ELEVATION
Blencoe	C. & N. W. R. R.	1,043
Grant Center	C., M. & St. P. R. R.	1,070
Kennebec	Ill. C. R. R.	1,061
Mapleton	C. & N. W. R. R.	(?)1,138
Mapleton	C., M. & St. P. R. R.	(?)1,263
Onawa	C. & N. W. R. R.	1,051
Rodney	C., M. & St. P. R. R.	1,088
Ticonic	Ill. C. R. R.	1,089
Ute	C., M. & St. P. R. R.	1,205
Whiting	C. & N. W. R. R.	1,061

Sloan, just north of the Monona county line, on the Chicago and Northwestern railroad, has an elevation of 1,076 feet. Smithland, on the Illinois Central railroad, also north of Monona county, has an elevation of 1,080 feet.

There is a manifest error in the Mapleton elevations, as the difference is too great, though the Chicago and Northwestern railroad is really lower than the Chicago, Milwaukee and St. Paul.

With the exception of those at Persia and Ute these elevations are but little above the bottom lands. At Missouri Valley the hills rise fully 225 feet above the valley; the summit of Murray Hill, four miles northeast of River Sioux, in section 8, township 81 north, range 44 west, is more than 300 feet above the valley, and the hills at Turin rise from ninety to more than 200 feet above the lowlands.

Drainage

The drainage of the counties under discussion is similar to that of all that part of the state bordering on the Missouri river. The great stream furnishes the outlet to all the surface waters of both counties. As has been noted its alluvial plain is so flat that drainage is very unsatisfactory, the difficulty being increased by the natural levees which border not only the Missouri, but those tributaries which meander across its valley.

This presents a serious problem not only in connection with the great artificial drainage system now being developed, but also in relation to sanitary drainage in the valley towns. Missouri Valley and Onawa have both struggled with this problem, and other similar towns are interested, but no satisfactory solution has yet been found and put into practice.

In a manner characteristic of streams with broad, low bottomlands, the Missouri and its eastern tributaries follow very tortuous courses. It is a little more than fifty miles in a direct line from the northwest corner of Monona county to the southwest corner of Harrison county, but the present course of the Missouri river between these points is more than eighty miles long, and its length was formerly still greater, for the Lewis and Clark survey shows that part bordering Harrison and Monona counties to have been at least forty miles longer than at the present time.* Similarly sixty miles of the Boyer river are crowded into the twenty-eight miles of valley lying within Harrison county.†

The Boyer, Willow, Soldier, Maple and Little Sioux rivers have recently had their courses shortened by artificial cut-offs—the more important of which are shown on the maps—for the purpose of increasing the fall and thus the rate of run-off. It is thus expected more rapidly to release the floods which are discharged by these tributaries upon the flat bottom-lands from the interior, and from the adjacent bluffs.

*See maps of Harrison and Monona counties.
†Smith's History of Harrison County, 1888, p. 21.

The Missouri river has naturally shortened its course, and increased its velocity, as already noted, and those who have watched the floods in the great valley for many years declare that the danger from floods of the Missouri has been thereby materially diminished.

Both the Missouri and its tributaries have so frequently changed their courses that numerous ox-bow or cut-off lakes have been formed. The largest of these in Harrison county are the following: Noble lake, lying partly in Pottawattamie county; Horseshoe lake, Round lake and Sol Smith lake. The last of these probably formed a part of the Little Sioux, and is the finest and deepest of these lakes, and the only larger lake in this territory lying close to the bluffs.

A shallow lake, now reduced to little more than a swamp, known as McWilliams lake, lies in section 27, township 81 north, range 44 west. It drains into the Soldier.

The principal lakes of Monona county are Gard lake, Blue lake, Badger lake, and East Skunk lake. A portion of Holman lake, now on the west side of the Missouri, also falls within this county.

Blue lake is the largest of these lakes, but all of them are being diminished more or less by the recent drainage operations, and by the cultivation of surrounding lands. On the Lewis and Clark map both Blue lake and Badger lake are represented as a part of the Missouri channel. These lakes have therefore been formed since 1804.

The principal streams of Harrison county which discharge their waters directly upon the great Missouri bottom are Mosquito creek, Pigeon creek, Boyer river, Willow river, Allen creek, Steer creek, Soldier river, and the Little Sioux river.

Mosquito creek is a small stream which crosses Washington township from north to south, and enters the Missouri plain in Pottawattamie county. Its valley within the county varies from less than half a mile to nearly a mile in width, and passes through a rolling loess-Kansan region. The upper course of Keg creek also crosses the eastern part of this township.

Pigeon creek is similar to Mosquito creek, but is somewhat smaller. It also enters the Missouri bottoms in Pottawattamie county, and receives as its chief tributary Potato creek, which is the smallest of these creeks. These creeks cross Union and Washington townships in a somewhat southwesterly direction, and their valleys divide the great loess-Kansan uplands of the southern tier of townships into four distinct blocks, of which the westernmost is the largest and most rugged, containing the Missouri bluffs. Its northern part in La Grange township drains to the north and west and is also very rough. The remainder of the area is typical rolling loess-Kansan.

Perhaps the finest view of this type of topography in this part of the state is that which may be obtained by looking east from Beebeetown, where the swells follow one another for miles in endless series.

The Boyer is one of the largest streams within the county, and also enters the Missouri in Pottawattamie county. Its source is near the Wisconsin divide, and it drains a large area the waters of which give rise to disastrous floods in the lower part of the valley.

The valley of the Boyer cuts the uplands for a distance of about twenty-six miles from northeast to southwest, and varies from one to two miles in width. At two points only does it become narrower, and those are where the bench opposite Willets Siding encroaches upon it and reduces it to less than one-half mile, and at Logan where it is similarly narrowed to less than a quarter of a mile. This is one of the most important valleys of the region, and contains the principal towns of the county.

Most of the tributaries of the Boyer within the county are creeks which drain the uplands on either side. The largest of these is *Willow river* (a river by courtesy only) which did not enter the Boyer until it had traversed several miles of the Missouri bottoms and passed into Pottawattamie county. Throughout the lower part of its course it has since been deflected, however, into the Willow creek ditch, and the Boyer has been connected with it by a cut-off in the southern part of St. Johns township. That part of the Willow valley which cuts the uplands is similar to the valley of the Boyer in direction and general character, but is narrower, varying from one-half to a mile in width.

Allen and *Steer creeks* drain the rugged uplands of Taylor, Magnolia, Raglan and Allen townships, and cut them by their deep, narrow valleys. Allen creek is now carried across the bottoms by the Allen creek ditch, which passes into Pottawattamie county. Steer creek is a tributary of the Soldier.

The Soldier river is scarcely more than a creek, and the greater part of its course lies in the alluvial plain of the Missouri, its natural outlet being in Cincinnati township. It is proposed, however, to make a cut-off from section 7 to section 16 in Morgan township, thus eliminating the greater part of the stream within the county.

That part of the Soldier valley which cuts the uplands is also similar to that of the Boyer in direction and general character, and like all the larger stream valleys of this part of the state, provides a railway outlet through the uplands. It averages about a mile in width, but it is much narrowed both above and below Pisgah by benches, which project from both sides.

The Little Sioux river crosses the northwest corner of the county, and empties into the Missouri just west of River Sioux. Its course within this county lies wholly in the alluvial plain of the Missouri.

The principal streams of Monona county are: the Soldier, Maple, Little Sioux and West Fork of the Little Sioux rivers.

The valley of the Soldier continues the same as at Pisgah as far as Ute, being narrowed by numerous benches on both sides of the stream. At Ute the valley divides, and that portion following the main stream becomes very much narrower.

Like all the preceding streams, the *Maple river* follows a southwesterly course, cutting through the uplands, and its valley is essentially like those of the Boyer and the Soldier. It varies from one to two miles in width, and is frequently narrowed by benches which make of this part of the county the most fertile region in our territory. The Maple emptied into the Little Sioux in section 28, Belvidere township, but a cut-off now connects the streams two miles farther north, in section 16.

The Maple also has its source on the Wisconsin divide, and drains a large area of rolling loess-Kansan. Its floods usually reach the great valley sooner than those of the larger Little

Sioux, and the result is that frequently in the earlier flood-stages the waters of the Maple run to the north, banking the waters of the Little Sioux, and causing higher water in the latter.

The Little Sioux river is the largest tributary of the Missouri in this section, and in this county the greater part of its course lies in the Missouri bottoms, chiefly along the low eastern part, close to the bluffs.

It cuts the uplands in the northern part of the county, its valley having the usual southwesterly direction, and averaging nearly three miles in width within the county.

The West Fork lies wholly in the Missouri plain, and joins the main stream northeast of Onawa.

The Little Sioux and the West Fork, reinforced by the Maple, cause the largest amount of annoyance and damage by floods.

The overflow area affected by this system reaches a total of 88,000 acres in Monona county and 8,000 acres in Harrison county, besides 47,000 acres along the West Fork in Woodbury county.* The width of the overflow area varies from two to more than eight miles.

Throughout both Harrison and Monona counties the bluffs bordering the Missouri valley are higher than the region to the east, and the result is that the smaller tributary streams draining the areas lying immediately east of the crest of the bluffs flow towards the east,—away from the Missouri valley! The most conspicuous illustrations in Harrison county are found in the western part of Jackson and the eastern part of Little Sioux townships, and in the bluffs southwest of Magnolia. Those in Monona county are in the region north of Grant Center, and in the western part of Sioux and the northwestern part of Spring Valley townships.

Interesting readjustments have evidently taken place in the gradients of the streams in this part of the state.

At various points at the base of the Missouri bluffs there are bordering banks of alluvial deposits, and most of the larger tributaries also show them. They ordinarily rise to about fifteen or twenty feet above the alluvial plain, and frequently contain molluscan shells. They are described more fully under Alluvium.

*This information was furnished by Mr. Mitchell Vincent of Onawa.

These banks suggest that the streams occupied a higher level, or were subject to vastly greater floods.

That there have been changes in the level of the streams is suggested perhaps most forcibly by the smaller tributary streams. The channels of nearly all the permanent and temporary streamlets in this region are very deep and narrow, sometimes, as in section 7, township 79 north, range 43 west, southwest of Magnolia, reaching a depth of fully forty feet, while the width in many places is less than the depth, suggesting that there has been a recent rapid degradation of the stream-bed. This is further shown by the not infrequent hanging valleys of their still smaller tributaries, as along Beaver creek in Jordan township and Woodward's glen in Grant township in Monona county, and in the Magnolia locality already cited.

These narrow gulches frequently give striking evidence of these fluctuations in level. That formed by Beaver creek in Jordan township, Monona county, is especially interesting, and will serve as a type. (See plate XXXII, figure 1.) Here the creek has cut to a depth of fifteen to eighteen feet through a heavy alluvial deposit which partly filled a wider and deeper gully, the banks of which are still visible rising several feet above the newer alluvial terrace. Evidently Beaver creek had first cut a deeper and wider gully; this was then largely filled with alluvium on account of some obstruction in the lower course of the stream; and when the obstruction disappeared, or was overcome, the stream again rapidly cut into the newer alluvial deposit. That this is not merely local is shown by the fact that nearly all the smaller streams of these counties, and especially those which pass out directly into the great valley, show the same deep narrow gullies cut into recent alluvium, though not all show
ods there was general slumping of the loess along the Missouri
the second, or older terraces. This suggests that some general
in the Missouri and its tributaries may have provided such ob-
obstruction blocked these streams at their outlets. Great floods
structions, and it is possible that during exceptionally wet peri-
bluffs, and the consequent blocking of the smaller streams.
However, no very satisfactory evidences of the latter were found

in the field at the points of debouchure of the small valleys, and moreover such obstructions would bring about much more unequal results.

Whatever may be the cause, the fact remains that the smaller streams have quite generally cut deep and narrow gullies in the alluvium which had been deposited during the earlier process of aggrading. The walls of these gullies are usually quite vertical, and in their lower parts especially they display alluvium which is almost as tough and tenacious as Nebraskan drift. In some cases the streamlets have cut through to sand, gravel or bowlders, which may be Aftonian or Kansan, and these materials are strewn along their beds. Some of the more striking illustrations of this kind are furnished by Woodward's glen, in Grant township, and Rock creek south of Ute, and the creek east of Mapleton, in Monona county, and portions of Allen and Harris Grove creek in Harrison county. In all these cases the streams are now nearer their base level than they were when the former aggrading commenced.

It should be noted that there is no connection between the narrow alluvial terraces of the creeks, and the larger benches along the rivers, which have already been discussed. The latter are older, and are in no sense terraces, as has already been explained on page 291.

In some cases the creeks cut their deep channels across the benches, as in Dunlap, Woodbine, opposite Logan, at Mapleton, etc.

STRATIGRAPHY

The only exposures of country rock known in the territory under discussion are those which are found in the valley of the Boyer river in Harrison county. They show Carboniferous limestone of the Missouri stage.

The greater part of these counties is covered with great beds of alluvium or drift and loess, and it is impossible to determine the character of the underlying rock, especially since but few deep wells have been sunk, and the records of most of these are imperfect or lost.

The Cretaceous is represented as extending into Harrison and Monona counties in the geological map of Iowa, published by

Calvin,* but the author clearly explains, on p. 199, that the Cretaceous was extensively eroded, and that on the map "the Cretaceous is indicated over the entire area upon which it was originally spread, the thick mantle of drift covering that part of Iowa making it now impossible to outline the individual remnants."

Keyes specifically reported the Cretaceous from Harrison county,† but the writer has been unable to find any evidence of it whatever, and the report was probably based on the approximations of the maps.

It is interesting also to note that Udden, writing of Pottawattamie county‡ which lies immediately south of Harrison, stated that "there seems to be no doubt that Cretaceous beds are absent from the greater part of the area comprising the western two-thirds of the county." This is the portion of Pottawattamie county which is contiguous to Harrison.

No rocks are exposed in Monona county, nor could any definite information be obtained concerning the deeply buried rock strata.

Bain, in his report on Woodbury county,§ represents the Cretaceous as extending to (and evidently passing over into) Monona county, the Dakota on the Missouri bottoms and "unresolved Cretaceous" in the uplands.

No evidence was found in the field, however, which would warrant the inclusion of the Cretaceous in a Monona county section, though it is not improbable that it does occur in the upland area north of Grant Center.

So far as could be determined there is a great hiatus in Harrison and Monona counties representing all that part of the geological column normally occurring between the Carboniferous and the Pleistocene. The latter is very well developed, and presents several features of unusual interest.

The following table represents a section of the formations definitely known from the counties under discussion:

*Iowa Geol. Survey, Vol. XVII, 1907, plate I. Similar maps had previously been published in Vols. I, II, III, VII, VIII, X and XIV.

†Iowa Geol. Sur., Vol. II, 1894, p. 436.

‡Geology of Pottawattamie County, Iowa Geol. Sur., Vol. XI, 1901, p. 239.

§Iowa Geol. Sur., Vol. V, 1895, map.

SYNOPTICAL TABLE.

GROUP	SYSTEM	SERIES	FORMATIONS, SOME HAVING THE RANK OF STAGES
Cenozoic	Quaternary	Recent	Alluvium Post-Wisconsin loess Sand-dunes
		Pleistocene	Post-Iowan loess Post-Kansan loess Loveland joint clay Kansan drift Aftonian sands and gravels Nebraskan drift
Paleozoic		Pennsylvanian	Missouri

No complete section was found in this territory, the nearest approach to it being the Peckenpaugh section opposite Logan (See plate XXX, figure 1), which lacks four members of the Pleistocene series. A large series of uniformly consistent sections, however, permitted a satisfactory determination of the stratigraphy. These sections are discussed in connection with the various formations represented.

CARBONIFEROUS SYSTEM

Pennsylvanian Series

MISSOURI STAGE.

The only known country rock of this territory belongs to the Missouri stage or the Upper Coal Measures and its presence has been satisfactorily determined at only a few points in Harrison county. The best of these exposures is that which appears opposite Logan in and near the old quarry near the dam, now the property of Mr. Frank Peckenpaugh.

This is the exposure reported by St. John* whose report was later practically reproduced by Keyes.†

The quarry has not been operated for some years, and slumping has somewhat obscured the sections, but a small exposure of gray limestone, about four feet in thickness, is discernible in the old quarry, and portions of the ledge on the east side were seen rising to a height of about twelve feet above the water in the river below the dam, which was then probably three or four feet

*White's Rep. Iowa Geol. Sur., 1870, Vol. II, p. 180.
†Iowa Geol. Surv., Vol. II, 1894, pp. 436-437.

above low water mark. The limestone was also reached in the Peckenpaugh well and in the sand-pit, both of which are described under the Aftonian. These several sections indicate that the rock rises to a height of from sixteen to eighteen feet above low water in the Boyer below the dam, and forms a part of the base of the great Logan bench.

The following fossils were collected in rock which had been taken from the quarry some years ago, and is now piled up on the west shore of the Boyer. They were identified by Professor Calvin.

FOSSILS FROM THE MISSOURI STAGE AT LOGAN, IOWA.

PROTOZOA

Fusulina cylindrica of American authors, probably *F. secalica* Say. Not common.

COELENTERATA

Campophyllum torquium Owen. One specimen.

ECHINODERMATA

*Numerous unidentified stem segments of crinoids.

MOLLUSCOIDEA

Meekella striatocostata Cox. Three specimens.
Productus nebraskensis Owen. Four specimens.
**Productus costatus* Sowerby. Twenty-six specimens.
Productus cora d'Orbigny. Two specimens.
Productus punctatus Martin. Seven specimens.
**Productus longispinus* Sowerby. Eight specimens.
**Spirifer cameratus* Morton. Twenty-two specimens.
**Spiriferina kentuckensis* Sh. Two specimens.
**Seminula subtilita* Hall. Forty specimens.

ARTHROPODA

Phillipsia major Shumard. One pygidium.

The other exposures in this portion of Harrison county which were reported by St. John are still more obscure, as no attempt to work the quarries has been made for many years. They are located respectively in section 24, township 79 north, range 43 west, and in the southeast quarter of section 28, township 80 north, range 42 west.

No other ledges lying near the surface are known, but Mr. Wattles reports that when borings were made for the bridge of the Chicago and Northwestern railroad across the Missouri opposite Blair, Nebraska, a hard gray limestone (evidently Missouri) was reached at a depth of forty-five feet below low water

*The species marked with an asterisk were reported in 1870 from the same exposure by St. John in White's Report, Vol. II, p. 180.

on the east side and fifty feet on the west side of the river. The four Chicago and Northwestern railway wells at Missouri Valley were sunk to a depth of ninety feet to a bed of similar rock, and the city well reached the same depth. It is evident that in this part of Harrison county the entire Missouri bottoms are underlain with Missouri limestone. Mr. Theodore Warren, well-digger at Woodbine, reports that on the flat along the Chicago and Northwestern railway in Woodbine he finds limestone at a depth of twenty-eight to thirty feet.

COAL.

Efforts to find coal suitable for mining have been of no avail. Such efforts were made years ago at Missouri Valley and elsewhere, and rumors of coal or possibilities of coal within Harrison county have been extant. St. John stated* that coal may be found at greater depths by boring, and Keyes† made indefinite references to possibilities of its occurrence in the county, and included Harrison county in the report on Coal Deposits in Iowa. In the more recent report of Hinds‡ Harrison county is omitted entirely from the list of coal-bearing counties of the state.

The only definite record which was obtained in the course of the work was given by Mr. J. C. Prather, a well-digger of Missouri Valley, who reports the following well-section made on the east slope at Missouri Valley, at the home of B. Cox. This is some distance above the Boyer bottoms. In substance Mr. Prather's report is as follows:

B. Cox Well-Section.

	FEET
Surface materials, clay, etc	144
Limestone, in layers of 3 to 9 feet	36
Coal	3
Rock (record not definite)	97
Soft coal	3

Shale appeared above and below the lower coal seam, but not with the upper.

*P. 181, l. c.
†P. 436, l. c.
‡Ia. Geol. Sur., Vol. XIX, 1909.

QUATERNARY SYSTEM

Pleistocene Series

The Quaternary covers Harrison and Monona counties with a great mantle of drift, sand, gravel, loess and alluvium, and practically determines all the surface features of these counties. Several members of the system as known in Iowa are not present in this territory, as would be expected from its geographical position, but those which constitute the known series are consistently arranged and some of them are of unusual interest.

So far as is definitely known the Quaternary here rests directly upon the Missouri limestone, and a general section shows the following members:

7. A yellow loess, light in both color and texture, probably post-Wisconsin, found chiefly on the bluffs bordering the Missouri valley and the valleys of the larger tributaries. Usually blends more or less with (6).
6. A yellow, rather heavy loess, probably post-Iowan, blending with (7), but sharply separated from (5).
5. A bluish gray, compact, post-Kansan loess.
4. The Loveland, a heavy joint clay, usually reddish, evidently closely associated with the close of the Kansan, reaching a thickness of at least forty feet.
3. The Kansan drift, very variable in thickness.
2. The Aftonian gravel, sand and silt, up to forty feet in thickness.
1. The Nebraskan drift (pre-Kansan), which is not fully revealed in sections, being largely buried under other deposits.

The aggregate thickness of (5), (6) and (7) sometimes reaches a total of ninety feet in this territory, but on the opposite side of the Missouri, in Nebraska, it seldom reaches thirty-five feet. The relative thickness of the three loess members is very variable.

The complete section is not shown at any one point, but the members which are present are always arranged in the order indicated, excepting where there has been a manifest disturbance due to the passing of the Kansan ice over the Aftonian and Nebraskan beds. The detailed description of the several members follows.

NEBRASKAN STAGE.

Throughout the western and southwestern parts of Iowa and southeastern Nebraska there are exposures of a dark blue-black drift, which, as far as could be ascertained, rests directly upon

Plate XXIV.—County-line exposure. (1) Looking north. AA, Nebraskan drift. B. Upper line of Nebraskan following road to left, rising abruptly to right. C. Aftonian sand and gravel. D. Fossiliferous Aftonian sand and silt (p. 338). (2) Nearer view of A showing Nebraskan drift (p. 307).

the older rocks of the region. It consists chiefly of a dark blue-black joint clay, sometimes more or less ferruginous, which when dry is hard and brittle, and breaks up into very small angular blocks (resembling lumps of ordinary starch, as has been suggested) as shown in plate XXIV, figure 2. It is almost impervious to water, and when wet is very tough, tenacious, "rubber-like," and so difficult to work that it is the abomination of well-diggers and road-workers, being the most despised of all "gumbos."

Scattered through this joint clay are relatively few, usually dark-colored pebbles and small bowlders (larger bowlders are very rare) which frequently show sharp angles and fractures, or distinctly planed striated faces, demonstrating that this is a true drift.

In some respects this drift resembles some of the dark Carboniferous shales, and it has been referred to the Carboniferous. Bain called attention to this as early as 1897,* stating that "its blackness * * * leads one on first view to expect a Carboniferous shale." It was identified as Carboniferous shale by Barbour, who makes repeated references† of the dark formation underlying the drift above Florence, Nebraska, to the Carboniferous. The formation is Nebraskan drift.

However, it must not be assumed that all dark formations underlying the Aftonian gravels are Nebraskan drift. Thus Leonard's reference‡ to Carboniferous shale below what is clearly Aftonian in the section north of Eldon, Iowa, is correct, as are most of the similar references for that county. The possible exception is the Cass township section, page 474, where in some places along Avery creek Nebraskan drift lies just below the Aftonian gravels.

In the earlier reports the Nebraskan, Aftonian and Kansan were simply collectively included in the drift.

In the Geology of Pottawattamie county§ Udden expresses doubt that there is here more than one drift sheet, but on page

*Iowa Geol. Sur., Vol. VIII, p. 287.

†Nebraska Geol. Survey, Vol. II, 1906, pp. 325 and 333; Science, n. s., Vol. XXV, 1907, p. 110; Putnam's Monthly, Jan., 1907, p. 502. Gilder also uses one of these references in the Am. Anthropologist, Vol. 9, 1907, p. 703.

‡Iowa Geol. Sur., Vol. XII, 1902, p. 474, etc.

§Iowa Geol. Sur., Vol. XI, 1901, p. 252.

254 he states that the dark blue bowlder clay is probably identical with the so-called pre-Kansan drift.

This drift has usually received the non-committal names of pre-Kansan or sub-Aftonian, but it has also been reported under the names Albertan and Jerseyan. The Albertan is probably not glacial* and the formation in Iowa and Nebraska, which has been known to students of Iowa geology for some years, cannot be correlated with it, or with the uncertain Jerseyan. For that reason it was recently named the Nebraskan,† and typical sections were pointed out near Omaha, Nebraska, and Council Bluffs, Iowa.

The finest known exposures of Nebraskan drift are displayed along the foot of the bluffs between Council Bluffs and Crescent, in Pottawattamie county, which borders Harrison county on the south. They may be traced here at intervals for several miles, the finest sections appearing about four miles north of Council Bluffs, and this older drift is exposed at longer intervals within Pottawattamie county almost to the Harrison county line.

Its position here as elsewhere is uniformly below the Aftonian, and it is exposed along the bluffs north of Council Bluffs to a depth of fully sixteen feet. Its total depth has not been ascertained.

In Harrison and Monona counties the Nebraskan drift is less prominent, but it is sufficiently well developed to fix its stratigraphic position, and to warrant the conclusion that it underlies much of the Kansan covered area. In color, texture, composition and position it is typical, and is undoubtedly a part of the formation which is so well displayed near Council Bluffs and Omaha.

Its presence was first noticed by St. John, for the blue clays mentioned in the report on Harrison county (l. c. page 177) and on Monona county (l. c. page 184) are undoubtedly Nebraskan.

The finest exposure observed in Harrison county is that in the County line section. Here a mass sixty-five feet in length and reaching a maximum height of ten feet above the road is exposed by a road-cut, and lies unconformably under a stratum of Aftonian gravel, its upper surface strongly oxidized. (See plate

*See Chamberlain and Salisbury's College Geology, 1909, p. 875.

†Science, n. s., Vol. XXXI, p. 75, Jan. 14, 1910. The name also appears in the Bulletin of the Geological Soc. of America, Vol. XX, in the part dated December, 1909, but this was distributed after the publication in Science.

XXXI, figure 1.) The Murray hill exposure shows fragmentary masses of Nebraskan drift which, together with a thin stratum of Aftonian, had evidently been plowed by the later Kansan ice. Mr. Peyton reports a "dark blue clay" (probably Nebraskan) under the sand in his pit south of Pisgah. These sections are discussed more fully in connection with the Aftonian. An exposure in a creek gully in Snyder's Hollow, Missouri Valley, also appears to be Nebraskan, but neither its structure nor its stratigraphic position could be studied satisfactorily.

The best exposure in Monona county was made in the Ordway well opposite Castana. Beneath the gravel in the Elliott pit at Turin, Mr. Babcock found tough dark-blue clay, with bowlders, undoubtedly Nebraskan. In Woodward's Glen, north of Grant Center, Nebraskan is exposed under Aftonian gravel and sand along the bottom of the creek-gully for some distance, and to a depth of one to two feet. These sections are also discussed more fully under the Aftonian.

Mr. Patrick of Ute also reports that he dug a well on the ridge at Ute to a depth of between sixty and seventy feet, to a very dark and very hard clay.

In the same vicinity Mr. Perkins made a drive well and reached a hard layer on which rested fifteen feet of gravel. Well-diggers in a number of cases report the discovery of a tough dark-blue clay, which may be Nebraskan.

AFTONIAN INTERGLACIAL STAGE.

One of the most important results of the survey of Harrison and Monona counties was the determination of large deposits of Aftonian gravel, sand and silt, and the discovery of a comparatively rich mammalian and molluscan fauna belonging to this interval.

The Aftonian had been known in Iowa for some years, and had been discussed by various writers in the Reports of the Iowa Geological Survey, the Proceedings of the Iowa Academy of Sciences, the Journal of Geology, etc.,* but no fossils were known from this horizon, excepting such as had clearly been derived from older formations.

*See especially Calvin's paper on The Aftonian Gravels, Proc. Davenport Acad. of Science; Vol. X, 1905.

The species constituting the fauna of the Aftonian, herein discussed, had also been known, but not from this formation. The mammalian fauna is represented in the Elephas imperator Zone, or "Loup River" horizon, of the "Upper Pliocene or Lower Pleistocene"* by *Elephas imperator, Mastodon mirificus* and *Equus,* but it appears at its best in the Equus Zone which includes the "Sheridan formation," "Equus beds," and "Rock Creek beds."** In no case was the reference definite, and the stratigraphic relation of the several beds remained more or less in doubt. If the mammalian fossils are a sufficient criterion, however, these beds may be definitely referred to the Aftonian interglacial stage as a result of the studies initiated in Harrison and Monona counties, and since extended to other parts of Iowa, and to Nebraska.

The molluscan fauna, consisting of numerous individuals of freshwater species and a few terrestrial forms which had evidently been washed down from adjoining land surfaces, has also been known from every interglacial period since the Kansan, and down to the present time. None, however, had been reported from the Aftonian, and the entire fauna, mammalian and molluscan, as here reported is new in its relation to that formation.

Aside from other considerations which are later herein presented, this fact alone made a careful study of the deposits desirable. The sands and gravels of Harrison and Monona counties, which are now referred to the Aftonian, had received previous brief notice. St. John† considered them modified drift, Bain reported "gravelly drift" from the northern part of Monona county,†† and Beyer and Williams‡ include them in the Logan section simply as "Pleistocene."

In nearby territory Udden included them with the drift in Pottawattamie county,‡‡ and Bain discussed "stratified drift" in Plymouth county, while Hayden had previously§ described those of Douglas county, Nebraska, as drift which had been deposited by turbulent waters.

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*Osborn, Bull. U. S. Geol. Sur., No. 361, 1909, p. 83.
**Osborn, op. cit., pp. 84-86. He classes them with the Lower Pleistocene, which he calls preglacial.
†White's Report, Ia. Geol. Sur., Vol. II, 1870, pp. 177, and 184.
††Iowa Geol. Sur., Vol. V, 1896, p. 281.
‡Iowa Geol. Sur., Vol. XVII, 1907, p. 496.
‡‡Iowa Geol. Sur., Vol. XI, 1901, pp. 251-254.
§Final Rep. U. S. Geol. Sur. of Nebraska, etc., 1872, p. 9.

Preliminary reports of the results of the present survey were published in Science,* and in the Bulletins of the Geological Society of America.†

Structure and Composition.

In structure and composition the Aftonian of this region varies within well-defined limits. It consists of gravel, sand and fine silt, variously inter-bedded and cross-bedded, and evidently deposited by currents of different velocities. No peat-beds, such as occur in other parts of the state, have been observed.

The gravel and sand are variously disposed. Sometimes the gravel is at the very base of the deposit, as in the Peckenpaugh section; again it forms the uppermost part, as in a portion of the County line exposure; or it is intermediate between beds of sand, as in the Cox pit; or it is irregularly interbedded with sand, as in parts of the County line exposure, Peyton pit, etc. In several sections fine sand only was exposed, but as the sections were not complete it is probable that gravel occurs in the deeper parts. Both the sands and gravels vary in coarseness and in degree of intermixing. The gravel beds commonly contain pebbles and bowlders up to four inches in diameter; and rarely very large bowlders of Sioux quartzite or granite occur. The sand and finer gravel frequently interbed and cross-bed, and the wedges and strata of sand are often sharply set off by lines of fine gravel. The wedges and strata are of all degrees of coarseness and vary in color. Beds of almost pure white sand occur, as in the Cox and Peyton pits; or the gravel and sand are stained with iron oxide, the stain sometimes permeating the entire wedge or stratum, or merely marking its limits with a more or less distinct line; or there is a similar black discoloration due to manganese dioxide (MnO_2) which occurs uniformly in greater or lesser quantity in all the sections examined. Some variation in color is also due to the different materials which compose the sand and gravel. Dark

*B. Shimek, Science, new series, Vol. XXVIII, Dec. 25, 1908, p. 923; also Vol. XXXI, 1910, p. 75.

†S. Calvin, "Present Phase of the Pleistocene Problem in Iowa," Vol. 20, 1909. pp. 133-152, and "Aftonian Mammalian Fauna." ibid. pp. 341-356.

B. Shimek, "Aftonian Sands and Gravels in Western Iowa," ibid, pp. 399-408; "Evidences that the Fossiliferous Gravel and Sand Beds of Iowa and Nebraska are Aftonian," ibid, Vol. 21, pp. 119-140.

colored pebbles and bowlders, such as occur in both the Nebraskan and Kansan drifts, are common, but there is a preponderance of rather light-colored materials.

The finer sands contain rather small, very soft, chalky, pure white, usually rounded calcareous nodules, and calcareous nodular plates usually two to four inches in thickness, frequently separate the Aftonian from the Kansan. These are very prominent in the Cox pit (plate XXV, figure 1), the Weniger pit* (plate XXVII, figure 2), and the Ferdig pit (see plate XXVIII figure 2).

In the Cox pit these calcareous plates exhibited markings which seem to be glacial striations, and which may be compared with similar striations found by Calvin on ferruginous plates in like situations at Afton Junction.† It is impossible to conceive of the presence of these calcareous plates in their present position just above the Aftonian sands and gravels at the time of the passing of the Kansan ice over the territory in which they occur. They have evidently been formed since the deposition of the overlying drift from material carried upward in the Aftonian in solution and deposited against the lower surface of the drift.

The Aftonian beds were evidently frozen solid before and during the maximum stage of Kansan glaciation, as is shown by the numerous detached Aftonian "sand-bowlders" imbedded in the lower part of the Kansan (see page 348) and still retaining their stratified and cross-bedded structure, and by the greater masses of Aftonian sand and gravel which similarly preserve their structure even where the strata have been so disturbed that they practically stand on edge. In this frozen condition the Aftonian beds were planed and striated by the Kansan ice as were other types of bed-rock, and when the Kansan till was deposited upon them it formed a reversed mold of the markings made by the glacial ice. Calcareous as well as ferruginous plates deposited against the lower surface of this till would reproduce all the grooves and furrows and all other markings which had originally been impressed on the planed surface of the frozen sand and gravel beds by the moving Kansan ice, and would thus appear as if they themselves had been glaciated.

*See also fig. 1, plate 2, in the Bull. Geol. Soc. of America, Vol. 21, 1910.
†Proc. Davenport Acad. of Science, Vol. X, 1905, p. 25, plate III, fig. 6.

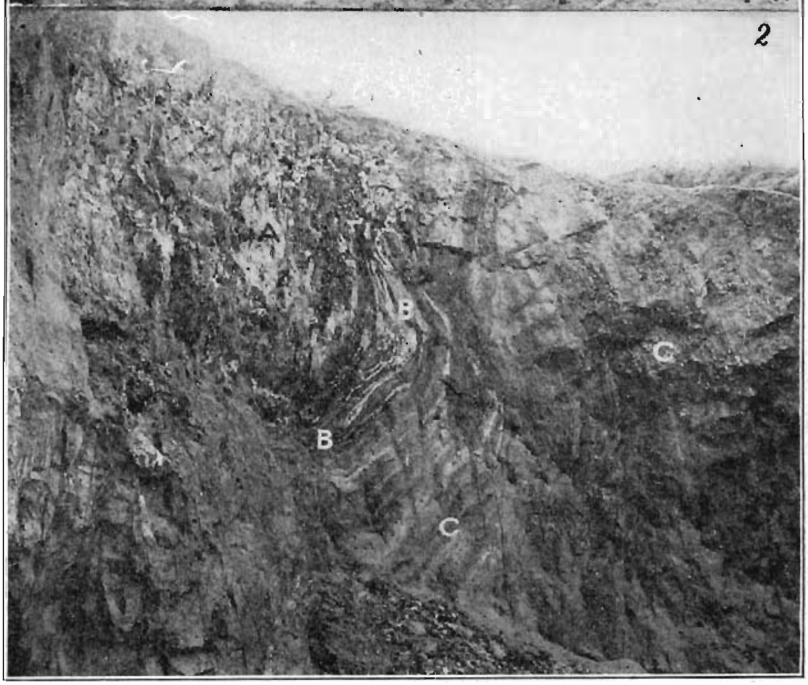

Plate XXV.—Aftonian sections. (1) Cox pit: A. Kansan drift. B. Calcareous nodular plates. C. Aftonian sand, 21 feet. D. Aftonian gravel, 14 feet (p. 333). (2) McGavern pit: A. Kansan. BB. Front of Kansan plow. CC. Aftonian sand, nearly vertical (p. 351).

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The silt bands and belts of the Aftonian are also variously distributed, but are most common in the uppermost or the lowermost parts of the formation and vary in thickness from a fraction of an inch to several feet. When occurring in the upper parts they consist of a heavy silt which is dull bluish gray, or less frequently yellowish or even ferruginous in color, but those in the lower part are usually made up of a finer whitish or light bluish silt which is decidedly putty-like when wet. Pellets of these silts, rolled into spherical or fusiform shapes, are frequently found in the sand and gravel. Such pellets are usually several inches in diameter; they were evidently detached and rolled by the currents which carried the coarser material, and they are usually incrusted with ferruginous sand. Sometimes similar pellets of Nebraskan drift, evidently formed in the same manner, are also found in the Aftonian sand and gravel. They are readily distinguished from the silt pellets by their darker color and by the presence of pebbles.

Occasionally more or less cylindrical masses of silt or sand penetrate the sand and gravel beds irregularly in the upper portions of the formation. These were evidently formed by silt and sand being carried down by water into cavities formed upon the decay of the roots of plants. They appear in cross-section as round spots, and some are shown in plate XXVIII, figure 1, representing the Elliott pit. Here these tubes, or rather cylinders, consisted of fine sands, silt, which is present in the uppermost part of the section, and loess which caps the ridge. In this section they vary up to about three inches in diameter.*

Organic Remains.

Organic remains are quite frequent in the Aftonian and form a feature of unusual interest. No plant remains were found, though mosses and conifers are known from the peat-beds in other parts of the state.

Animal remains, consisting of bones, teeth and tusks of mammals, and shells of mollusks, are quite abundant and widely distributed. One small vertebra of a fish was also found.

*See also Bull. Geol. Soc. of Am., Vol. 21, plate 2, figure 2.

THE MAMMALIAN FAUNA.

The following species of mammals have been definitely identified by Professor Calvin:

Mammut americanum (Kerr).
Elephas imperator Leidy.
Elephas columbi Falconer.
Equus scotti Gidley.
Equus complicatus Leidy.

Two molars, fragments of a tusk and of cranial bones of *Mammut mirificum* (Leidy) were also collected in the Aftonian of Plymouth county, in the same general territory, and a tooth of *Elephas primigenius* Blumenbach was collected in what appears to be Aftonian at Denison, only a few miles from the Harrison county line.

In addition to these Professor Calvin recognizes bones of unidentifiable species belonging to the following genera:

Camelus (?)
Cervus (?)
Mylodon.
Undetermined ruminant, probably *Ovibos*, represented by two horn-cores.
Ursus.
Also *Megalonyx* from the Aftonian of Sioux City, and *Cervalces* from the Denison deposit. There are also bones of other mammals not yet identified.

The bones and teeth were mostly scattered, often fragmentary and usually freely intermingled as though the bodies of the animals had been stranded on ancient bars and, after the decay of the softer parts, their skeletons had been scattered by the same floods which moved the great mass of gravel. Occasionally, however, they were transported when at least some of the bones were still united by ligaments, for in some cases the bones and teeth of evidently the same skeleton lie in close proximity, as in the Wilkenson well, and in the Akron well in Plymouth county.

Professor Calvin has discussed these Aftonian mammals quite fully,* and that part of his paper which has a direct bearing on the Aftonian of our territory is here reproduced. In the paper quoted the discussion of the teeth of horses from the Aftonian

*In the Bulletin of the Geol. Survey of America, vol. 20, pp. 341-356, plates 16-27.

of Harrison and Monona counties is so intimately connected with that of the fine sets of upper and lower left molars and premolars of the Gladwin horse obtained from Mills county, that the latter is also here included, though the specimens are extra-limital.* The discussion is presented in Professor Calvin's own words:

The Aftonian Horses.

In the collections under consideration horses are represented by a much larger number of bones and teeth than any of the other types of Aftonian mammals. There are bones from nearly all parts of the skeleton, but leg bones and foot bones are most common and most significant. Among the teeth there are more than twenty superior molars and premolars and about an equal number from the lower series. The Gladwin set is the only one that is complete; the other teeth show great variations in the amount of wear and in minor details, and it is quite certain that they represent a number of individuals. At least two species seem to be clearly indicated. In one the teeth are larger than those of the modern species, as is shown by the following comparisons and measurements of the upper molars of the Gladwin horse. Comparison is made with the measurements of the teeth of the domestic species, expressed in millimeters, as given by Gidley in the table on page 98 of volume xiv of the Bulletin of the American Museum of Natural History. Only the transverse diameters are compared, but the other dimensions show corresponding differences in size. In the case of the teeth of the Gladwin horse, to quote from Gidley, "the transverse diameters were measured across from the exterior ridge of the mesostyle to the exterior wall of the posterior lobe of the protocone, exclusive of cement." In the Gladwin horse fully half the original length of the teeth has been worn away. The antero-posterior dimensions of the entire series of superior grinders, measured in a straight line from the sharp, anterior enamel fold of p^2 to the posterior, outer fold of m^3, is 187 millimeters. The antero-posterior dimensions of the individual teeth, following the outer curve of the series, but inside of the metastyle and parastyle, are: p^2, 43.5 millimeters; p^3, 33 millimeters; p^4, 31 millimeters; m^1, 25 millimeters; m^2, 26 millimeters, and m^3, 32 millimeters. This gives a total length of the series around the outer curve, but inside the external styloid ridges, of 190.5 millimeters.

*Professor Calvin refers to the Gladwin horse as follows: "A complete set of left molars of a large horse, upper and lower, was found by Mr. E. L. Gladwin while grading a road in section 35, Lyons township, Mills county. A considerable portion of the skeleton was present, but the bones were too soft for preservation. The Gladwin horse was found in a fine blue clay, a bed of silt, that here in places overlies the gravels but is of the same age." Loc. cit., p. 344.

Table showing comparative transverse Diameters of the Teeth of the Gladwin Horse.

	p^2.	p^3.	p^4.	m^1.	m^2.	m^3.
Gidley's largest draft horse	28 0	30.0	28.5	28.0	26.5	23.0
Gladwin fossil horse	28.7	32.0	32.5	30.0	26.5	26.0
Differences	.7	2.0	4.0	2.6	2.0	3.0
Average of the 8 horses recorded in Gidley's table	24.8	26.1	26.9	26.0	23.4	22.2
Differences when the Gladwin horse is compared with the aver. of Gidley's 8 horses	3.9	5.9	5.6	4.0	3.1	3.8

There are a number of teeth from the Cox pit at Missouri Valley, and one from Turin, which agree in dimensions with the larger teeth of the Gladwin horse, and are evidently from the same species, if transverse diameters may be taken as a guide. These may be noted in tabular form as follows:

Catalogue number	Transverse diameter.	Antero-posterior diameter.	Length.
116	33.0	33.0	95
117	33.5	35.0	82
118	32.0	32.0	38
119	31.5	29.0	50
125	31.0	30.0	62
136	33.0	35.0	80

An imperfect second upper premolar, with the thin, anterior edge broken away and having a transverse diameter of 29 millimeters, belongs in this group of large teeth. Nearly one-third of the crown has been worn off by use; the part remaining measures 65 millimeters in length.

Among the recognized species of Pleistocene horses the teeth of the Gladwin horse and the others above noted agree best in size with *Equus scotti* Gidley, from the Sheridan beds, Rock Creek, Brisco county, Texas,* though tooth number 117 is practically identical in size and other details with the superior third and fourth premolars referred by Gidley to *Equus pacificus* Leidy.† Comparing the Gladwin teeth with the measurements given for *Equus scotti* in the American Museum Bulletin, volume xiv, page 136, the close agreement becomes apparent:

*Bulletin of the American Museum of Natural History, Vol. XIV, p. 134.
†Op. cit., p. 117.

	p^2.	p^3.	p^4.	m^1.	m^2.	m^3.
Antero-posterior diameter:						
Equus scotti	43.0	34	33	30	31	31
Gladwin horse	43.5	33	31	25	26	32
Transverse diameter:						
Equus scotti	30.5	33.0	33.0	30	29.0	24
Gladwin horse	28.7	32.0	32.5	30	28.5	26

The differences that appear in making these comparisons may be accounted for on the basis (1) of individual variations and (2) of differences in the amount of wear which the teeth of the two animals has undergone. The measurements of *Equus scotti* given on page 136 of the work cited are those of an individual "in which all the teeth have come into full use," but presumably an animal comparatively young. The teeth of the Gladwin horse, on the other hand, have been worn down to about half their original length. The greatest discrepancy appears in the antero-posterior diameters of m^1 and m^2 and in the transverse diameters of p^2 and m^3. Applying Gidley's "Laws governing the changes of diameters of the tooth crowns," formulated on page 99 of the American Museum Bulletin already quoted, the differences are largely, if not wholly, explained. After the molar-premolar series comes into full use, according to law (1), the antero-posterior diameter of each of the intermediate teeth diminishes at first very rapidly, and then more gradually to the roots. Differences even as great as those seen in m^1 and m^2 are to be expected. The antero-posterior diameter of m^3 in the Gladwin horse accords with law (3). The differences in transverse diameters of the first and last teeth of the series exemplifies that part of law (4) which is expressed in the clause "p^2 gradually diminishes, while m^3 increases in transverse diameter as the crown wears away." In the present case the teeth are the only parts available for study, but these are in such perfect accord with the teeth of *Equus scotti* Gidley that there need be little hesitation in referring them to that species. *Equus scotti* has been recognized with doubt in collections from the Sheridan beds near Hay Springs, Nebraska,* a point farther north than southwestern Iowa and equally as far from the type locality.

The collection contains a few teeth of smaller size, agreeing in dimensions and in the enamel foldings with teeth which have been referred to *Equus complicatus* Leidy. A superior third molar,

*W. D. Mathew: List of the Pleistocene fauna from Hay Springs, Nebraska. Bulletin of the American Museum of Natural History, Vol. XVI, 1902, p. 317.

number 128, from Missouri Valley, shows a very complicated pattern, even though considerably worn. Its dimensions are: transverse diameter, 24 millimeters; antero-posterior diameter, 27 millimeters; length, 60 millimeters. An Aftonian gravel pit at Turin, Iowa, has furnished an imperfect superior molar, number 122, intermediate between the first and the last of the series, but its exact position undetermined, which shows a transverse diameter of 28 millimeters and a length of 70 millimeters. The anterior fourth of the tooth has been split off, but what remains shows very complicated enamel foldings. Another tooth, number 124, of somewhat simpler pattern, but still sufficiently intricate to belong to *E. complicatus*, is from the Cox pit at Missouri Valley; it is 28 millimeters in transverse diameter, 29 millimeters antero-posteriorly, and 70 millimeters in length. Tooth number 121 is also from the Cox pit; it is 75 millimeters in length, but little worn; the enamel pattern is much simpler than in any of the other teeth so far noted. It agrees with *Equus excelsus* and *E. occidentalis* in the absence "of the little enamel fold near the bottom of the deep valley between the protocone and the hypocone." It is 28.5 millimeters in transverse diameter and 30 millimeters from front to back. In size and pattern, however, this tooth is almost identical with Gidley's figure 3A, in the American Museum Bulletin, volume xiv, page 97, and this figure is described as a molar of *Equus complicatus*. If the teeth illustrated in figure 3, page 97, and in figure 7, page 109, of the bulletin above quoted may be referred to one species, then all the superior molars from the Aftonian gravels of southwestern Iowa may be arranged under two species distinguished by differences in the size of the teeth, namely, *Equus scotti* Gidley and *Equus complicatus* Leidy.

Of the lower molar-premolars there are two well marked types which probably correspond to the two species, *Equus scotti* and *Equus complicatus*. The left mandibular series of the Gladwin horse illustrates one of these types. The teeth have very thick cementum and are unusually heavy; the transverse diameters measured in millimeters, exclusive of the cementum, are: p_2, 18; p_3, 19; p_4, 21; m_1, 17. The other molars are broken and cannot be measured. The thickness of p_4, including cementum, is 24 millimeters. The length of the series antero-posteriorly is 195 millimeters. Another notable feature of these teeth is the great thickness of the enamel. The same thick enamel and massive character are seen in two inferior molars from the Cox pit at Missouri Valley. This specimen may without doubt be referred to the same species as the Gladwin horse. All the other inferior molars in the collections belong to the other type. The transverse diameters are less, the cementum very meager, and the enamel is much thinner and more flexuous. * * * The thinner teeth, with thinner and more flexuous enamel, may be looked upon as teeth belonging to a species quite distinct from the Gladwin horse and may be associated with the superior molars which have been referred to *Equus complicatus*. * * *

* * * One tooth shows the effects of alveolar abscesses from which the animal probably suffered seriously. Whether this disease hastened the death of the individual may not be known, but it is certain that life was cut short from some cause before the teeth were very much worn.

There are many equine bones from the Aftonian beds of Harrison and Monona counties which, while more or less fragmentary, are in a fair state of preservation. There are two humeri, right and left, each lacking the proximal articulation. These indicate an animal about the size of the average modern horse, the radius and ulna of the domestic species fitting perfectly with the radial articulation of the fossil humerus. There are portions of the radius among the fossil bones, four tibiæ, four imperfect metapodials, four first phalanges, and other portions of equine skeletons. The most perfect of the tibiæ is comparatively small. The animal to which it belonged was adult, but the size would indicate a rather small pony. On the other hand, the distal ends of two of the fossil tibiæ are equally as large as the corresponding part of *Equus caballus*, and the same is true of the distal end of a fossil radius. The sides of the broadened articular extremity of the Aftonian radius are abraded, making measurements impossible, but 70 millimeters above the articulation both modern and fossil bones are 60 millimeters in transverse diameter and 35 millimeters in thickness. The fossil metapodials are large and strong and differ in cross-section from the same bone of the domestic species, being more nearly circular in corresponding parts of the shaft. The splint bones were evidently more rudimentary than in the modern horse. Three of the first phalanges are as large as those of the present coach horse; the largest one measures 92 millimeters in length, is 58 millimeters in transverse diameter at the proximal end, 41 millimeters broad at the narrowest part of the shaft, and 51 millimeters at the distal end. A slenderer phalanx, that of an immature individual, is 87 millimeters long and the narrow shaft is 33 millimeters wide. An examination of the equine bones from the Aftonian gravels, entirely apart from the evidence furnished by the teeth, suggests the possibility of at least two Aftonian species, one somewhat smaller than the average horse of today, the other fully equaling the modern horse in size.

The teeth of the Gladwin horse and the other teeth above referred to *Equus scotti* Gidley are all notably larger than those of *Equus caballus,* while the teeth referred to *Equus complicatus* are about the size of the teeth of the domestic horse. According to Gidley, in the article from the American Museum Bulletin, volume xiv, frequently quoted in this paper, the head and the teeth of the Pleistocene horses were proportionately larger than in the modern species. On page 139 of the bulletin *Equus complicatus* is described as "a species with teeth about the size of those of the ordinary draft horse and of moderately complex pattern, but with the bones of the skeleton about the size of those of the smaller varieties of the western pony." Notwithstanding the large size of the teeth in *Equus scotti,* it is said that "this species represents a horse about the size of the largest western pony." While in all probability the Aftonian horses represent but two species, *Equus complicatus* and *Equus scotti,* the fact should not be overlooked that some of the bones and teeth agree with those of *Equus pacificus,* concerning which it is stated that "the skeleton indicates a horse about the size of the ordinary draft horse, but the skull is proportionately larger." Many of the fossil bones are about the size of those of the ordinary draft horse.

Two of the equine metatarsals and two of the phalanges from Turin are decidedly larger than the corresponding bones from the modern horse. One of these large cannon bones is complete and measures 30.5 centimeters in length, while a metatarsal of a fair sized modern horse, with which it is compared, measures but 27 centimeters. Other measurements show corresponding differences between the fossil and the domestic species. One of the teeth noted in the paper agrees in size with *Equus pacificus* Leidy. It is larger than the teeth of *Equus scotti* recorded by Gidley. It may be possible that this large tooth and these large cannon bones belong to a species larger than *Equus scotti;* but on the other hand it is possible that individuals varied, and that some of the animals belonging to the species *Equus scotti* may have exceeded "the size of the largest western pony." The solution of some of these questions must await additional evidence.

Other Ungulates.

Of the ungulates associated with the Aftonian horses, one of the more significant is the camel. This is represented by a single first phalanx which came from the Peyton pit at Pisgah.* It is 127 millimeters long, 36 millimeters in transverse diameter at the proximal end, 31 millimeters across at the distal end, and the smallest diameter of the shaft is 20 millimeters. Other Artiodactyls are indicated by the distal ends of two metapodials, and there are two unidentified horn cores. There are two large calcanea and other undetermined bones, probably of Ungulata.†

Proboscideans

ELEPHANTS.

Elephas imperator.—Three elephants are indicated by the collections from the Aftonian gravel pits. A large, slightly worn molar has the massive proportions and the coarse ribs which distinguish *Elephas imperator* Leidy. This ponderous, clumsy tooth is from the Peyton pit at Pisgah; it is 290 millimeters (about 11⅜ inches) in length, 108 millimeters (4¼ inches) across the grinding surface, and 265 millimeters (10¾ inches) high, measured between two planes parallel to the grinding surface. The enamel loops, corresponding to the longitudinal ridges on the lateral faces of the tooth, vary in thickness and in the width of the intervening spaces, but on the whole they are more constant in these respects than are those of the tooth illustrated by Holmes‡ and Lucas§ and which served to re-establish *Elephas imperator* as a valid species. In some parts of the Iowa specimen the ridges are fully an inch in width, the number in 10 inches ranging from 11 to 14, according to the part of the tooth selected for measurement. Besides the large tooth from Pisgah, there is an imperfect lower jaw from the Cox pit at Missouri Valley (plate XXVI, figure 1) which belongs to this species. In both rami the inner side of the alveolus has been broken away, but the outer wall is intact and shows the broad, vertical grooves corresponding to the wide ridges on the lateral face of the tooth. These are of the same order of magnitude as the ridges of the Pisgah tooth referred to *Elephas imperator*. A large femur to be noted later probably belongs to this species.

Elephas primigenius and *E. columbi.*—There are other and very different elephant teeth in the Pleistocene collections of the University of Iowa in which the number of ridges in 10 inches

*Two teeth and three additional phalanges have been received since this paper was published.

†Since the publication of Professor Calvin's paper a part of a left ramus of *Cervus* (?) was received from the Cox pit. It contains the last premolar and the first and second molars.

‡William Henry Holmes: Flint implements and fossil remains from a sulphur spring at Afton, Indian Territory. Report of U. S. National Museum for 1901, p. 244, plate 9.

§F. A. Lucas: Maryland Geological Survey, 1906. Pliocene and Pleistocene mammalia, p. 167, plate XXXVIII, fig. 2.

range from 20 to 25. There is one from the Cox pit showing 20 folds or ridges in the space mentioned, and another from the gravels at Denison showing 25. The specific relationship of these admits of little doubt. Lucas, in the work cited, page 159, specifies 18 ridges in 10 inches as characteristic of *Elephas columbi* and 24 in the same space as marking the molars of *E. primigenius*. Making the necessary allowance for individual variations, the Cox Pit tooth, with its average of two folds to the inch, is referred to *E. columbi*, and the Denison tooth, with two and a half folds to the inch, represents, without doubt, the *E. primigenius*. The last agrees in almost every minute detail with a tooth of *E. primigenius* from Europe.*

MASTODON: MAMMUT AMERICANUM.

The common American mastodon is represented in the Aftonian collections by a portion of the lower jaw—the symphysis and left ramus, with the last three molars in place (plate XXVI, figure 2)—and by three separate molars. The jaw is from the Pisgah pit and the separate molars are from Missouri Valley. The Pisgah specimen is massive and shows the deep sockets for the mandibular tusks. The teeth from Missouri Valley are molars 4, 5 and 6, but they are not from the same individual. The fifth molar has the crown completely worn down, and the fangs show effects of absorption; the sixth molar is perfectly developed, but practically unworn.

OTHER PROBOSCIDEAN REMAINS.

The other proboscidean fossils worthy of note include a complete left tibia (plate XXVI, figure 5) from Missouri Valley, a humerus and a femur (plate XXVI, figures 4, 6), both imperfect, from Pisgah, and a cervical vertebra (figure 8) from Turin. A scapula, complete when taken from the pit at Missouri Valley, was allowed to crumble to pieces for lack of care by the finders. There are two caudal vertebræ, and a fragment of a pelvis, and, in addition, there is a section of a lower tusk of the mastodon.

The large femur mentioned above is 45 inches long, and yet it lacks all of the enlarged proximal end; it is broken at the thin, flattened part of the shaft below the great trochanter. When complete the length was certainly more than 61 inches, the reported length of the femur of *E. imperator* from Keene, Oklahoma, noted by Lucas on page 168 of the work cited above. The Warren mastodon was among the largest of its species; its

*A very fine fourth molar of *Elephas columbi* has since been found in Aftonian gravels in the Peckenpaugh pit at Logan.

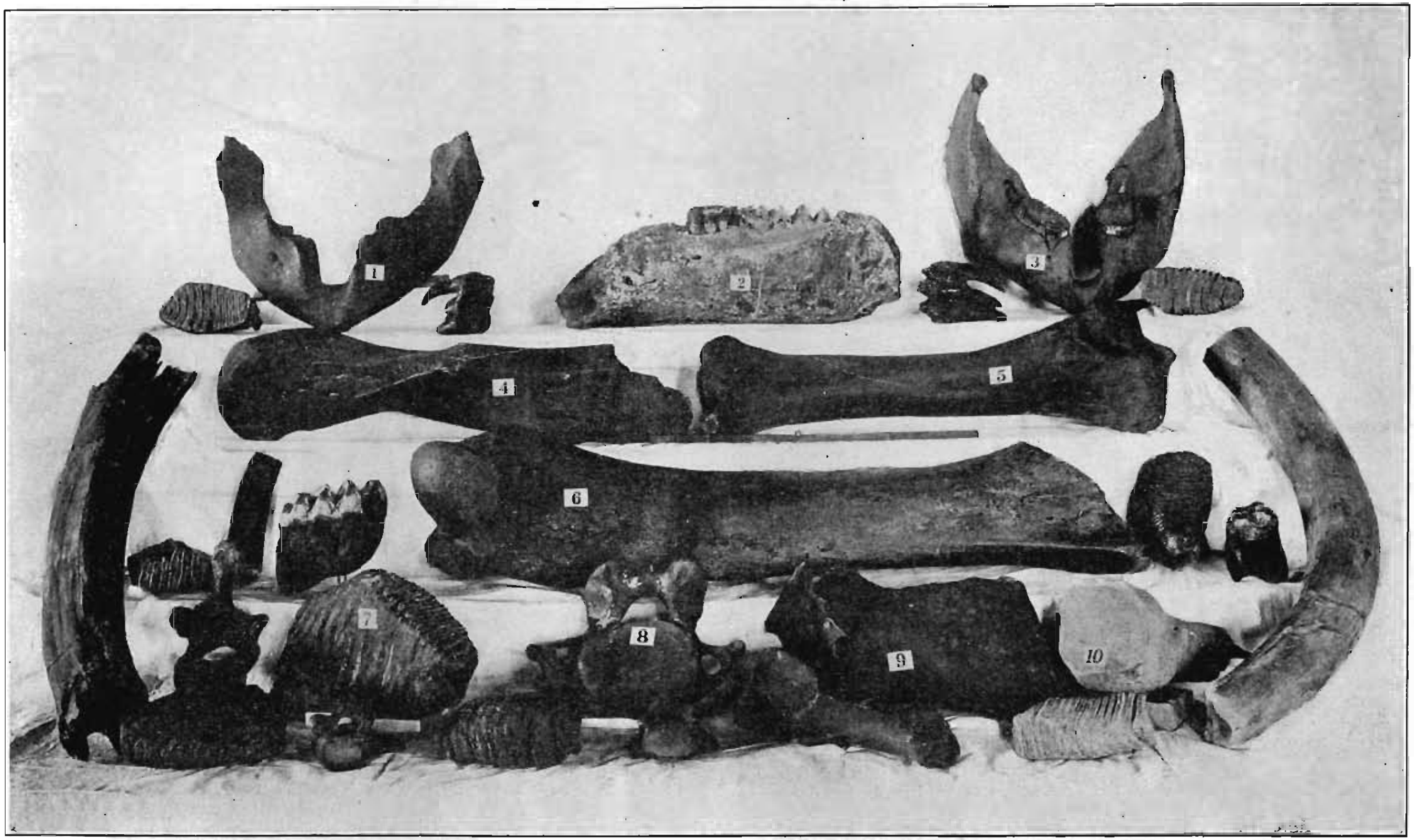

Plate XXVI.—Proboscidian remains from the Aftonian (see pp. 323, 324, 335).

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femur, complete, is said to be 45 inches in length.* The Pisgah femur belonged to an animal larger than the ordinary mastodon, larger than the modern elephant or the northern mammoth, and it is a fair inference from its great size that it belonged to the imperial mammoth, a tooth of which comes from the same gravel pit.

Edentata

MYLODON.

From the noted Cox pit at Missouri Valley there comes an imperfect terminal phalanx of Mylodon. The tip of the ungual process is broken off; otherwise it is practically complete and shows the characteristics of this part of Mylodon very clearly. The claw as a whole is proportionately much thicker, is less falcate, and tapers less rapidly toward the point than do the claws of Megalonyx. The ungual process is regularly rounded on the upper side instead of being compressed to a relatively sharp ridge. All the characteristics coincide with Owen's classical description of the distal phalanges of Mylodon.†

MEGALONYX.

The probable presence of Megalonyx as a member of the Aftonian fauna is noted in the body of the paper; the only point concerning which there might be possible doubt is the age of the beds in which the specimen collected by Todd was found; a claw now in hand from Sioux City places the matter of an Aftonian Megalonyx beyond question, but the genus is not yet represented in the Aftonian fauna of Harrison and Monona counties.

Correlation.

The Aftonian fauna is as yet very incomplete. Additions to the list of species must wait on the further development of the sand pits and gravel beds. Besides the sloths, the forms thus far discovered and recognized are all large herbivores.‡ An attempt

*The length of the femur of the Warren mastodon does not seem to be stated in Doctor Warren's classic memoir, but on page 107 he compares the femur of the Cambridge mastodon with that of the elephant Pizarro. This bone in the Cambridge specimen measures only 36 inches in length. In the Twenty-first Annual Report of the Regents of the University of the State of New York, pages 120 and 127, there are comparative measurements; the femur of the Warren mastodon is given as 45 inches long and that of the Cohoes mastodon as 41½ inches.

†Richard Owen: Description of the skelton of an extinct gigantic sloth, ***Mylodon robustus*** Owen, pp. 94, 95, 107, 122. Leidy's work, A memoir on the extinct sloth tribe of North America, Smithsonian Contributions to Knowledge, accepted for publication December, 1853, p. 37, describes the ungual phalanges of Megalonyx. The plates in both of these publications assist in making clear the differences between the claws of the two great sloths mentioned.

‡An exception must be made of *Ursus*, discovered since the publiction of Professor Calvin's paper.

to correlate the Aftonian beds with Pleistocene faunal zones which have been established in regions lying outside the glaciated area would probably, at the present time, be somewhat premature, but there are a few facts of some significance which may be noted. The deposition of the pre-Kansan drift certainly did not take place until some time after the actual beginning of the Pleistocene, and yet *Elephas imperator* was present in the long, mild interval which followed the pre-Kansan. Associated with the imperial mammoth were such typical members of the Equus fauna as *Equus scotti* and *Equus complicatus*. The camel and the Mylodon add other faunal elements which have some bearing on the question of correlation. Fragmentary and incomplete as is our knowledge of the Aftonian fauna, enough is known to warrant the statement that it resembles most closely the fauna of the Equus zone or "Sheridan formation" as that fauna has been listed by Matthew* and Osborne.† The localities from which the Aftonian fossils have been collected are not very far from the type localities of the Sheridan beds in Sheridan county, Nebraska. A statement by Scott, remarkable for its insight and suggestiveness, may here be quoted. Speaking of the Sheridan stage (*Equus beds*), he says:‡

> "It is to a large extent, of æolian origin and in places contains great numbers of fossil bones. In South Dakota the Sheridan passes under a drift sheet, and probably it corresponds to one of the earlier interglacial stages."

If, as now seems probable, the Sheridan may be correlated with the Aftonian, it corresponds to the very earliest of the known interglacial stages.

THE MOLLUSCAN FAUNA.

The mollusks of the Aftonian of this region, though apparently insignificant when compared with their giant mammalian contemporaries, are of great interest, for not only do they throw light upon the conditions under which the Aftonian deposits were formed, but they demonstrate the remarkable stability and persistence of the species represented; for notwithstanding the invasion of Iowa by four distinct ice-sheets since the Aftonian, all the species of Aftonian mollusks thus far identified have come down to the present time without material change!

*W. D. Matthew: List of the Pleistocene fauna from Hay Springs, Nebraska. Bulletin of the American Museum of Natural History, Vol. XVI, p. 317.

†Henry Fairfield Osborne: Cenozoic Mammal Horizons of Western North America. Bulletin No. 361, U. S. Geological Survey, p. 85.

‡William B. Scott: An introduction to Geology, second edition, p. 782. New York. 1908.

In order that the similarity of the Aftonian and modern mollusks may be more fully appreciated a list is here presented showing the species which were collected by the writer in the Aftonian of Harrison and Monona counties, together with a comparison with the modern fauna from Lake Okoboji.

AQUATIC SPECIES.

Unio metanever Raf.
Unio anodontoides Lea.
**Sphaerium sulcatum* (Lam.) Pr.
**Pisidium abditum* Hald.
Pisidium compressum Prime.
**Amnicola* ———.
**Bythinella obtusa* (Lea) St.
**Valvata tricarinata* Say.
Valvata bicarinata Lea.
Ancylus rivularis Say.
Lymnaea reflexa Say.
**Lymnaea caperata* Say.
**Lymnaea humilis* Say.
**Physa integra* Hald. (?)
**Planorbis bicarinatus* Say.
**Planorbis parvus* Say.
**Planorbis dilatatus* Gld.
Segmentina armigera (Say) H. & A. Adams.

TERRESTRIAL SPECIES.

Polygyra ——— (fragments).
Pyramidula alternata (Say) Pils.
Pyramidula striatella (Anth.) Pils.
**Vallonia gracilicosta* Reinh.
**Vitrea hammonis* (Strom.) Pils.
Zonitoides arboreus (Say) Pils.
Bifidaria armifera (Say) Sterki.
Succinea ovalis Say (=*obliqua* Say).
**Succinea avara* Say.
Succinea retusa Lea.

Unlike the mammalian remains, which are usually found in gravel, the foregoing species of mollusks were collected chiefly in the finer sands of the Aftonian. A few valves of *Sphaerium sulcatum* and fragments of Unios are sometimes found in gravel, but this is exceptional. In number of individuals the aquatic species predominate, the land shells being represented by but few specimens which were evidently washed in from nearby land surfaces.

The species which are marked with an asterisk were also collected in Millers Bay, West Lake Okoboji, Iowa. This set of modern shells was selected for comparison because while Lake Okoboji is some distance to the north and east of our territory, the molluscan fauna of its vicinity is essentially the same, and moreover the lake is a reservoir into which shells may be washed from the surrounding land surfaces on which terrestrial species are quite common, and we have here a fair means of determining to what extent they are so transported. These shells were obtained by dredging in Millers Bay which forms a regular rounded indentation in the west shore of West Lake Okoboji. The dredging was done in water four to eight feet deep near the head of the bay just opposite the Iowa Lakeside Laboratory.

It will be noticed that practically all the Aftonian aquatic species were also collected in the bay. Where only the generic name is given the identification has not been completed, but the Aftonian and lake specimens are evidently identical. All the species which were not dredged from the bay are also living in Iowa today. *Unio metanever* (= *Quadrula metanevra* (Raf.) Simp.) and *Unio anodontoides* (= *Lampsilis anodontoides* (Lea) Baker) are common in the larger streams of Iowa and eastern Nebraska today; *Valvata bicarinata* is found in the state occasionally, more frequently in the eastern part; *Ancylus rivularis* is common in the Des Moines river less than twenty miles away; and *Lymnaea reflexa* is common in ponds near the lake, and also along the shores of other portions of the lake. The bay also yielded several aquatic species which have not been found in the Aftonian. They are: *Unio luteolus* Lam. (=*Lampsilis luteolus* (Lam.) Bak.), an *Anodonta,* four additional species of *Planorbis,* two of *Lymnaea,* one of *Aplexa,* all living in the bay or in ponds communicating with it. The similarity of the aquatic fauna of the bay to that of the Aftonian is striking. It is a fauna belonging to the larger streams and lakes, and is unlike the terrestrial fauna with its occasional small-pond pulmonates which characterizes the loess.

It will be noticed that three of the terrestrial species occurring in the Aftonian were also dredged from the bay. Two specimens of *Succinea avara* and one each of *Vitrea hammonis* and *Vallonia gracilicosta* were secured in this way, together with one specimen of *Vallonia parvula* Sterki, a species not known from the Aftonian.

It is important to note the small number of terrestrial shells which find their way to the bottom of the bay, especially since terrestrial species are abundant in the groves bordering the bay, and great numbers of them are carried out on the lake by freshets to be thrown ashore again. This was well illustrated during the summer of 1909, when great numbers of shells, largely terrestrial species, were thrown out upon the north shore of Millers Bay. The bay is bordered by native forest on the west and south shores, and in these groves dwell more than twenty-five species of terrestrial mollusks, some of them in large numbers. The dead shells of these species, often perfectly fresh, are washed into the bay, and are driven to the north shore by the prevailing southerly or southwesterly winds, where they are massed literally in thousands on the flat beach, together with aquatic species from the bay itself. No forest suitable as a habitat for these species occurs on the slopes adjacent to the north shore of the bay, and the only possible source of these shells is on the opposite, or southerly, timbered part of the shore. Yet notwithstanding the great number and variety of forms which were so carried across the bay,* but few find their way to the bottom as was shown by the result of the dredging. In the light of this fact it seems fair to conclude that the relatively larger number of terrestrial forms in the Aftonian points to a rich terrestrial fauna and large land areas bordering the ancient Aftonian streams.†

Significance of the Aftonian Fauna.

The importance of the Aftonian mammalian fauna in determining the age of certain beds containing remains of large mammals has already been noted.

Certain other considerations make the entire fauna, mammalian and molluscan, worthy of further note. The presence of this fauna makes possible a more accurate approximation to the correct determination of the climatic and surface conditions which prevailed during the Aftonian.

Some light is thrown upon these conditions by the presence of the mammalian fauna made up chiefly of large herbivorous animals which evidently required large quantities of plant food and which could therefore probably live only in a climate supporting

*The drifted material from the north shore of the bay contained the following aquatic forms: one species of *Pisidium*, one *Amnicola*, one *Valvata*, five *Planorbis*, one *Segmentina*, four *Lymnaea* and one *Aplexa*. Mingled with them in great numbers were the following terrestrial forms: one species of *Carychium*, one *Euconulus*, two *Zonitoides*, one *Vitrea*, one *Pyramidula*, one *Helicodiscus*, one *Punctum*, one *Strobilops*, five *Bifidaria*, three *Vertigo*, one *Pupoides* and one *Cochlicopa*. Hundreds of specimens of some of these species were collected.

†In making the comparison with Millers Bay conditions it should be understood, however, that strong currents such as evidently prevailed in Aftonian streams would cause a larger number of shells to sink.

abundant plant life. While all these species of mammals are extinct and it is not safe to draw conclusions concerning the habits of animals from mere relationship, it seems reasonable to conclude that the climate was sufficiently mild to support this necessary abundant flora.

The same conclusion is suggested by the mollusks, and here the result is even more satisfactory, for the species are identical with those living today and we have a much more accurate measure of their habits. The presence of the land shells in the Aftonian is especially suggestive, for land species probably suffer much more from climatic changes than aquatic forms. Moreover they are herbivorous and require a relatively rich flora for shelter. Their presence seems to prove the proximity to the Aftonian streams of plant-covered land areas similar to those which now prevail in the region under discussion, and a climate not materially different from that of Iowa today, at least so far as temperature is concerned.

The presence of the widely distributed manganese dioxide (MnO_2) in the Aftonian would also suggest large quantities of decaying organic matter* and hence the occurrence of mild seasons.

These facts then go to prove that the Aftonian was an interglacial period with a moderately mild climate, and that there were plant-covered land areas on which numerous animals found shelter and sustenance.

The scattered condition of the bones and the presence of numerous fluviatile shells corroborate the evidence furnished by the structure and composition of the beds that the Aftonian is of fluviatile origin.

Are the Beds Aftonian?

In view of the importance of these fossils it is necessary that so far as possible the age and stratigraphic relation of these beds be fixed beyond question. It is fortunate that all the species of Aftonian mollusks are still living today and furnish an opportunity for the exact determination of their habits, but that very fact introduces an element of possible error in the determination

*See Geikie's Text-book of Geology, 3d ed., 1893, pp. 63-64, 456-459, and 495. Also 4th ed., Vol. I, 1903, p. 585.

of the age of the beds if reliance should be placed upon the molluscan fossils alone, for similar or identical series of shells may be collected both in our present waters and in every modern alluvial deposit; and all these species probably invaded the region of Iowa during every interglacial period of Pleistocene time.*

The position of the Aftonian beds between the Nebraskan and Kansan tills has already been noted in the general Pleistocene section. So far as concerns the two counties under discussion, the position of the Aftonian sands and gravels below Kansan drift was first determined in the Cox pit near Missouri Valley, and the first complete section showing their relation to both the Nebraskan and the Kansan was observed near the county line northeast of Little Sioux, also in Harrison county. Subsequently numerous other sections in Harrison and Monona counties and at other points in western Iowa and eastern Nebraska verified this determination and demonstrated the widespread distribution of the Aftonian.

In order that the evidence, on the basis of which the reference of these beds to the Aftonian was made, may be properly set forth, and to give some conception of the extent of the beds, a detailed description of the principal sections is here presented. Where fossils were found separate lists are also given for each section to show the extent and character of their distribution. For convenience in reference these are given separately for each county.

FOSSILIFEROUS SECTIONS

Harrison County.

1. *The Cox pit.*†—This is located in the southeast bluffs of the Boyer river, in the northeast quarter of section 24, township 78 north, range 44 west, and is one of the finest sections of the entire series. The Aftonian here rises to a height of about thirty-five feet above the Boyer bottoms. The section shows the following:

*For a comparison of the Aftonian, loess, alluvial and modern molluscan faunas see table on p. 395.

†See plate XXV, figure 1, also Bull. Geol. Soc. of Am., Vol. 20, 1909, plate 2, figure 1, plate 16, figure 1 and plate 33, figures 1 and 2.

4. Loess, capping the ridge above, but not appearing in the pit.
3. Loveland, exposed just above the pit.
2. Kansan, typical bluish calcareous till, 13 feet (plate xxv, figure 1, A).
1. Aftonian:
   - Sand, varying in coarseness, beautifully cross-bedded, 21 feet. (plate xxv, figure 1, C).
   - Gravel, light colored, cross-bedded, with small bowlders, 6 to 8 feet. (plate xxv, figure 1, D).
   - Gravel, dark colored with much MnO_2, 6 to 8 feet.
   - Fine bluish silt, 6 inches.
   - White sand, penetrated to a depth of 4 feet.

The Aftonian is typical in structure and composition, and both gravel beds contained mammalian and molluscan fossils. No fossils were observed in the sand.

The line between the Aftonian and Kansan is very sharply defined, more or less ferruginous, and with large nodular calcareous plates. Aftonian sand and gravel "bowlders," which are scattered through the lower part of the Kansan, also give evidence of plowing by the latter. About thirty-three rods* east of the pit, at Mr. P. R. Cox's house, and about 100 feet above the valley, a well-section according to Mr. Cox showed forty feet of yellow clay (evidently loess and probably Loveland) and blue joint clay (evidently Kansan), below which a great bed of sand and gravel was penetrated to a depth of eighty-seven feet.

Just south of the road and south of the Cox pit on the same slope is the abandoned Diehl pit, from which it is said many bones and teeth were taken when the pit was operated. None of these could be traced, however.

The following fossils were collected in the Cox pit†:

MAMMALS:

1. *Elephas imperator*, lower jaw (plate xxvi, figure 1).
16. *Elephas columbi*, molar.
12. *Mammut americanum*, sixth molar (figure to left of fig. 6, plate xxvi).
    Mammut americanum, other molars.

*This was erroneously reported as 15 rods in the Bull. Geol. Soc. of Am., Vol. 20. p. 405.

†Since this paper was set up the following additional mammalian remains were received from the Cox pit:

Ursus—(?) A complete right ramus. It is smaller than that of the grizzly or polar bears, but the compressed canine, here somewhat worn, is quite as large at the base as that of the latter, and exceeds that of the former. This is the first Carnivore obtained from the Aftonian.

Equus scotti. Inferior molar.

Equus ——. A left tibia.

Cervus (?). Part of left ramus with one premolar and two molars.

42. (a) *Mammut americanum*, piece of mandibular tusk (figure just below left end of figure 4, plate xxvi).
5. *Elephas* or *Mammut*, left tibia (plate xxvi, figure 5).
18, 25. *Elephas* or *Mammut*, caudal vertebræ.
30. *Elephas* or *Mammut*, pubic bone, part.
138. *Elephas* or *Mammut*, distal end of radius.
45, 46. *Elephas* or *Mammut*, scapula, fragments (plate xxvi, figure 9).
19. Vertebra, unidentified.
57. Incisor, unidentified.
64. Ruminant, probably *Ovibos* ———, horn cores (Bull. Geol. Soc. of Am., vol. 20, plate xxiii, figure 1).
83. Astragalus of large ruminant (op. cit., plate xxii, figure 1). Piece of cannon bone of large ruminant (op. cit., plate xxii, figure 3).
183. *Camelus* (?), second right inferior molar.
185. *Camelus* (?), second phalanx.
67. Large, undetermined ungulate os calcaneum, three specimens.
69. *Equus* ———, proximal end of radius.
72. *Equus* ———, ulna, part.
75. *Equus* ———, scapula, part.
77. *Equus* ———, three incisors.
78. *Equus* ———, dorsal vertebra.
79. *Equus* ———, astragalus.
80. *Equus* ———, five metatarsals.
81. *Equus* ———, humerus, two specimens.
82. *Equus* ———, entire tibia and fragments.
85. *Equus* ———, distal end of femur.
86. *Equus* ———, first phalanx, three bones.
87. *Equus* ———, part of large vertebra.
88. *Equus* ———, distal end of radius, two pieces.
137. *Equus* ———, distal end of left tibia.
70, 120, 123, 126, 127, 129-135. *Equus* ———, molars.
116-119 125, 185. *Equus scotti*, molars (op. cit., plate xviii, figures 1 to 6).
121, 124, 128. *Equus complicatus*, molars (op. cit., plate xix, figures 1 to 5, and plate xxi, figures 2 to 4).
162. *Mylodon* ———, claw (op. cit., plate xxvi).
225. Numerous fragments of bones and teeth.

MOLLUSKS:

Unio ———, smooth heavy shell.
Unio metanever, one valve.
Unio ———, smooth shell.

2. *Peckenpaugh sections.*—These are located on the east side of the Boyer river near the mill-dam, at Logan, Iowa. There are really three sections, but they lie in close proximity and present the same essential facts.

The largest section was made in quarrying rock just above the dam.*

*See photograph of this section, plate XXX, figure 1.

The quarry section shows the following formations:

4. Loess and soil, 20 feet (figure 1, D).
3. Loveland, reddish, somewhat sandy, 6 feet (figure 1, C).
2. Aftonian:
   Sand, cross-bedded, 7 feet (figure 1, B).
   Coarse ferruginous gravel 2 feet.
1. Missouri limestone, exposed 4 feet (upper surface at A, figure 1).

The water in the Boyer river above the dam is about five feet lower than the bottom of this section.

A well located just opposite the dam and about five rods from the river revealed the following:

4. Loess, } 23 feet.
3. Loveland, }
2. Aftonian:
   Colored sand, 4 feet.
   White sand, 5 feet.
   Coarse gravel, 2 feet.
1. Missouri limestone, penetrated 4 feet.

The top of the well rises thirty-nine feet above the dam.

The third section is in a sand pit, excavated at the level of the road, which is about twenty-three feet lower than the top of the well. The following section was shown:

2. Aftonian:
   Sand and finer gravel, 9 to 12 feet.
   Fine silt, about 1 foot.
   Coarse ferruginous gravel, 18 inches.
1. Missouri limestone.

It will be noticed that the Kansan and Nebraskan drifts are wanting in all these sections, but the arrangement of the formations present is consistent with the typical section.

The lowest gravel bed is the only fossiliferous part of the Aftonian in these sections. It yielded the following:

Elephas columbi, a good molar, collected north of the middle of the quarry section.

Fragment of a large scapula (?), with the preceding.

Equus (?), a fragment, probably from limb bone of a horse, was taken from the well.

Part of a rib and a fragment of an unidentified bone were taken from the gravel in the sand pit.

3. *Robinson pit.*—The Robinson pit is located in the southwest quarter of section 16, township 80 north, range 44 west, and shows a typical Aftonian section with Kansan drift, Loveland joint clay and loess above. The Aftonian rises to a height of

forty feet above the valley, and is sharply separated from the Kansan by an oxidized band and by large nodular calcareous plates. It contains very little silt, but is made up chiefly of sand and gravel of the usual Aftonian type.

The following mollusks were collected in the sand:

Unio ———, fragments of a thick-shelled species.
Sphaerium sulcatum.
Pisidium compressum.
Valvata tricarinata.
Bythinella obtusa.
Planorbis parvus
Lymnaea reflexa.
Segmentina armigera.
Polygyra ———, fragments of a large species.
Vitrea hammonis.
Succinea ovalis.

4. *Wallace pit.*—The Wallace sand pit is located in the bluffs of the Little Sioux-Missouri valley just north of Sol. Smith lake in the northwest quarter of section 31, township 81 north, range 45 west. This section is cut into the edge of a narrow bench and shows that these benches are not ordinary river-terraces but exhibit the usual structure of the uplands. It faces the great valley and shows the following members:

4. Loess, rising above the section to the top of the bench.
3. Loveland joint clay, 6 to 8 feet exposed; upper part covered by slump. In its lower part next to the Kansan it usually contains very large calcareous nodules.
2. Kansan till, typical, 10 feet. Its lowermost line is also marked by large calcareous nodules.
1. Aftonian, exhibiting two distinct phases:
   a. Mixed and interstratified sand and silt, 15 feet. The silt is yellow and the sand very fine, the combination resembling very closely that which may be found in most of the modern Missouri river bars.
   b. Fine and coarse sand and fine gravel, variously interstratified and cross-bedded, containing the usual soft calcareous concretions and concretions and plates of sand and iron oxide. Exposed up to 20 feet above the valley but the lower part is covered with talus

The Aftonian sand contained fragments and flakes of a *Unio* or related mussel.

About sixty yards south of this pit Mr. Wallace opened another pit some time ago in which he found the upper Aftonian sand and silt layer reduced to about one foot in thickness, and below it he exposed a bed of gravel sixteen to eighteen feet in thickness.

On this bench, and several rods from its edge in which these pits are located, Mr. Wallace has a well which he reports to be ninety-five feet deep. It is located at a point about eighty feet above the valley, and its lowest eighteen feet passed through gravel. The gravel is evidently Aftonian, and the well-section shows that these gravels are not comparatively recent formations deposited along the edge of the modern valley.

5. *County-line Exposure.*—This is a section made by a road cut along the Little Sioux river, in the north half of section 5, township 81 north, range 44 west, less than half a mile south of the Monona and Harrison county line. (See plate XXIV.)

The road is here about twenty-five feet above the Little Sioux river and parallel with it. Three cuts appear in close proximity, making an almost continuous section more than 500 feet in length. The southernmost of these cuts is the best and shows the following:

5. Loess, appearing above the cut, and ascending to top of bluff.
4. Loveland, a reddish joint clay, with lines of very large calcareous nodules, more than 15 feet.
3. Kansan, typical bluish, very calcareous till, 12 feet.
2. Aftonian:
   - Fine whitish silt, about 15 feet.
   - Fine silt, mixed with sand, shell-bearing, 5 feet (figure 1, D).
   - Coarse gravel, very ferruginous, about 7 feet. This reaches 10 feet in the northernmost cut.
   - Fine cross-bedded sand 6 to 12 feet.
1. Nebraskan drift, 10 feet exposed, but running out both ways (figure 1, A, A).

1. The Nebraskan is typical blue-black till, breaking up into very small blocks, and containing scattered pebbles and bowlders. It is exposed along the road for a distance of about sixty-five feet, and its upper line is very irregular, but sharply defined. The Aftonian, which lies unconformably upon it, has a very ferruginous band at its base.*

2. The Aftonian is more or less variable in the distribution of its materials. In some parts fine silt appears above, and the sand and gravel are variously disposed. However, they show the characteristic structure already noted and are typical. Large slabs or blocks of sand-conglomerate are found in the sand beds. The measurements of the several parts of this formation as

*See Bull. Geological Society of America, volume 20, plate 34, figure 1.

given in the section are maxima. At no point do these appear together, the total exposure at any one point being about twenty feet.

3. The exposed parts of the Kansan vary in thickness in the several cuts from zero to fifteen feet. None appears in the northern cut, the Loveland resting directly on the Aftonian.

The Kansan is separated from the Aftonian by a sharp ferruginous line.*

4. The Loveland consists of typical reddish joint clay and varies from eight to more than fifteen feet in thickness.

Fossils were found in the layer of sandy silt, with the exception of the fragments of *Unio*, which were collected in sand in the northern cut. The list follows:

Unio ————, fragments.
Sphaerium sulcatum.
Pisidium abditum.
Planorbis bicarinatus.
Planorbis dilatatus.
Lymnaea ————, probably *L. caperata*, fragments.

6. *Peyton pit.*†—This sand pit is located in the northeast quarter of section 23, township 81 north, range 44 west. The Aftonian here rises about forty feet above the Soldier river bottoms and is at least thirty feet thick. It is made up largely of sand, but with beds and wedges of gravel, and it presents all the characters of typical Aftonian.

Near the base of the section a bed of white sand six to eight feet thick appears, and just above it, in sand and gravel, a Sioux quartzite bowlder measuring 4 by 2 by 1½ feet was found.

Mr. Peyton reports a dark blue clay under the sand and gravel. This is probably Nebraskan drift.

The Kansan lies unconformably on the Aftonian, which it has evidently plowed in its upper portions, and is very distinct. It contains numerous Aftonian sand-bowlders.

The following fossils were collected, the mammals in gravel and the mollusks in sand‡:

*See op. cit., plate 34, figure 2.

†See Bull. Geol. Soc. of Am., Vol. 20, 1909, plate 16, figure 2.

‡Recently two inferior molars belonging to *Equus*, probably *scotti*, were added to the collection from this pit.

MAMMALS:

2. *Mammut americanum*, jaw with four teeth (see plate xxvi, figure 2).
4. *Elephas* ——— (?), part of humerus (see plate xxvi, figure 4).
6. *Elephas imperator* (?), femur, four feet long, broken (see plate xxvi, figure 6).
7. *Elephas imperator*, sixth molar (see plate xxvi, figure 7).
9. *Elephas* ——— (?) scapula, fragment.
157. Limb bone of proboscidean.
18a. Rib, unidentified.
56. Camel, first phalanx (see Bull. Geol. Soc. Am., vol. 20, plate xxi, figure 1, and plate xxii, figure 2).
66. *Equus* ———, acetabulum.
84. *Equus* ———, part of metapodial.

MOLLUSKS:

Sphaerium sulcatum.

7. *Sand-pit in the northwest quarter of section 26, township 81 north, range 44 west.*—This sand-pit is located south of the creek and east of the wagon-road, and is only a few feet above the creek bottoms. It shows two or three feet of typical Kansan lying over six to eight feet of mixed sand and Kansan, and below this an exposure of five feet of Aftonian sand. The sand is separated from the Kansan by calcareous nodular plates and an oxidized band, and contained fragments of a *Sphaerium*, probably *S. sulcatum.*

In Monona County.

Monona county furnished a number of fossiliferous sections of which the Elliott pit at Turin is the richest in fossils. A discussion of the several sections follows:

8. *The Elliott pit.*—This is a sand pit located in the northeastern part of Turin. The sand and gravel in this pit are typically Aftonian in the cross-bedding, streaking with iron and MnO_2, the presence of silt and drift nodules or pellets and white, soft calcareous nodules, and the occurrence of mollusks in the sand and mammalian remains in the gravel.

Moreover, the position of these beds removes all doubt as to their identity. Superintendent W. E. Babcock, of the cement tile factory operating this pit, reports that in boring in the pit they encountered, below the sand and gravel, a layer of "dark clay which was like rubber," into which they penetrated about four feet. They found it putty-like, tough, very hard to work, and containing occasional bowlders. This is evidently Nebraskan drift, which is also well exposed in the same valley at Castana.

The Aftonian was exposed to a depth of about twelve feet. In the greater part of the exposure the fine sand lies above the gravel, though there is some interbedding, but near the south end a layer of coarse, ferruginous gravel rests on the sand.

The bones and teeth were found in gravel at a depth of ten to twelve feet below the top of the Aftonian.

A distinct band of bluish or reddish laminated silt was found above the sand and gravel. It is about two feet thick, and evidently represents a slack-water deposit of the Aftonian. It grades downward into fine sand.

The superimposed formations, the Kansan drift, the Loveland, and the loess, are well developed, and the entire section is typical. The sharp contact line between the Kansan and Aftonian is shown in plate XXVIII, figure 1, A being the Kansan and B the Aftonian.

The following fossils were collected*:

VERTEBRATES:

8. *Elephas* or *Mammut*, a cervical vertebra (see plate xxvi, figure 8).
161. Part of rib of proboscidean.
166. *Mammut americanum*, sixth molar.
54. Large ruminant. Distal end of metapodial.
187, 231. *Camelus* (?) ———, first phalanx.
122, 136. *Equus scotti*, superior molars.
227. *Equus scotti*, inferior molars.
184. *Equus complicatus*, premolar.
Miscellaneous bones and teeth of *Equus*: four cannon bones (169); phalanges (171-172, 195); a tooth (199); fragments of teeth (228); left radius (232).
197. Jaw of ruminant, fragment.
233. Various unidentified bones, mostly fragmentary.
229. Incisor of a horse (?).
230. Premolar of animal related to camel.
Vertebra of a fish. Found in fine sand.

*Since this paper has gone to the printer the following specimens were received from the Elliott pit:

Elephas columbi, a worn molar.
Proboscidean scapula, fragments.
Equus complicatus, a worn molar.
Equus ——, a splint bone.
Numerous unidentifiable fragments.

MOLLUSKS:

- *Unio anodontoides* Lea. (?)
- *Unio* ———, fragments of a heavier species.
- *Sphaerium sulcatum.*
- *Pisidium compressum.*
- *Amnicola* ———.
- *Valvata tricarinata.*
- *Valvata bicarinata.*
- *Ancylus rivularis.*
- *Lymnaea caperata.*
- *Planorbis parvus.*
- *Segmentina armigera.*
- *Pyramidula alternata.*
- *Pyramidula striatella.*
- *Vallonia gracilicosta.*
- *Vitrea hammonis.*
- *Zonitoides arboreus.*
- *Bifidaria armifera.*
- *Succinea ovalis.*
- Fragments of two or three other species.

9. *Ordway pit.*—This is located in the bluff on the southwest side of the Maple river, opposite Castana, in the southeast quarter of section 13, township 84 north, range 44 west.

The Aftonian here rises about forty feet above the Maple bottoms. The section shows the following members present:

5. Loess, abundant on the ridge above the section.
4. Loveland, 5 to 6 feet.
3. Kansan drift, 6 to 18 feet.
2. Aftonian: Fine, cross-bedded, with interstratified silt, and other characteristics of typical Aftonian, 5 to 8 feet.
1. Aftonian ferruginous gravel, in part forming conglomerate plates, 3 to 4 feet.

Both this and the following section are on a Kansan sloping bench with no over-lying loess. The loess begins higher up on the slope, and the ridge is capped with a thick deposit of it.

In the northern part of the same pit a layer of gravel three feet in thickness lies under the sand, and contained a stratum of mussel shells (mostly heavy-shelled *Unio*) in which the shells were closely massed. They were very fragile and could not be taken out entire. With them were shells of *Sphaerium sulcatum* and a shell of *Ancylus rivularis.* Several large bowlders rested on this gravel layer.

The finer sand contained the following mollusks:

- *Unio* ———, fragments.
- *Sphaerium sulcatum.*
- *Pisidium abditum.*
- *Pisidium compressum.*
- *Valvata tricarinata.*
- *Planorbis bicarinatus.*
- *Planorbis dilatatus.*
- *Segmentina armigera.*
- *Physa integra* (?).
- *Ancylus rivularis.*
- *Succinea retusa.*
- *Succinea avara.*

10. Ordway well.—This well was excavated on the same terrace-like slope, about an eighth of a mile northeast from the pit.

Measurements of the well section could not be made, but it was plain that the Kansan reaches the surface here, and may be traced upward for thirty feet more (vertically) before it disappears under the loess which covers the ridge in its upper parts. In the well itself bluish Kansan till was clearly discernible. Below this Aftonian sand, with a little gravel, rested on a deep bed of Nebraskan drift.

An examination of the materials brought up from the well corroborated the correctness of the record. The sand is here clearly interglacial, lying between the Kansan and the Nebraskan drift sheets, and hence Aftonian.

The sand in the well section yielded the following fossils:

Unio ———, fragments.
Sphaerium sulcatum.
Pisidium compressum.
Valvata tricarinata.
Planorbis bicarinatus.

Some years ago a fragment of a large scapula was obtained from an old gravel pit near this well, and it has been added to the collection (number 91).

11. Griffin well.—This is located near Mapleton, on the farm of C. H. Griffin, on the east side of section 17, township 85 north, range 42 west. It is situated in a rolling Kansan area about fifty feet above the valley of Heisler creek.

The section was made through loess, Kansan drift, and into Aftonian sand and gravel to a depth of about forty feet. The writer examined the material taken from the well. Moreover, Kansan appears at the surface on the same slope at a lower level, the loess covering only the upper parts of the ridge. At a depth of thirty-five feet a part of the tooth of *Elephas imperator* was found in the gravel.

12. Wilkenson well.—This is located in the northwest quarter of section 6, township 85 north, range 42 west. Here, in a typical Kansan drift region, a large tusk (234), a molar, nearly eight feet long on the outer curve, and fragments of cranial bones (numbers 204-211) of *Mammut americanum* were found at a depth of about thirty-five to forty feet, in loose sand and gravel. This section is similar to number 9.

13. Hawthorn pit.—This is a sand and gravel pit in the same region, being located in the northwest quarter of section 14, township 85 north, range 43 west.

The section is typical, showing loess, Loveland, Kansan drift, and Aftonian, the latter here chiefly sand. Mr. C. A. Hawthorn discovered bones in this at various times, but none were saved.

14. McCleary pit.—This is also located in the same region, in the southwest quarter of section 1, township 84 north, range 42 west. The pit is remarkable because it is situated more than two miles inland from the line of the Maple river bluffs, on a small tributary creek. It shows distinct plowing by the Kansan, which here lies distinctly above a stratum of typical Aftonian sand, with some gravel, about twelve feet in depth. The owner reported that in the gravelly portions of the pit he has found "regular clam shells."

15. The New Woodward section.—This is a new sand pit located in the southwest quarter of section 9, township 85 north, range 44 west, about two miles southwest of Rodney. The exposure shows about three feet of fine, white, cross-bedded sand, containing shells of mollusks, and above it an irregular mass of sand and gravel about eight feet deep.

The material lying above the sand is not clearly defined, on account of slumping, but it is mixed drift and gravel, such as is common in this region, where the Kansan plowed into the upper part of the Aftonian.

The sand contains silt balls or pellets, such as are common in the Aftonian, and in all respects the structure and composition of the beds are typical. Moreover, several sections in the vicinity show the unmistakable presence of the Aftonian, one, located in Woodwards Glen in the southwest quarter of section 17, showing a distinct layer of Nebraskan drift immediately below the Aftonian.

The following mollusks were collected in the white sand in section *15*:

Pisidium compressum.
Sphaerium ———, probably *S. sulcatum*, fragments.
Lymnaea ———, probably *L. humilis*, broken.

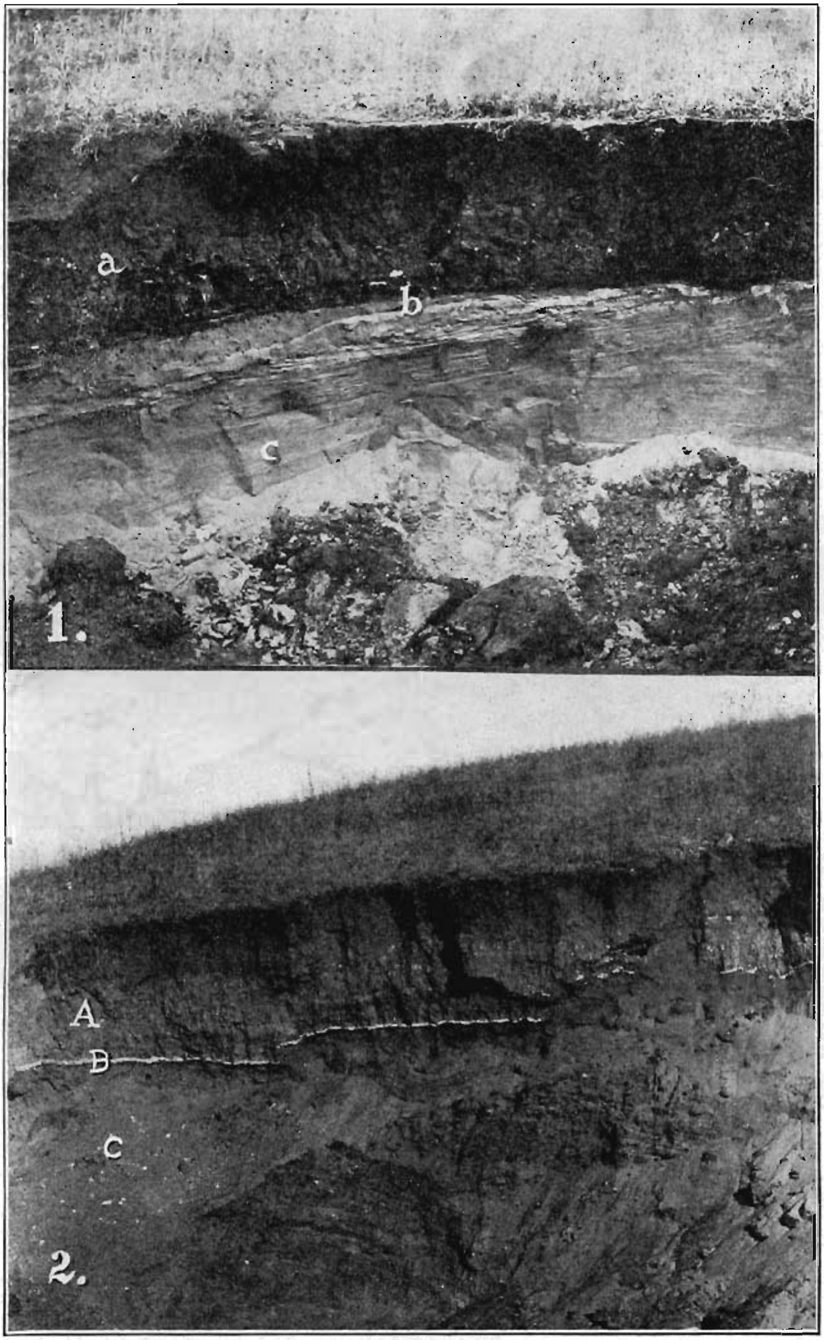

Plate XXVII.—Kansan on Aftonian. (1) In northwest quarter section 7, township 85 north, range 44 west. (a) Kansan. (b) Narrow ferruginous band. (c) Aftonian sand (p. 359). (2) Weniger pit. (A) Kansan. (B) Calcareous nodular plates. (C) Aftonian sand (p. 347).

16. Weniger pit.—This is a sand pit located in the east half of section 18, township 84 north, range 44 west, in Monona county, in the bluffs facing the Missouri valley. (See plate XXVII, figure 2.)

It shows eight feet of sand and gravel (figure 2, C) on which typical Kansan drift, two to four feet thick (figure 2, A), rests unconformably. The two deposits are separated by a distinct oxidized band and by a layer of calcareous nodular plates. (See figure 2, B.)

The Aftonian here rises to about forty feet above the Missouri bottoms, the average altitude of these beds in this territory.

Fragments of shells, probably *Sphaerium,* were found in the upper, finer sand.

Some question may arise as to whether the foregoing fossils really belong to the Aftonian, or were derived from other formations. Fossils from older formations are sometimes found in the Aftonian, as well as in the drifts, and a similar origin might be suggested for the fossils herein enumerated. The mollusks occur in various alluvial and loess deposits, but these uniformly overlie the Aftonian beds and moreover the fragile chalky shells would be destroyed by transportation with the coarse Aftonian materials.

The mammalian remains are especially subject to the suspicion that they are derived from older formations. However, the excellent preservation of the fossils, their distribution and abundance, the occurrence of parts of the same skeleton in such position that ligaments evidently united them at the time of transportation, the position of tusks and teeth in their sockets so loosely attached that they were easily removed, the absence of these fossils from the drifts above and below and the fact that the fauna as a whole is not known from any clearly older horizon, all give strong testimony that the fossils are really contemporaneous with the Aftonian beds in which they lie.

SECTIONS IN WHICH NO FOSSILS WERE FOUND.

In addition to the sixteen fossiliferous sections already described,* at least fifty exposures of Aftonian in which no fossils have been found were observed within the limits of these counties,

*For a description of additional fossiliferous Aftonian sections in other parts of Iowa and in Nebraska, see Bull. Geol. Soc. Am., Vol. 21, pp. 119-140.

in sand pits, along the bases of bluffs, in road-cuts, well-sections, etc. Some of these sections throw much light on the Pleistocene history of this territory, and for that reason the more important are described in detail.

One feature which so far as observed is best displayed in many of these non-fossiliferous sections, though also present in the uppermost portions of some of the fossiliferous sections already described, is worthy of special attention. This is the evidence of the disturbance and plowing of the Aftonian and Nebraskan beds by the Kansan ice-sheet which passed over them. The Kansan drift overlying the Aftonian frequently contains bowlders of sand and gravel, and more rarely of Nebraskan drift, evidently introduced when the Kansan ice-sheet plowed the underlying beds to a greater or lesser depth and incorporated frozen fragments of them in its own mass. Similar bowlders have already been described by Calvin from the Thayer-Afton region in southern Iowa.* But more striking than the testimony of these bowlders is the evidence furnished by the variously folded and distorted strata of the usually cross-bedded or stratified Aftonian sands and gravels which have in some cases been forced into a vertical position or even folded back upon themselves by the Kansan ice. In such cases the line between the Aftonian and Kansan is variously bent and folded as shown in several of the sections described (see plate XXV, figure 2, plate XXVII, figure 2, and plate XXVIII, figure 2), and above it detached fragments or "bowlders" of Aftonian sand and gravel are common. In some cases huge masses of Aftonian were thus set up on edge and pushed far up above their normal level, and occasionally the point of the Kansan plow may be clearly seen back of the disturbed masses of Aftonian, as in the McGavern, Murray hill and other sections. These twisted and distorted masses indicate that the tremendous pushing and crushing force came from the north or northeast, which is consistent with the recognized direction of the Kansan ice movement in this region. The peculiarities of these disturbed strata are brought out in the detailed descriptions of the sections which follow.

*Proc. Davenport Acad. of Science, Vol. X, 1905, pp. 28-29.

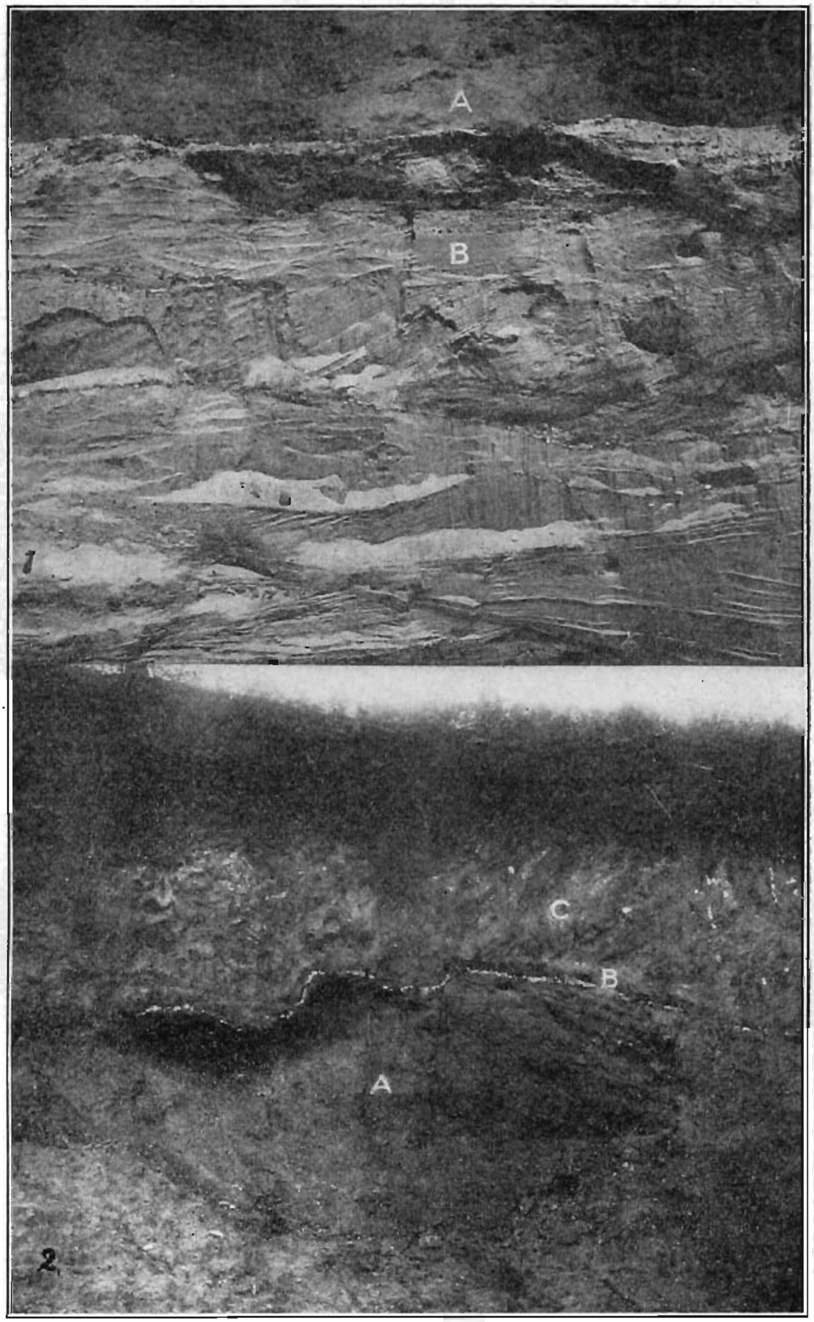

Plate XXVIII.—Kansan and Aftonian. (1) Elliott pit. (A) Kansan. (B) Aftonian sand (p. 341). (2) Ferdig pit. (A) Aftonian sand. (B) Folded layer of calcereous plates. (C) Kansan (p. 358).

In Harrison County.

17. McGavern pit.—The remarkable section displayed in the McGavern sand-pit south of Missouri Valley, in the southeast quarter of section 27, township 78 north, range 44 west, has already been described and figured by Calvin,* and also by the writer.†

The pit is located on the rounded point or angle formed by the Missouri and Boyer valleys on the south side of the latter. Its base as exposed when examined was about forty-five feet above the valley of the Missouri and the total height of the exposed section was about eighteen feet. The southeast face of the section, the upper portion of which is represented in plate XXV, figure 2, showed a horizontal bed of cross-bedded sand and gravel, about three feet in thickness, which seemed to be practically undisturbed, but it was impossible to determine whether this is a part of a lower undisturbed stratum of Aftonian, or merely a portion of the disturbed mass which had been accidentally left in a horizontal position. Above this layer, and just below (A) in the figure, there is a bed of sand eight feet in thickness, which has evidently been pushed and crowded so that its cross-bedded wedges and strata are variously tilted and folded (see C, C). To the right of (A) this bed, which here contains streaks of fine gravel, is folded upward and rises to the top of the section. It is evident that this part of the Aftonian bed was pushed and distorted by the Kansan mass (A) until some portions were folded back through an angle of more than 90 degrees. Excepting for the folding the Aftonian is typical, consisting of strata of sand and fine gravel, the former predominating, which are marked by occasional streaks and stains of MnO_2 and iron oxide.

The Kansan mass at (A) is about seven feet thick, but varies irregularly to much less than that in other parts of the section. The Kansan consists of typical bluish till which is here very calcareous. The great pressure of the Kansan mass upon the frozen Aftonian sand and gravel resulted in the development of a concentric lamination in the till which follows the irregular line

*Bull. Geol. Soc. of Am., Vol. 20, p. 140, plate 3, fig. 2.
†Op. cit., Vol. 20, p. 406, plate 36, figures 1 and 2.

between the Kansan and Aftonian (at B, B). The Aftonian sand shows a similar lamination near the line of contact.

This section is of special interest because, to quote from Calvin's description, "here is a mass of deformed and displaced Aftonian, an enormous sand and gravel bowlder, and here, in the exact position assumed while the work was being done, is the agent through which was transmitted the shove and thrust recorded in the distorted gravels."

18. Persia pit.—In the west bluff of Mosquito creek, one block south of the Chicago, Milwaukee and St. Paul railway depot at Persia, and about twenty-five feet above the valley, there is an old sand-pit which also illustrates the effect of the Kansan plowing. Here there is an irregular mass of Kansan till containing numerous pockets of sand, evidently Aftonian sand-bowlders, for they show the cross-bedding and other characteristic features of that formation. Some of these are so large that they have been worked as sand-pits.

19. Mefferd pit.—This sand-pit, owned by G. L. Mefferd, is located in the southeast quarter of section 31, township 80 north, range 41 west, on the south side of a small creek. The Aftonian has been exposed here to a depth of ten feet, and consists of sand which passes below into fine gravel. It is typical cross-bedded Aftonian, with ferruginous and MnO_2 stains, and is separated from the overlying Kansan by calcareous nodular plates. The Kansan is typical, very calcareous till, and the portion exposed is from three to eight feet in thickness. The ridge above the section is covered with loess. A few rods farther down the creek outcrops of the Kansan and Aftonian appear in a bank twenty feet high, but here in the lower six feet the Kansan is folded and contains bowlders or pockets of coarse sand and gravel.

20. Sand-pit in the northeast quarter of section 28, township 80 north, range 42 west.—This sand-pit is located about two and one-half miles southwest of Woodbine, and more than twenty feet above the valley. It shows Aftonian gravel and sand-beds variously folded and twisted, and containing bowlders of silt covered with a white calcareous deposit. Above and back of these masses of gravel intricately folded Kansan appears, the whole mass shown in the section having evidently been folded and crumpled together.

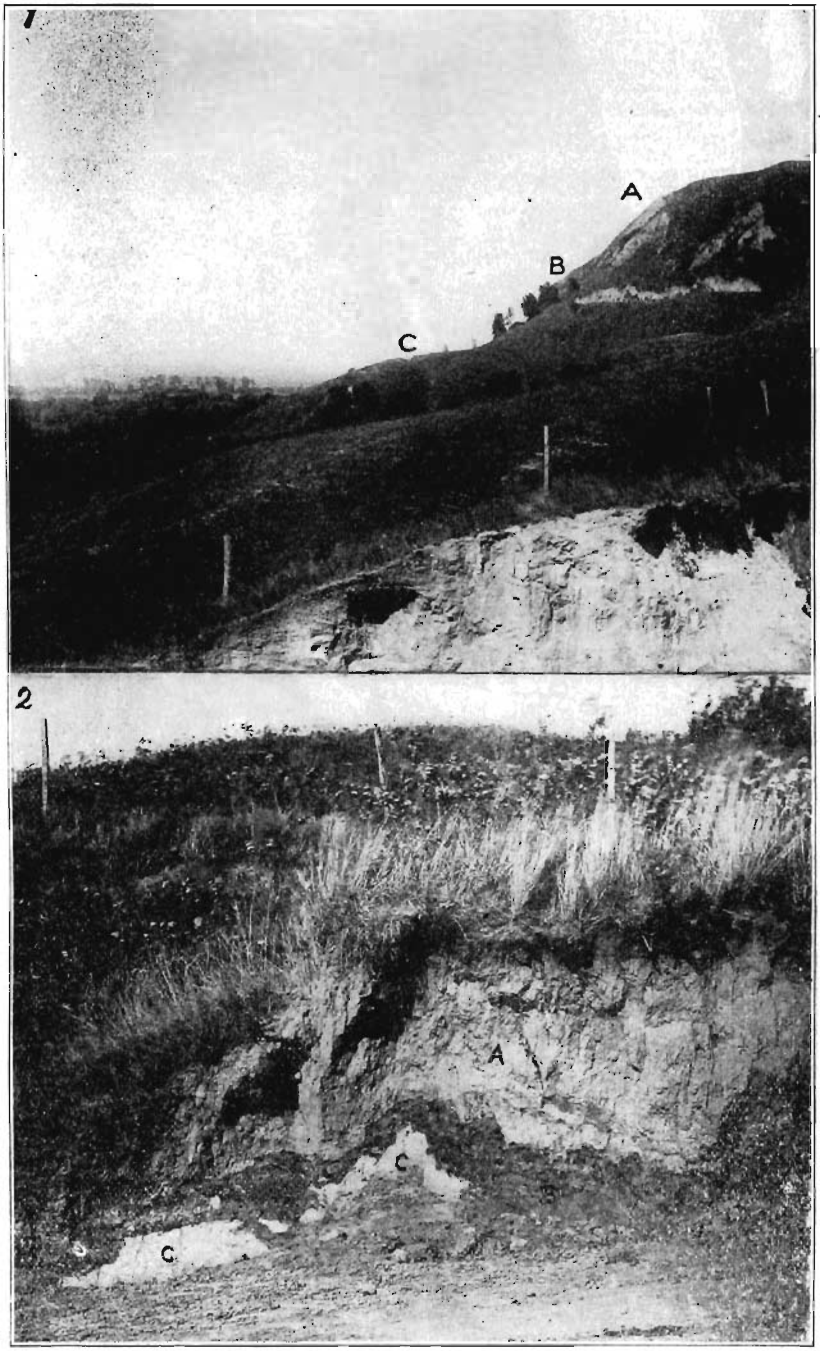

Plate XXIX.—Murray Hill exposures. (1) Profile, looking north (pp. 280, 355.) (2) Section along road. (A) Kansan. (B) Ferruginous Aftonian gravel. (CC) Aftonian white sand (p. 355).

21. The Murray Hill section.—Murray hill is located in the southeast quarter of section 8, township 81 north, range 44 west, and the section here discussed is exposed in part by the road which ascends the hill.* The section is of great interest because it shows the Aftonian sand and gravel crowded and piled up to a height of at least 120 feet above the valley, the highest point at which the Aftonian has been observed. The entire section gives unmistakable evidence of the overwhelming force of the Kansan ice.

The section is more or less interrupted and that part displaying the Aftonian follows the road for a distance of more than 800 feet and rises from the valley to a height exceeding 120 feet. Along almost the entire section, and especially between the altitudes of thirty and 115 feet above the valley, there are exposures of Nebraskan, Aftonian and Kansan variously folded. (See plate XXIX, figure 2.) At an altitude of about seventy feet the Nebraskan rises ten feet above the road, and was here, as at other points in the section, folded and strongly laminated by the pressure of the Kansan mass which still lies back of it. At eighty-five feet a sand-pit shows, in its upper or eastern part, the following section:

3. Kansan drift, 6 feet.
2. Aftonian:
    Sand, 8 feet.
    Gravel, 6 feet.
1. Nebraskan drift, irregular band exposed.

The lower or western part of the pit shows a mass of sand and gravel which seems to be standing almost on edge. So violent was the action of the Kansan ice that in some places the Nebraskan is folded and pushed into or over the Aftonian.

A profile of Murray hill is shown in plate XXIX, figure 1. The portion marked (C) is made up largely of Aftonian, but the Kansan drift has slipped over it and is discernible toward the base, but in the upper part of (C) the Aftonian comes to the surface. Loess is also present on the southwest slopes of (C). The upper part of the sand-pit section reaches almost to the top of (C). Farther up the slope, at (B), the Loveland joint-clay, ex-

*This section has been in part described and figured in the Bull. Geol. Soc. of Am., Vol. 20, p. 406, plate 37, figure 1. The ridge which it follows is shown in plate XXI, figure 1, ascending from the left end of the grove to the more abrupt loess slope above.

posed to a depth of at least ten feet, rests upon the Kansan, and above it, and separated by a sharp line, is a yellow fossiliferous loess, (A).

In addition to the foregoing several minor sections were observed in Harrison county, and without exception they were consistent in structure and position with those already described.

Some of the best of these are located as follows: the John Hull pit in the northwest quarter of section 3, township 78 north, range 43 west; the Fred Mefferd pit in the southeast quarter of section 28, township 80 north, range 41 west; the Tuttle pit in the southwest quarter of section 24, township 80 north, range 42 west; the sand-pit in the northeast quarter of section 28, township 80 north, range 42 west; an old sand-pit near the middle of the west line of section 10, township 78 north, range 44 west; the Jardine pit north of the Robinson pit in section 16, township 80 north, range 44 west; the Hagerman pit south of the Robinson pit; an irregular exposure of sand and drift along the road between sections 17 and 18, township 81 north, range 44 west; and a similar exposure north of the county line exposure near the north line of section 3, township 81 north, range 44 west.

Well-sections in various parts of Harrison county also reveal sand and gravel which are certainly or probably Aftonian, and further demonstrate the important fact that the Aftonian beds extend far beyond the limits of the present river valleys. The well records here presented possess added interest because they throw additional light on the structure of the benches which so prominently border the larger river valleys, for these wells are all located on benches.

The following records are of interest:

At Dunlap.—Mr. David Tacy, a well-digger, reports that in the northern part of the Dunlap bench he finds gravel (it is probably Aftonian), at a depth of sixty-five feet.

At Woodbine.—Mr. Theodore Warren, a well-digger, reports the following usual section for the northern part of the Woodbine bench:

Yellow clay (evidently loess), 25 to 40 feet.

Blue-gray clay (probably Kansan till or post-Kansan loess), 4 to 10 feet.

Blue fine sand, and beneath it a coarser ferruginous sand.

He also reports less sand and more coarse gravel in the southern part of the same bench.

At Logan.—Mr. J. C. McCabe had a well dug at his residence on the Logan bench, and at a depth of sixty-two feet sand was encountered, and beneath it a layer of gravel. On this sand rested a layer of heavy blue clay (probably Kansan till), and above that was the usual covering of yellow loess. A comparison of this section with the Peckenpaugh sections on the opposite side of the Boyer demonstrates quite clearly that the sand and gravel found in the Logan bench are Aftonian.

On the bench southeast of Logan on the opposite side of the Boyer Mr. R. H. Reed reached sand at a depth of seventy feet, in digging a well in the northeast quarter of the northwest quarter of section 30, township 79 north, range 42 west, and Mr. R. Hill obtained the same result in the southwest quarter of section 19, township 79 north, range 42 west.

In Monona County.

Exposures of Aftonian which have not yet yielded fossils are even more numerous in Monona than in Harrison county, but they are mostly small pits and it is more than probable that more extensive excavations will transfer many of them to the fossiliferous list. Similar slight excavations in the upper parts of the Cox and Peyton pits would have exposed no fossils, notwithstanding their abundance in the lower strata.

The more noteworthy of these exposures follow:

22. *Sand-pit in the southwest quarter of section 35, township 84 north, range 44 west.*—This pit lies above the road, and shows the Kansan and Aftonian intermixed and folded. The Kansan may be traced along the slope above the pit for some distance.

23. *Pinckney pit.*—This sand-pit is located in the southwest quarter of section 30, township 85 north, range 42 west, southeast of Mapleton, on a hillside about twenty-five feet above the creek valley, which is here about eighteen feet above the bed of the creek. (See figure 29.)

The section exposed was as follows:

5. Loess, 2 to 3 feet (a) in figure.
4. Loveland, ½ to 1½ feet (b).

3. Kansan, a wedge running out at the west end, where the Loveland rests directly on the Aftonian (c).
2. An oxidized band with calcareous nodular plates, 1 to 3 inches (d).
1. Aftonian, consisting of a layer of coarse gravel about 1 foot in thickness (e), resting on 2 feet (exposed) of fine sand (f).

24. Old Hawthorn pit.—This sand and gravel pit is located on a hillside about forty-five feet above the valley of Wilsey creek in the southeast quarter of section 14, township 85 north, range 43 west, northwest of Mapleton. It shows evidence of great disturbance, the Kansan till and Aftonian gravel being folded and inter-bedded in the upper part of the section in a complicated manner. Manganese dioxide is very abundant in the gravel. The lower part of the section shows several feet of tilted strata of sand and gravel.

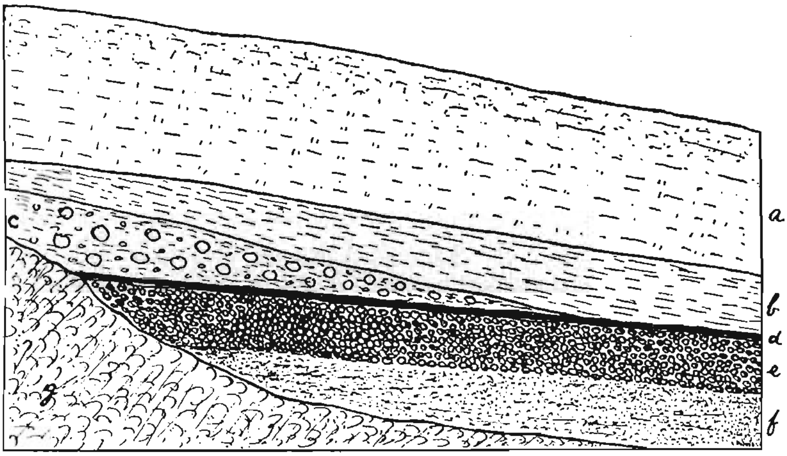

Figure 29. Section of the Pinckney sand pit, southeast of Mapleton.

25. Ferdig pit.—The Ferdig pit is located near the southwest corner of section 10, township 85 north, range 43 west, on a slope some distance from the creek valley. (See plate XXVIII, figure 2.)

The section presented the following members:

4. Loess, 1 to 3 feet.
3. Loveland, 2 to 3 feet, its line of contact with the Kansan irregular, and marked by a band of fine silt 5 to 8 inches thick.
2. Kansan, 4 to 6 feet (c), more or less folded, becoming thicker laterally, and separated from the following by distinct stratum of white, calcareous nodular plates at (b).
1. Aftonian, about 8 feet of typical cross-bedded sand exposed (a).

The irregular calcareous line between the Kansan and Aftonian is especially prominent, as is clearly shown in the figure.

26. Sand and gravel pit in the northeast quarter of section 30, township 85 north, range 44 west.—This pit is located on the detached knob south of the Chicago, Milwaukee and St. Paul railroad near Grant Center. The gravel here rises to a height of fifty feet above the valley, and is exposed along the surface of the slope, and also in three artificial excavations. The one on the northern slope shows three to four feet of Kansan above the gravel, but in the other two which are on the west slope the gravel extends to the surface. A twelve-foot well and borings from fourteen to twenty-five feet in depth, penetrated into but not through the bed of sand and gravel.

The upper part of the Aftonian has been somewhat disturbed, and the overlying Kansan may be traced on the slope to a height of eighty feet above the valley.

27. Sand-pit in the northwest quarter of section 7, township 85 north, range 44 west.—This exposure presents the following section:

2. Kansan, typical calcareous till, plate xxvii, figure 1 (a), 2 to 3 feet, its lower limit marked by an oxidized band (b), 2 inches in thickness.
1. Aftonian, a bed of fine stratified and cross-bedded sand, 4 feet exposed, separated from the Kansan by a layer of calcareous nodular plates interstratified with sand which form a band 1 foot in thickness (c).

28. Blakely pit.—The Blakely pit is situated near the middle of the west line of section 20, township 85 north, range 44 west. The exposure is irregular. At a height of thirty-five feet above the valley a stratum of cross-bedded sand two feet in thickness is exposed beneath distinct Kansan. Reaching to an altitude of forty-five feet above the valley is a section of a bed of tilted cross-bedded sand and fine gravel, four feet exposed, which was more or less folded by the shove of the later Kansan ice.

29. Woodwards Glen section.—This section appears in a high bank of the east fork of the creek in the southwest quarter of section 17, township 85 north, range 44 west. It revealed the following members:

3. Kansan, with the upper part of the bed evidently a secondary deposit, 16 to 18 feet.
2. Aftonian, cross-bedded, ferruginous sand and gravel, 5 to 6 feet.
1. Nebraskan drift, typical, 1 to 2 feet exposed above the creek bed.

Another section reported from the same region by Bain* shows no Nebraskan, and its sixth member is probably not loess, but a secondary silt deposit, at least in its lower part.

30. Aldrich and Young pit.—This pit is situated near the north line of section 12, township 85 north, range 44 west. The section consists in the main of tilted Aftonian gravel beds, with some sand, separated from the overlying Kansan by calcareous nodular plates. The Kansan rises high above the Aftonian bed and forms the main part of the lower ridges bordering the valley of the Little Sioux.

31. Sand-pit in the southwest quarter of section 27, township 85 north, range 44 west.—This is a small exposure facing the valley of the Little Sioux, and shows two feet of Kansan resting on three feet (exposed) of Aftonian sand, with the usual calcareous nodular plates separating them.

Turman pit.—This pit, which lies just north of Monona county, at Smithland, is worthy of mention in this connection because it furnishes additional testimony of the crushing power of the Kansan ice in this region. Here the Aftonian, Nebraskan and Kansan are folded in intricate fashion, and sand and joint-clay bowlders of Aftonian and Nebraskan origin are conspicuous in the Kansan.

Numerous small exposures were also observed in Monona county. Along the main bluffs within the first three miles north of the south line of the county ten or twelve such exposures were observed along or above the wagon road; two small pits are located in the southwest quarter of section 34, township 83 north, range 44 west; a gravel pit showing overlying Loveland is located in Crabb's bluff in the northwest quarter of section 27, township 83 north, range 44 west; another is on the east side of section 33, township 84 north, range 44 west; in the southeast quarter of section 19, township 85 north, range 44 west, there are two exposures; another is located near the center of section 19;

*Rep. Iowa Geol. Sur., Vol. V, 1896, where the region is designated as "Woodwarth's Glen."

another, in the north half of section 19, shows plowed Aftonian gravel twenty-five feet above the road; on the south line of section 18, township 85 north, range 44 west, Aftonian appears, with Kansan rising above it to a height of 140 feet above the valley; Aftonian sand and overlying Loveland are exposed in the southeast quarter of section 17, township 85 north, range 44 west; and a small pit is located in the northwest quarter of section 27, township 85 north, range 44 west.

Several well-sections are of great interest not only because they again show the structure of the river-valley benches, but because they also demonstrate that the Aftonian beds extend much beyond the present valleys of the larger streams and are not mere river terraces. The following well-records were obtained from various sources.

At Soldier.—A well-digger at Soldier reports that on the bench on which the village stands he finds fifteen feet of yellow clay (evidently loess), a layer with many calcareous nodules, a harder clay (the two latter probably Kansan) and at fifty feet he reaches sand, probably Aftonian.

Mr. David Tacy, a well-digger of Castana, gives in substance the following report on the Belvidere and Castana benches:

On the Belvidere bench.—On the farm of Mr. Chas. Bisbee, located on the Belvidere bench in section 11, township 83 north, range 44 west, gravel was reached at a depth of about 125 feet. Above this was blue clay, and then yellow clay (loess) to the surface.

At Castana.—On the lower part of the Castana bench yellow clay (loess) is uppermost and reaches a depth of thirty to forty feet; then follows a layer of blue clay (evidently usually Kansan but sometimes probably including post-Kansan loess) varying from three to twenty-five feet in thickness, and this is followed by gravel.

The depth at which gravel is reached varies from about ninety to 130 feet according to the height of the bench.

At Mapleton.—Mr. W. M. Osborne of Mapleton reports that on the Mapleton bench he usually reaches sand at a depth of about forty to forty-two feet, and above this he finds seven to eight feet of a bluish layer which is limy (evidently Kansan), and on this and reaching the surface, is a yellow clay (loess).

The Griffin well already described is also on a similar bench.

While the identification of the members above the Aftonian is not always satisfactory, it is very evident that these well-sections show a stratigraphic arrangement which is consistent with the general sections, and that the sand and gravel belong to the Aftonian.

The foregoing sections which were studied in Harrison and Monona counties show beyond doubt that the sands and gravels here referred to the Aftonian occupy a consistent position below the Kansan drift, and between it and the Nebraskan drift; that they are unconformable with both and separated from them sharply by strongly oxidized ferruginous bands suggesting old surfaces representing long time-intervals; that the Kansan ice-sheet passed over them and plowed and disturbed them to a greater or less extent while they were frozen; that they represent an interglacial interval in which great floods moved enormous masses of gravel, sand and silt, and during which plant and animal life was abundant; that they are of much wider extent than modern river-valleys, and hence cannot represent marginal deposits of modern streams over which the materials of older deposits had slipped and slumped; and that in short they truly belong to the Aftonian interglacial interval.

The thickness of the Aftonian beds is variable, but where they are not disturbed by the Kansan, it does not exceed forty-five feet, which also represents about their usual height above the alluvial plain of the Missouri river and its larger tributaries.

Where the base of the Aftonian rises somewhat above the valley springs are abundant, the Aftonian being a great water-bearing stratum resting upon the almost impervious Nebraskan drift. Such springs are common on the Missouri valley side north of Grant Center in Monona county, and thence they occur southward at intervals along the bluffs in both Monona and Harrison counties. They are especially abundant between Crescent and Council Bluffs in Pottawattamie county, and at Florence and South Omaha on the Nebraska side of the Missouri. So generally does this horizon furnish springs that wherever water issues from the bluffs in this territory it is worth while to search for Aftonian gravels.

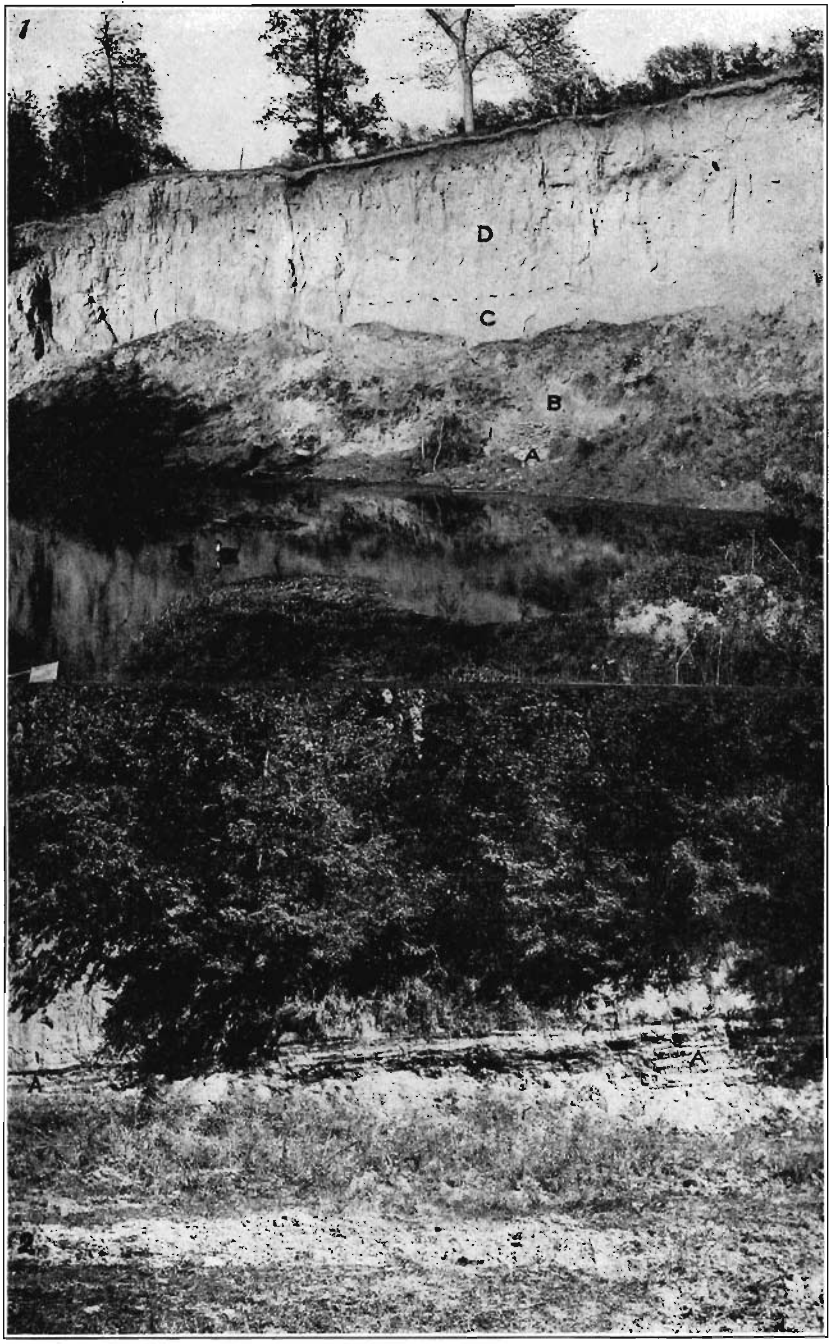

Plate XXX.—Harrison county exposures. (1) Peckenpaugh quarry section. (A) Top of Missouri limestone at base of rock wall. (B) Aftonian sand. (C) Loveland. (D) Yellow loess (pp. 301, 335). (2) MnO^2 bed in Snyders Hollow. (AA) Northern part of exposure. (p. 365).

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(v. 20)

SNYDERS HOLLOW SECTION.

A discussion of the Aftonian sections of this territory should not be completed without some reference to a unique deposit which is prominently exposed in Snyders Hollow just north of Missouri Valley, and which is probably Aftonian. (See plate XXX, figure 2, AA.)

The section is exposed along the east side of the first lateral ravine extending to the south. It is more or less interrupted and obscured by slumping and overwash, but the northern part, which is shown in the figure, exhibits the structure and composition clearly. The entire exposure is more than 200 feet long, and shows at the base a mass of inter-stratified black manganese dioxide (MnO_2) and white marly calcium carbonate, the upper line of which rises above the flat bottom of the valley from zero at the north end to twelve feet at the south end.

The clear northern section of this stratum is about seventy-five feet long, and from zero to eight feet high. Just opposite its higher end a shallow well shows that at this point the black and white stratum extends about two feet below the surface, and that beneath it there is a layer of silt similar to that which overlies it. The lower silt was exposed in the well to a depth of two feet.

The black bands and layers of MnO_2 are made up of fine loose material, or they are consolidated into very hard plates. They vary from mere streaks to layers several inches in thickness, and contain very few fossils.

The white calcareous bands are equally variable in thickness as well as in texture, being sometimes soft and chalky and again forming nodular masses. Rarely narrow bands of silt are inter-stratified with the MnO_2 and calcareous layers. They are very fossiliferous.

Above this stratum lies a band of rather dark silt from one and one-half to two feet in thickness which is also fossiliferous. All of these fossils are listed in the comparative table of mollusks on page 395.

The uppermost part of this section is made up of a stratum twelve feet in thickness which consists of a sparingly fossiliferous yellow loess somewhat modified below. It is possible that this lower portion represents the Loveland.

The absence of several members of the usual Pleistocene series makes it very difficult to determine the stratigraphic position of the manganese and silt beds, but the rather scant evidence at hand would point to the Aftonian. It may be briefly summarized as follows:

1. On the opposite or west side of the same lobe of the ridge, and only a few rods away, there is a strong spring at a level only a little below that of the base of the manganese deposit. In this territory springs almost universally have their source in the Aftonian gravels, and these gravels are commonly associated with such silt as appears above and below the manganese deposit. Moreover it is very probable that the shallow well already noted, which is now partly filled, derives its water from the same stratum of Aftonian gravels immediately below the lower silt.

2. Manganese dioxide is widely distributed throughout the Aftonian sand and gravel beds in greater or lesser quantities, and has not in this region been detected in any other formation. Its abundance in this section is suggestive.

3. The thickness of the overlying loess, and the resemblance of its lower part to some of the Loveland joint clay would also suggest a comparatively great age for the manganese bed.

4. While the fossil shells from this stratum are somewhat unlike those which were collected in the Aftonian beds, the difference is no greater than that which we might expect in different parts of the same region, especially since here no doubt special conditions existed. It is probable that the deposit was formed in a swamp or shallow lake, and both its shores and bottom would produce environment unlike that of the Aftonian streams. The preponderance of terrestrial species is, however, very unusual. If this deposit proves to be Aftonian the list of Aftonian molluscan fossils will be increased by ten terrestrial and two aquatic species, as is shown by the comparative table. It should be noted that all these species live in Iowa today, and that one only, *Helicina occulta,* does not now live in the western part of the state, where it was formerly quite common, as is shown by the fossil shells in the two older loesses.

KANSAN STAGE.

The Kansan drift is well developed in the uplands of both Harrison and Monona counties, but is usually deeply buried under the loess. For that reason few exposures appear excepting in the bluffs of the Missouri and its larger tributaries.

This drift consists in the main of a light ashen blue joint clay, which is more or less clouded and streaked with calcium carbonate, in which the western Kansan is especially rich, and contains pebbles and bowlders among which larger bowlders of Sioux quartzite are common. While the greater part of this formation in the western part of the state (and in our territory) contains chiefly pebbles and small bowlders, occasionally very large bowlders of granite and Sioux quartzite are found, especially along the Missouri and Little Sioux bluffs in the northern part of Monona county.

When present the Kansan rests directly on Aftonian, being very sharply separated from it by usually oxidized lines, as in figure 1, plate XXVIII, or calcareous nodular plates, as shown in figure 2, plate XXVII, and figure 2, plate XXVIII. With its associated Loveland it uniformly lies below the bluish gray post-Kansan loess, and when the Loveland is not developed the drift is separated from the loess by a more or less distinct ferretto zone.

That this is Kansan drift is shown by its stratigraphical position between the Aftonian and the post-Kansan loess, and by its composition, which shows the ordinary blue joint clay with dark colored pebbles and bowlders predominating. It is also frequently stained with iron, especially along lines of fracture and old roots.

It differs from the Kansan of the eastern part of the state in the relatively larger amount of calcium carbonate, which usually whitens the lines of fracture and the faces of the little blocks of joint clay and covers the pebbles and small bowlders to such an extent that it sometimes gives a chalky appearance to the exposure, and large calcareous nodules are not uncommon. It also differs in the more frequent occurrence of Sioux quartzite bowlders.

It differs from the Nebraskan drift in its lighter color, more abundant bowlders (including Sioux quartzite) and calcium carbonate, and in its coarser fracture.

It varies in thickness up to twenty feet in the exposures, but well-borings indicate that it probably reaches a thickness of at least 100 feet.

Its hypsometric distribution is quite variable. In the interior of the upland regions it is usually so deeply buried under loess and Loveland that but few exposures appear, and wells furnish the chief source of information. Unfortunately well-diggers do not as a rule discriminate between the several members of this series, and the records are not therefore always satisfactory.

The loess covering thins out eastward, however, and brings the Kansan and Loveland much nearer to the surface. This is especially true of the southeastern part of our area. Thus at various points in Washington township, Harrison county, cuts in the road, especially on the lower slopes of hills, display typical Kansan. Such cuts may be seen on the section line between sections 30 and 31, 5 and 6, and 6 and 7, and in the southeast quarter of section 17, all in township 78 north, range 41 west. Here the overlying Loveland and loesses are thin, each usually not exceeding five or six feet in thickness, especially on the slopes, the contours of which the loesses follow approximately, usually thickening toward the top of the ridge.

Northward and westward the superimposed deposits are thicker, and the drift is exposed only along the lower slopes in the deeper ravines and valleys of the rough areas already noted, or along the bases of the bluffs of the larger streams. Illustrations of the former may be seen in the wagon-road in the southeast quarter of section 11, township 78 north, range 43 west, and on the north line of the same section, and above the Hull sandpit in the northwest quarter of section 3 of the same township; and the latter, which are much more common, may be found at the bases of many of the bluffs bordering the valleys of the larger tributaries, as well as along the bluffs of the great valley. Examples of Kansan exposures along the larger tributaries in Harrison county may be seen at the following points: at and near the Cox pit on the east side of the Boyer; along the Willow in the north half of section 7, and the east half of section 6, township 80 north, range 42 west; and along the Soldier in the northeast quarter of section 6, township 80 north, range 44 west, near the northeast corner of section 13, township 81 north, range 44 west, and in the Peyton pit. Along the Missouri and Little Sioux bluffs the chief exposures of Kansan are located at the following points: at the McGavern pit; in Missouri Valley at the Charles Smith brickyard, and on the south side of the entrance to Snyders Hollow; at the Robinson and Wallace pits; and at the Murray hill and county line exposures.

The section in the Charles Smith brickyard shows the following:

5. Yellow loess, 90 feet.
4. Blue-gray loess (post-Kansan) about 2 feet exposed but apparently about 10 feet thick.
3. Loveland, 2 to 7 feet.
2. Kansan, 10 to 12 feet exposed, but reported by Mr. Smith as about 90 feet in thickness as determined by boring.
1. Sand, reported by Mr. Smith.

The Loveland becomes thicker southward near the schoolhouse.

The section at the entrance to Snyders Hollow is as follows:

3. Blue-gray loess (post-Kansan), exposed 6 feet.
2. Loveland, slightly pebbly below, 2 to 3 feet.
1. Kansan, exposed to 20 feet above the valley, but obscured below by a talus.

The remaining sections have already been described in connection with the Aftonian.

Northward the elevation above the alluvial plain reached by the Kansan drift increases, being fully 120 feet at Murray hill,* and the total elevation of the uplands becomes correspondingly greater.

In Monona county the loess is also thinner in the eastern part and thickens towards the bluffs and, as in the northern part of Harrison county, the Kansan drift rises to a height of probably not less than 100 feet above the Missouri valley and makes up a large part of the bulk of the uplands, which are everywhere

*It is probable that the Kansan mass was abnormally pushed upward here by the ice which plowed the Aftonian, but the Kansan is normally higher in the northern part of the county.

topped with loess. In the bluffs facing the Missouri valley north and west of Grant Center, and also in those extending for some distance to the northeast on the west side of the Little Sioux, the Kansan is exposed to a height of not less than eighty feet above the valley and forms an imperfect bench, or gentler lower slope, similar to that formed by the Aftonian and Kansan on Murray hill (see plate XXIX, figure 1). This bench or slope is usually conspicuously strewn with large bowlders of granite and Sioux quartzite, and Aftonian sand and gravel frequently appear in its basal part. Near the line between sections 12 and 13, township 85 north, range 44 west, northwest of Mapleton, Kansan drift may also be seen in the road ascending a steep hill rising to a height of more than eighty feet above the Maple valley.

The best inland exposures of Kansan in the northeastern part of Monona county are those in the McCleary pit, the Pinckney pit, the slope near the Griffin well, and the Ferdig pit, which have been noted in connection with the discussion of the Aftonian.

The most conspicuous exposures which were noticed along the larger tributaries were the following:

A series of small exposures along the wagon-road between Turin and Castana, and extending beyond Castana, on the west side of the Maple valley; the Ordway pit which presented eighteen feet of typical Kansan till; the Hawthorn pits northwest of Mapleton; the Woodwards Glen section on the west side of the Little Sioux valley, and the Aldrich and Young pit and the pit in section 12, township 85 north, range 44 west, on the east side of the same valley.

Exposures of Kansan in the bluffs facing the great valley were observed at the following points in Monona county: A series of irregular sections at least fifteen in number appearing just above the wagon-road at the foot of the bluffs and extending across Sioux township; the Elliott pit at Turin; the Weniger pit; and the sand-pits in sections 7 and 30, township 85 north, range 44 west, already described, and various exposures lying between them. All the sections specifically named have been described under the Aftonian.

In all cases the Kansan till in the sections is typical, and is sharply separated from the underlying Aftonian by an oxidized line or band, or a layer of calcareous nodular plates, as described in the discussion of the Aftonian. Where the Kansan ice plowed the underlying strata Aftonian sand-bowlders and less frequently Nebraskan joint-clay bowlders are found in the lower part of the Kansan, and the line between the Aftonian and Kansan is then usually very irregular as in the McGavern pit, Murray hill section, the Ferdig pit, etc.

THE LOVELAND.

The name Loveland was proposed by the writer* for a formation consisting of heavy clay resembling somewhat the drift joint-clays. It was named from Loveland, a station on the Chicago and Northwestern railway located a short distance south of the Harrison county line, where the type section well displays the formation.

The Loveland is usually associated with the Kansan drift, and where both are present the former invariably rests upon the latter, the line between them usually being quite sharp, though sometimes the Loveland becomes somewhat pebbly below and blends with the Kansan through a mixed stratum which seldom exceeds three or four inches in thickness.

The Loveland has evidently usually been confused with loess which it somewhat resembles, but as early as 1880 Aughey† recognized it as distinct, and later Udden‡ discussed it under the name "Gumbo or Red Clay." It is a heavy, compact, reddish (especially on exposure to the air) or sometimes yellowish silt which when dry is hard with a tendency to break into blocks like a joint clay, and when wet becomes very tough and sticky and hence is sometimes called a gumbo.

It is usually homogeneous, consisting of fine materials, but quite frequently coarse grains of sand and small pebbles are scattered through its lower portions, these sometimes being so abundant that they cause a blending of this formation with the underlying Kansan. Sometimes the Loveland appears to be

*Bull. Geol. Soc. of America, Vol. 20, p. 405, 1910, foot-note. See also Science, N. S., Vol. XXXI, pp. 75-76, 1910.

†The Physical Geography and Geology of Nebraska, pp. 260-261.

‡Geology of Pottawattamie County, Rep. Iowa Geol. Survey, Vol XI, 1901, pp. 255-256.

quite homogeneous and unstratified, but usually it shows more or less distinct horizontal lamination and stratification,* and sometimes contains interlaminated thin layers of sand, the whole evidently being a water deposit. On the Nebraska side of the Missouri river above Florence such a stratified bed of Loveland also contains a layer of volcanic ashes varying from two to fifteen inches in thickness.

The Loveland is usually quite calcareous, and frequently contains lines or layers of very large calcareous concretions not infrequently three to six inches in diameter and six to twelve inches in length. These are sometimes in the uppermost part of the Loveland or at the very base of the overlying loess as though the solution from which they were developed had been arrested in its downward course by the much less pervious Loveland. Less frequently distinct lines of similar nodules are found within the Loveland or at its very base. The bands of nodules within the body of the Loveland follow the lines of stratification or lamination and probably occupy more porous layers through which the calcareous solution penetrated laterally. Scattered nodules are very infrequent in the Loveland.

The line of demarkation between the Loveland and the loess is usually very sharp, as in the upper part of the Murray hill exposure, the section at the entrance to Snyders Hollow, and in the great majority of sections observed in this territory and elsewhere, but in two sections, one at the point marked x in plate XXXI, figure 2, and the other north of Florence, Nebraska, there seems to be a blending of the two formations which is probably due to local rain-wash at the time that the loess commenced to form on the old plant-covered Loveland surface. In both of the sections mentioned loess shells, more or less broken, are found in the transition portion, but nowhere in the several hundred sections examined in Iowa, Nebraska, Kansas and Missouri, where the formation is best developed, or in the states where it is less prominent, has any trace of fossils been observed in typical Loveland.

*This lamination however is not like that of the loess, but is regular and the lines are continuous as in typical water-lamination.

In thickness the Loveland is very variable, reaching fully forty feet in the Council Bluffs and Omaha area where it is best developed, but in the Harrison and Monona county sections the maximum exposure observed does not exceed twenty feet.

In vertical distribution the Loveland is very irregular. Sometimes it rises to a height of fully 180 feet above the valley, as on Murray hill, or it may be found near the very base of the bluffs as at the Third Ward schoolhouse in Missouri Valley, in the exposure east of Pisgah, and at many other points. Not infrequently the section of a ridge shows the Loveland to be the thickest in the highest portion of the ridge with its thinner edges extending down over the slopes of the Kansan core, the whole mass thus roughly following the vertical contour of the loess-covered ridge.

This irregularity in the vertical distribution of the Loveland, which is clearly a water-deposit, suggests that it was formed during the melting of the Kansan ice when silt was carried into ice-bound basins, these being located at first on the higher ridges where the thinner ice was the first to melt, and when the ice finally disappeared these masses of silt, often lens-shaped, were spread upon the underlying Kansan drift, the entire process being carried on in the manner described by McGee.*

In short the explanation of the genesis of the Loveland is probably to be found in that which McGee suggested for the loess in the classic cited.†

The total absence of fossils from true Loveland further strengthens the conclusion that it was formed under the conditions stated, and removes one of the most serious objections which could be made to the application of the explanation to the genesis of the fossiliferous loess.

In age the Loveland evidently corresponds roughly to the Buchanan gravels,‡ but was probably formed somewhat earlier, before strong currents were developed, or in places where such currents did not occur.

*11th An. Report U. S. Geol. Survey, Vol. XI, part I, 1891, pp. 567-577.
†It is evident that McGee did not distinguish between the Loveland and the loess.
‡For a discussion of the Buchanan see Professor Calvin's report in Iowa Geol. Sur., Vol. VIII, 1898, pp. 241-244.

The Loveland may be distinguished from the loess by its reddish color, by its greater hardness or toughness, this being so striking that the hoe will usually reveal the difference even in the dark, by the absence of characteristic horizontal loess cleavage and the tendency to break up in the manner of joint clay, by the distinct water-lamination with the occasional inter-lamination of sand, by the presence of sand and pebbles in the lower part, and by the total absence of fossils. Moreover its position with reference to the Kansan and loess is uniformly consistent and the line of demarkation between it and the loess is almost invariably sharp. When the Kansan is absent, as in the Peckenpaugh section, the Loveland still holds a consistent position with reference to other formations. The manner in which the Kansan sometimes runs out, permitting the Loveland to rest directly upon the Aftonian is illustrated in the Pinckney pit, figure 29.

The Loveland is as widely distributed as the Kansan drift, but it seems to have reached its maximum development in the Missouri valley. In Harrison and Monona counties it is present in nearly all the sections showing Kansan drift, and in a number of cases it appears where the Kansan is missing or buried from sight. Some of the Loveland exposures have already been noted in connection with the Aftonian sections, as for example in the County-line exposure, the Wallace pit, the Peckenpaugh section, above the Cox pit and in the Murray hill section in Harrison county, and in the Elliott pit, the Ordway pit, the Hawthorn pit, the Pinckney pit and the Ferdig pit in Monona county. The Washington township sections, the Smith section and the Snyders Hollow sections, described in connection with the Kansan sections of Harrison county, also show typical Loveland. Other exposures were observed at the following points:

In Harrison county, at several points near the base of the Boyer valley bluffs in sections 11 and 12, township 78 north, range 44 west, along the road at the foot of the hill near the southwest corner of section 35, township 80 north, range 43 west, along the bluffs of the main valley in the east half of section 27, the southeast quarter of section 21, and the southeast quarter and the northeast quarter of section 16, all in township 80 north, range 44 west, and near the foot of the hill east of Pisgah; and in Monona county in numerous exposures along the bluffs in Sioux township (one of the best being just east of the intersection of the roads in the east half of section 21, where the Loveland reaches to an altitude fully eighty feet above the valley), near the south line of section 34 and in the northwest quarter of section 27 in township 83 north, range 44 west, along the Maple valley bluffs in the northeast quarter of section 7, the northwest quarter of section 9, and the southeast quarter of section 17, in township 84 north, range 44 west, and in the west half of section 12, township 85 north, range 43 west, where the Loveland is at least twenty feet thick and reaches an altitude of over 100 feet above the Maple valley.

As noted, the Loveland rests directly on Kansan drift when the latter is present; its upper contact is uniformly with the bluish gray post-Kansan loess when that member is present, as in several of the Washington township sections near Persia, in the section at the entrance to Snyders Hollow, in the exposures in sections 3, 10 and 15 in Sioux township, Monona county, and elsewhere. When the post-Kansan loess is present the line between it and the Loveland is very sharp and the difference is frequently made still more prominent by a ferruginous line. When the post-Kansan loess is absent the lower yellow loess rests on the Loveland and the difference is then less marked because of greater similarity in color, though the line of demarkation is usually sharp, as in the Murray hill section.

The Loveland is deemed worthy of a special name because it is a distinct, wide-spread formation, evidently developed under circumstances which were wholly unlike either typical glacial or interglacial conditions, and because it is convenient to have a name by which it may be designated in connection with discussions of the apparently similar loess.

It does not often reach the surface excepting in narrow belts on hillsides, but where it does so it is highly valued, being especially adapted, according to Mr. J. B. P. Day, who has had extensive experience, to the growth of fruit-trees, probably because of its ability to retain moisture.

THE LOESS.

The uppermost member of the upland Pleistocene series consists of the loess, or more properly the loesses, for there are certainly two and possibly three within the limits of our territory.

The writer has already pointed out* that in the Missouri valley there are several loesses, that some are interglacial, some post-glacial.

Various formations, such as alluvium, Loveland joint-clay, drift and Aftonian silt have been confused with the loess, and these various deposits were supposed to represent different phases of the loess formation, but probably the first recognition of two distinct loesses was made by Pratt at Davenport, Iowa, who described† two distinct loesses, clearly describing our post-Kansan loess as a "bluish-gray clay" (number 3) containing a few terrestrial shells, and the later loess as "yellow clay" (number 2), containing five species of terrestrial mollusks.

Later McGee‡ recognized a lower light-blue loess, evidently post-Kansan, and Leverett distinguished a whitish or blue loess and a yellow loess in Illinois.§

That at least some of the loess is inter-glacial was also observed by McGee and Call** at Des Moines, Iowa, where loess was found between what we now know as the Kansan and Wisconsin drifts, and by Leverett,†† who found loess under the Wisconsin drift in Illinois.

The loesses agree in consisting of fine, fairly homogeneous material of which usually at least two-thirds are made up of quartz sand dust, and they were evidently formed under essentially the same conditions. They usually contain nodules of calcium carbonate‡‡ which vary greatly in form and size, and they are frequently fossiliferous, the fossils being mollusks among which terrestrial species vastly predominate.

*Bulletin from the Laboratories of Natural History, State University of Iowa, vol. V, 1904, pp. 352-368.

†Proceedings of the Davenport Academy of Science, vol. I, p. 97, plate XXXII. 1876. It is interesting to note that his peat-bed (number 4), ancient soil (number 5) and probably the member number 6 are evidently Aftonian. Number 6 may be partly or wholly Nebraskan.

‡11th Annual Report U. S. Geological Survey, part I, p. 437, 1891.

§Monograph U. S. Geological Survey, vol. XXXVIII, 1899, pp. 125 and 127.

**American Journal of Science and Arts, 3d series, vol. XXIV, 1882, pp. 202-223.

††Loc. cit., pp. 187 and 188.

‡‡Similar nodules are found in the Loveland, the Kansan, etc. They are therefore not peculiar to the loess.

They possess more or less distinct peculiarities of color, texture, lamination, distribution of ferric oxide, size and distribution of calcareous nodules and even to some extent in the distribution of the species of fossils, and these will be brought out more fully in connection with the discussion of the several loesses.

These loesses, being inter-glacial, are not of the same age, but in our territory they form a continuous series, the intermediate drifts being absent, and for this reason, and also because of the similarity of their genesis, they may be considered together. The oldest of these loesses was formed in the interval following the Kansan; all the subsequent drifts failed to reach this region, but their influence extended to it more or less, producing new conditions which left their impress on the loess of each succeeding interval, that of the most remote Illinoian being least evident.

The loesses are distributed generally but not uniformly over all the uplands; they are absent from the alluvial flats and frequently from the bases of the bluffs, as at C in figure 1, plate XXIX. They form a more or less irregular veneer over the uplands, and are usually thickest at the tops of the more prominent ridges, the greater prominence of these ridges being due in large part to the accumulated loess.

The fact that the loess thus follows the vertical contours of the ridges has led to exaggerated estimates of its thickness, especially where this was based on observations made in shallow road-cuts and gullies extending from the base to the top of the ridge, the assumption then being made that the entire ridge consisted of loess.

The greatest total thickness of the loesses in our territory which the writer has been able to determine with reasonable certainty is about 100 feet. This measurement was made in the great cut which was excavated through the loess ridge at Smith's brickyard in Missouri Valley, where a deposit of ninety feet of yellow loess was found resting on bluish gray post-Kansan loess of which only about one foot was exposed but which, according to Mr. Charles Smith, who operates the brickyard and who has made sections and borings, is not to exceed ten feet in thickness, thus making a total of about 100 feet.

On the opposite or west side of the Missouri river and along the entire eastern border of Nebraska the writer has been unable after several years' search to find a single point at which the aggregate thickness of the loesses exceeds thirty-five feet. Nor has he found any point thus far anywhere within the loess territory at which the thickness of the loess certainly exceeds 100 feet. It is possible, indeed probable, that on some of the highest ridges on the east side of the Missouri river the loess does exceed this thickness, but so far as the writer knows no authentic measurements have demonstrated this. The estimates of greater thickness which have been hitherto published were either based on the erroneous assumption that the underlying formations are horizontal and that a hill covered with loess from base to summit is made up wholly of loess, or they included the Loveland joint clay with the loess.

The lowest member of the loess series, designated as the post-Kansan loess, is usually readily distinguished by its bluish gray color, usually varied by ferruginous stains, lines or very prominent root-tubes, and it is sharply set off from the upper loess, the line of demarkation frequently being made very conspicuous by a ferruginous line or band.

The upper members of the series blend more or less, usually intergrading very gradually, and for this reason, and because of their color, they will be referred to collectively as the yellow loess.

The discussion of the loess here presented is based on a more or less careful study of 208 sections in Harrison county and eighty-nine in Monona county. Many other sections were observed and examined casually, but they seemed to offer neither additional or contradictory evidence, and they are not here considered.

Fossils were found in ninety-three of the 208 sections in Harrison county, and thirty-two of the eighty-nine sections in Monona county. Larger sections or closer search would probably reveal fossils in many of the deposits in which none were observed, but there are undoubtedly large areas, especially on the interior prairie uplands, where no fossils are found in the loess because no mollusks live in such places.

In all cases in our territory where sections show the bluish post-Kansan loess, the yellow loess also appears in the same section or on the slopes immediately above it.

In three such sections in Harrison county and one in Monona county fossils were found in both the bluish and the yellow loesses; in thirteen sections in Harrison county and two sections in Monona county fossils were found only in the bluish loess; and in one case only, in Harrison county, they were found only in the upper or yellow loess. No fossils were found in either blue or yellow loess in twenty-four sections in Harrison county and thirteen sections in Monona county.

Of the sections in which yellow loess only appeared ninety-three in Harrison county and twenty-nine in Monona county were fossiliferous, while no fossils were found in seventy-four sections in Harrison county and forty-five in Monona county.

The fossils are considered more fully in connection with the discussion of the genesis of the loess.

Bluish Loess (Post-Kansan)

The post-Kansan loess is the oldest of the loesses, and in our territory it does not, so far as observed, exceed fifteen feet in thickness. It is probably a remnant in large part of a deposit which was formerly much larger, for its upper surface frequently presents evidence of weathering and erosion, and it is often unconformable with the loess above.

As already noted the post-Kansan loess is usually light bluish gray in color, more or less varied with ferruginous cloudings, streaks, bands, and especially root-tubules. The stains and bands are more frequent in the upper part and in the sections they appear at or near the line of contact with the upper loess. The root-tubules usually form a very conspicuous feature of this loess, being often very numerous and reaching a diameter of two inches or even more. They follow a more or less vertical course, this being determined by the direction of the roots whose decay left channels through which the iron oxide entered from above. That the sesquioxide of iron ($Fe_2 O_3$) which produces the ferruginous colors did come from the upper loess is suggested by its usual presence in the form of bands and lines in the upper part of this loess; by the fact that it does so follow old roots, remnants of some of which have been found in the tubules of this loess, while in the lower part of the upper loess similar tubules have been found even on living roots;* and by the further fact that the lower part of the superimposed yellow loess is frequently partly leached of its iron, leaving the leached portions (which seem to follow roots or crevices) bluish gray and not unlike the body of the post-Kansan loess in appearance.†

This might suggest that the bluish gray color of the post-Kansan loess was due to a similar leaching, but it is quite probable that the color is determined by the source of the material in the bluish Kansan till and silts which contributed to the formation of river-bars during the deposition of this loess.

In texture this loess is very fine and compact, when moist resembling putty, and because of its closer grain it takes up moisture more slowly but retains it better than the yellow loess. For this reason, where exposures of this loess appear at the surface, they are frequently covered with a vigorous vegetation, while the more porous yellow loess is bare, or its vegetation is suffering.

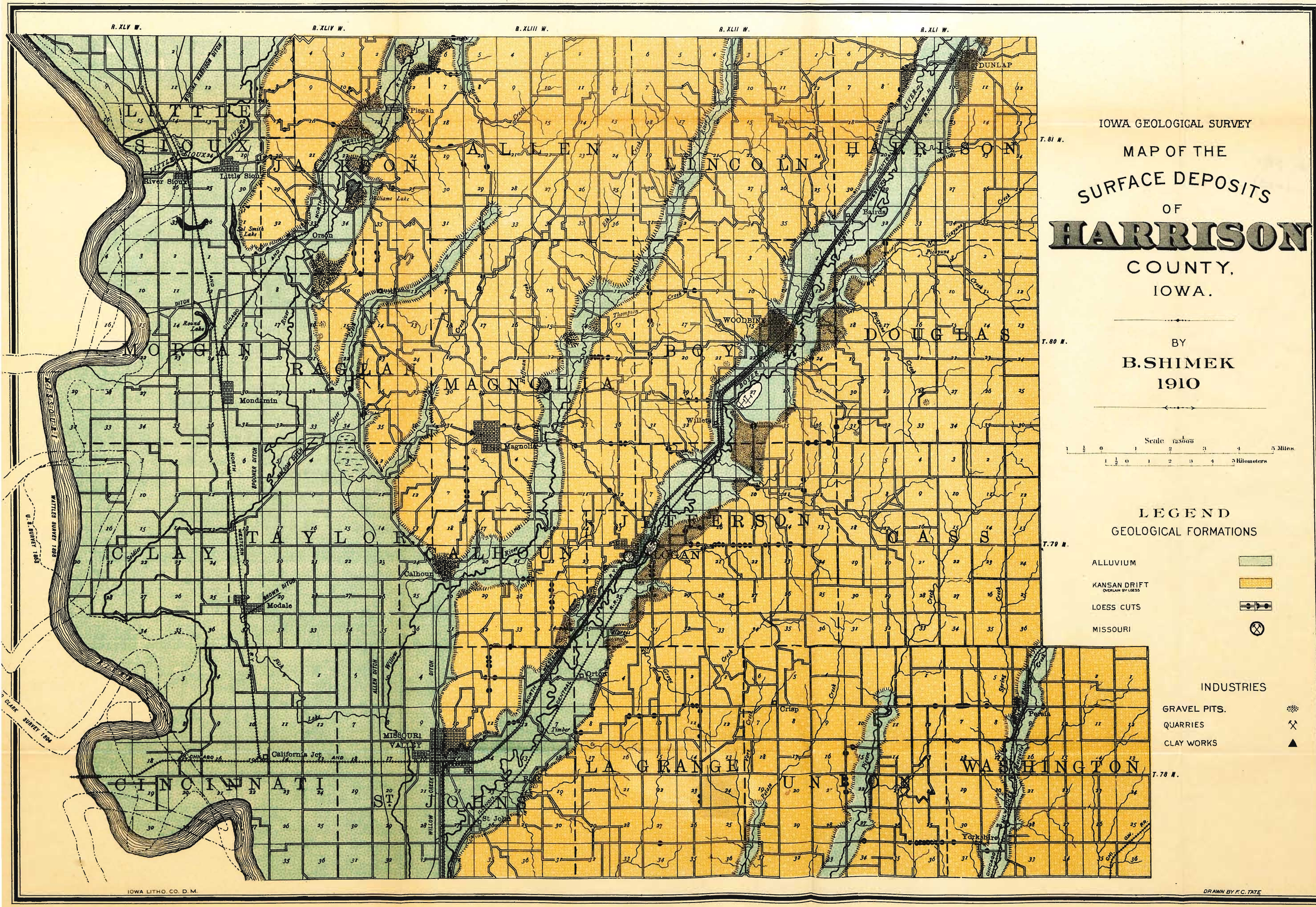
Calcareous nodules may or may not be present. When present they are usually less abundant than those in the upper yellow loess, and are generally smooth and rounded, though small irregular nodules also appear.

The presence of iron root-tubules and calcareous nodules has but little significance however, as both are found in other formations, and both have been observed on living roots. Being formed from solutions which may be carried upward or downward in these formations they are of little value in determining the identity or age of the loess.

The post-Kansan loess frequently shows very fine but distinct lamination parallel to the contour of the upper surface. Even where this lamination does not appear on the surface of the section the loess will break readily along corresponding planes thus indicating that even the apparently homogeneous portions are really laminated.

*In a cut west of Logan, in the southeast quarter of section 12, township 79 north, range 43 west, such tubules were found in the lower part of the yellow loess on the roots of an old bur-oak.

†For further reference to this leaching and for an illustration of the ferruginous and leached tubules, see the writer's paper on "The Genesis of Loess a Problem in Plant Ecology", in the Proceedings of the Iowa Academy of Science, vol. XV, 1909, p. 63, plate VII, figures 1 and 2. (The latter is reproduced in figure 31.)


IOWA GEOLOGICAL SURVEY
MAP OF THE
SURFACE DEPOSITS
OF
HARRISON
COUNTY,
IOWA.
BY
B. SHIMEK
1910
Scale
5 Miles
5 Kilometers
LEGEND
GEOLOGICAL FORMATIONS
ALLUVIUM
KANSAN DRIFT
LOESS CUTS
MISSOURI
INDUSTRIES
GRAVEL PITS.
QUARRIES
CLAY WORKS
R. XLV W.
R. XLIV W.
R. XLIII W.
R. XLII W.
R. XLI W.
T. 81 N.
T. 80 N.
T. 79 N.
T. 78 N.
LITTLE SIOUX
JACKSON
ALLEN
LINCOLN
HARRISON
MORGAN
RAGLAN
MAGNOLIA
BOYER
DOUGLAS
CLAY
TAYLOR
CALHOUN
JEFFERSON
CASS
CINCINNATI
ST. JOHNS
LA GRANGE
UNION
WASHINGTON
DUNLAP
Pisgah
Little Sioux
River Sioux
Orson
Woodbine
Mondamin
Magnolia
Modale
Calhoun
Logan
Missouri Valley
California Jct.
St. John
Crisp
Persia
Yorkshire
Pigeon
Willow
IOWA LITHO. CO. D. M.
DRAWN BY F. C. TATE

The post-Kansan loess is frequently fossiliferous. Of the forty-one sections examined in Harrison county sixteen yielded fossils, and of the fifteen examined in Monona county three were fossiliferous. In other portions of the state, however, the number of fossil-bearing sections is relatively larger. The distribution and relative abundance of the species of fossil mollusks occurring in this loess will be discussed on succeeding pages. It may be stated, however, that the fossils furnish no safe criterion by which we might distinguish between the several loesses. Those in the post-Kansan loess are usually softer and more fragile, probably because of greater age and because they have been imbedded in a formation which more readily retains water. There is, however, no material difference between the species of this and the upper loesses.

That this loess belongs to the interglacial period immediately following the Kansan is shown by the following two significant facts:

1. Throughout the territory of wide extent in which it occurs it invariably rests upon the Kansan or Loveland, or where these are not present, on the next older member of our series which is present. No formation intervening between the Kansan-Loveland and this loess has been found.

2. In one instance in Muscatine the writer found a bed of fossiliferous bluish gray Kansan loess, in all respects like our post-Kansan loess, between the Kansan and Illinoian drifts.* Some of the buried "silts" described by Leverett† may prove to be the same.‡

The post-Kansan loess seems to be quite generally distributed in the uplands of Harrison and Monona counties, but it is more frequently brought to light in road-cuts and other sections in the eastern and southeastern part of the territory east of the region of the high bluffs, because it is much nearer the surface, the superimposed yellow loess being quite thin. In such sections the bluish gray loess is usually better displayed on the lower slopes of the hills, usually tapering out or disappearing under the heavier upper yellow loess towards the summits of the ridges.

*See Proceedings of the Iowa Academy of Sciences, vol. XIV, 1908, pp. 239-240, plate I, figure 2.

†Loc. cit., pp. 114-116.

‡Others are probably Aftonian silts.

POST-KANSAN LOESS SECTIONS IN HARRISON COUNTY.

Such sections were observed in Harrison county at the following points:

1. A road-cut on the north line of the northeast quarter of section 12, township 78 north, range 41 west, showing the following section:

Yellow loess, 5 to 6 feet.
Bluish loess, with iron root-tubules and fossils, laminated, 4 to 5 feet.

2. A road-cut on the north line of the northwest quarter of the same section, showing the following:

Yellow loess, 5 to 6 feet.
Ferruginous line.
Bluish loess with iron tubules, 1 foot.

3. A road-cut on the north line of the northeast quarter of section 36, in the same township, gives

Yellow loess, 4 to 5 feet.
Ferruginous band, narrow.
Bluish loess, with calcareous nodules, iron tubules, and shells, 6 feet. Contained a few Lymnæas which were arranged in a nearly horizontal line or band as if deposited on the edge of a pond.

4. A road-cut in the southwest quarter of section 19, township 78 north, range 43 west, in which is exposed

Yellow loess, 2 to 4 feet.
Bluish loess, with ferruginous streaks and a few very fragile land shells.

5. A road-cut at foot of hill in the southeast quarter of section 28, township 78 north, range 43 west, shows

Yellow loess, 6 feet.
Ferruginous band, 1 inch.
Bluish loess, typical.

6. In a road-cut near foot of slope, in the southeast quarter of section 23, township 78 north, range 43 west, is seen

Yellow loess, 6 to 7 feet.
Ferruginous band, 4 to 6 inches.
Bluish loess, with iron tubules and small calcareous nodules, 3 feet.

Similar sections were observed on the north line of section 30, in the southwest quarter of section 28, and in the southeast quarter of section 23, township 78 north, range 43 west; and on the south line of the southeast quarter of section 8, and the north line of section 7, township 78 north, range 41 west.

In the northern part of the county, northeast of Pisgah, several similar sections were observed in like situations. The following sections will serve as types.

7. A road-cut on the south line of the southwest quarter of section 6, township 81 north, range 43 west.

Yellow loess, 5 feet.
Bluish loess, with iron tubules, 3 to 4 feet.

8. A road-cut located at the southeast corner of the same section.

Yellow loess, thin and irregular.
Bluish loess, with iron tubules (more abundant below) and fragments of fossils, nearly 10 feet.

Other similar sections in this area are located as follows: In the northwest quarter of section 12, township 81 north, range 44 west, and several cuts in the northeast quarter of section 7, township 81 north, range 43 west.

Sections of the same character were also seen in the rough, inland, timbered areas in the eastern part of Harrison county. Thus a section on the south side of the northwest quarter of section 35, township 80 north, range 42 west, showed the following:

Yellow loess, 6 feet.
Bluish loess, with iron tubules, less than 1 foot.

Other sections in the same kind of territory are located on the east side of the southwest quarter of the northeast quarter of section 31, township 80 north, range 41 west, and on the north line of the northwest quarter of section 11, and the north line of section 10, in township 78 north, range 43 west.

In the rough territory west of Logan and in the vicinity of Magnolia the post-Kansan loess also frequently appears in rather shallow cuts, and this quite frequently at rather high altitudes. Some of these sections are located as follows:

9. A road-cut in the southeast quarter of section 12, township 79 north, range 43 west.

Brownish loess and soil, 1 to 4 feet.
Yellow loess streaked with bluish, 5 feet.
Bluish loess (post-Kansan), 1 to 2 feet.

10. A road-cut in the southeast quarter of section 6, township 79 north, range 43 west. (See figure 30.)

Yellow, slightly reddish loess (A), 4 feet.
Bluish post-Kansan loess, more or less streaked and stained with iron (B), 4 feet.
Bluish gray post-Kansan with large iron tubules, 2 feet.

11. A road-cut near the southwest corner of section 8, township 79 north, range 43 west, southwest of Magnolia.

Yellow loess, fossils in lower part, 7 to 9 feet.
Bluish post-Kansan loess, laminated, with large iron tubules, especially below, with fossils, 5 feet exposed.

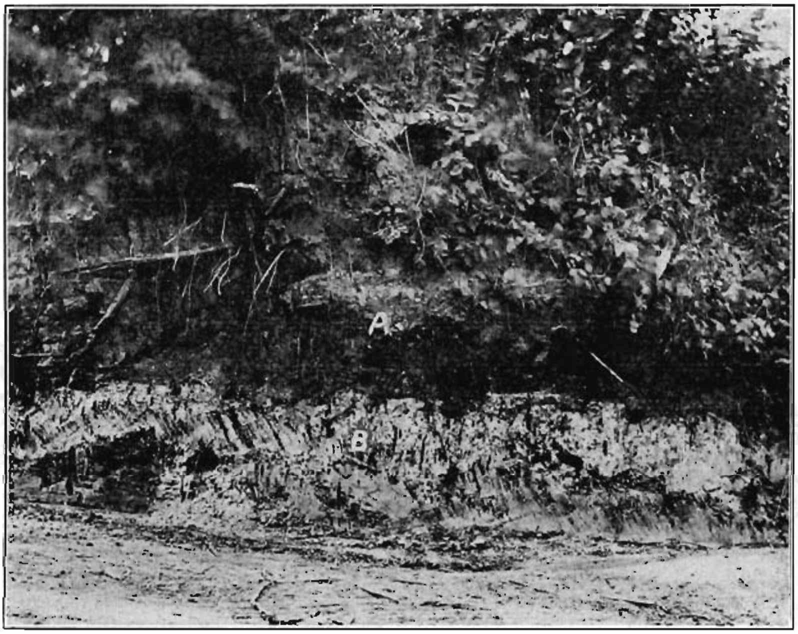


Figure 30. Two loesses, southeast quarter section 6, township 79 north, range 43 west. (A) Upper yellow loess. (B) Lower post-Kansan loess. Its upper part marked B, is stained and streaked with iron (see p. 383).

The bluish loess here nearly follows the vertical contour of the hill, but disappears under the heavier yellow loess near the summit.

12. A road-cut twelve to fifteen feet deep south of the northwest corner of section 8, township 79 north, range 43 west, shows bluish loess, especially on lower part of the slope, with yellow loess above. The blue loess is laminated, and contains fossils, large iron-tubules and some nodules.

Other sections in this area are located as follows: In the west half of section 33, and the southeast quarter of section 31, township 80 north, range 43 west; on the east line of the southeast quarter of section 7, township 79 north, range 43 west; and in the northwest quarter of section 1, township 79 north, range 44 west.

Along the bluffs of the Missouri valley post-Kansan loess is exposed at a number of points. The sections in the Smith brickyard and at the entrance to Snyders Hollow at Missouri Valley have been given in connection with the discussion of the Kansan drift.

Other sections showing post-Kansan loess are located as follows:

In the southeast quarter of section 17, and in section 20, township 81 north, range 44 west; and in a road-cut just north of Calhoun. The last section is here presented in detail:

13. A road-cut on hill just north of Calhoun. The post-Kansan loess here extends for some distance up the slope along the road and almost parallel to the surface.

Yellow loess, with numerous calcareous nodules and some fossils, 3 feet.
Brownish yellow loess, with fossils, 2 feet.
Bluish (post-Kansan) loess, with fossils and iron tubes, 3 feet exposed, but thicker near the foot of the hill.

In some cases post-Kansan loess is exposed along the valleys of the larger tributaries of the Missouri. The following sections were observed along the Boyer valley:

14. An exposure in the southeast quarter of section 11, township 78 north, range 44 west.

Yellow loess, 6 to 8 feet.
Ferruginous line.
Bluish post-Kansan loess, less than 1 foot exposed.

An exposure in the northwest quarter of section 31, township 81 north, range 41 west, and a street cut in Logan one-half a block north and one block west of the Chicago & Northwestern railway depot, also show post-Kansan loess.

Similar exposures in the Willow valley in the north half of section 7, township 80 north, range 42 west, and in the Soldier valley in the northwest quarter of section 3, township 80 north, range 44 west, also show the post-Kansan bluish loess.

POST-KANSAN LOESS IN MONONA COUNTY.

The post-Kansan loess of Monona county is in all respects like that of Harrison county and is found in similar situations.

Inland sections were observed less frequently than in Harrison county. The following section is the best one observed in the eastern rolling prairie regions.

15. A road cut on the line between sections 33 and 34, township 85 north, range 42 west, in which the bluish loess may be seen in the lower two-thirds of the slope. It presents the following section:

Yellow or reddish loess 2 feet, becoming thicker near the top of the hill.
Bluish loess (post-Kansan); with iron tubules, 2 feet exposed.

Another inland exposure of typical post-Kansan loess was observed in a gully, in the rough timbered area near the southwest corner of section 16, township 83 north, range 42 west.

A series of exposures of this loess was also found along the Missouri bluffs in Sioux township (township 82 north, range 44 west), located as follows:

16. A road-cut near the middle of section 15, showing the following section:

Yellow loess, rising above the section.
Bluish loess, with iron tubules, 12 feet.
Kansan drift, its upper surface 105 feet above the valley.

17. A road-cut in the southwest quarter of section 10, exhibits Loveland at the base, with fossiliferous bluish post-Kansan loess resting on it, and above this a compact yellow loess the lower part of which is also fossiliferous.

Two sections in the northwest quarter of section 10 also show bluish loess which is fossiliferous, and seven sections in the west half of section 3 expose blue-gray loess in which no fossils have been found.

Exposures of this loess were also observed in Grant township (township 85 north, range 44 west). One of these is located in the northeast quarter of section 19 at an altitude of 80 feet above the valley, and several are found in the southwest quarter of section 7 in a similar position.

The Yellow Loess

The yellow loess is the most conspicuous member of the Pleistocene series in the counties here discussed. It determines the extreme features of the bluff topography, being thickest on the highest ridges, and forms the immediate subsoil over all the upland region.

As already noted it consists of two members which are more or less distinct in their extreme phases but which blend to such an extent that a clear separation is impossible. The maximum aggregate thickness of these yellow loesses so far as observed is

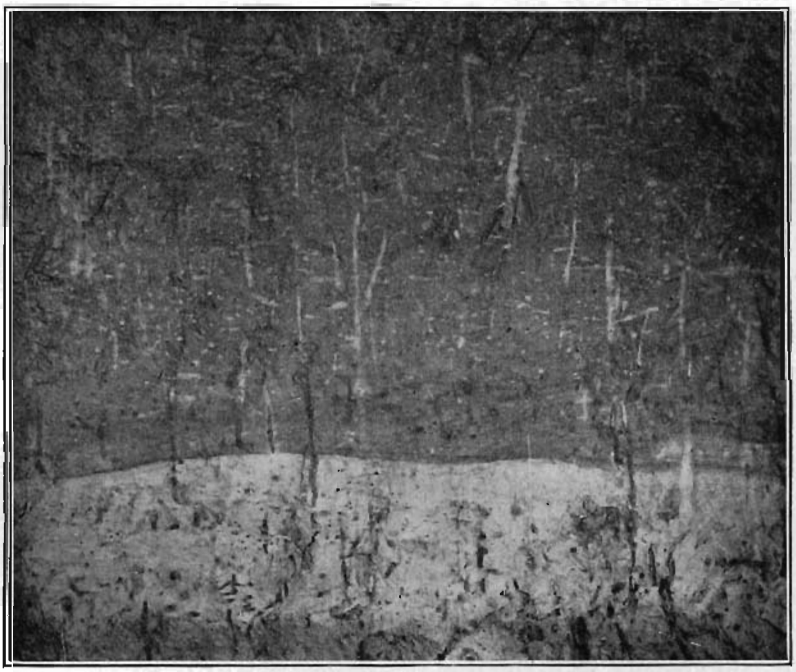


Figure 31. Section in Gaulocher's brickyard in Iowa City, Iowa, showing two loesses very sharply separated but with scarcely a trace of an oxidized line between them. The lower is a gray post-Kansan loess with iron tubules. The upper yellow loess has gray vertical lines or streaks which resemble the lower loess, and which were evidently formed by the roots. In some cases the gray upper streak is continuous with the iron tube in the lower loess; both having evidently been formed by the same root long after both loesses were formed. (See p. 388.)

about ninety feet (see record of the Smith brickyard section at Missouri Valley), and they are very much thicker along the bluffs of the Missouri valley and the abrupt bluffs of the large tributaries than they are farther inland.

The lower yellow loess is compact, usually laminated, especially in its lower part, and when dry it breaks vertically into irregular columns. While the prevailing color is yellow, and sometimes uniform, usually the lower part shows lines and small irregular areas of bluish gray, evidently formed by leaching along rootlets and crevices, somewhat in the manner suggested by figure 31 on a larger scale. These bluish lines are also sometimes parallel with the laminations, and it is probable that the lines and irregular streaks of bluish gray were formed long after the deposition of the loess. This portion of the loess is also streaked with sesquioxide of iron, the streaks and cloudings probably consisting of material leached from the bluish gray portions just described.

This loess contains scattered, commonly rounded and smooth calcareous nodules which usually vary from one-half to two inches in diameter, but are occasionally much larger, especially in the lowest part of the deposit. Where this loess comes to the surface, as is commonly the case on the inland areas, the uppermost three to five feet usually contains very numerous small and irregular calcareous nodules which prominently mark this part of the loess in nearly all the road-cuts and other sections.

The same portion of the loess is usually broken up into small irregular blocks (probably by the action of roots and frost) which separate readily when dry, causing the loess to crumble.

The lower yellow loess is usually quite fossiliferous, and fossils were collected in nearly one-half of the exposures examined. Not infrequently, especially in sections in the main bluffs, the lower part of this loess contains a more or less distinct band or belt, usually three to six feet in depth, in which shells are very abundant, suggesting that during the deposition of this part of the loess the conditions were very favorable to snails (the surface probably being forest-covered) and that later, as the deposit piled up, the conditions became more and more xerophytic and consequently less suited to the majority of the species which form the loess fauna. The best illustration of the shell band was found in the Murray Hill exposure just above the Loveland, where it reaches a thickness of more than six feet, shading out upward.

The upper yellow loess is lighter in both color and texture, and does not usually show distinct lamination. It is uniform in color and sometimes contains scattered calcareous nodules and a few shells, of which *Succinea ovalis* is the most common. Sometimes it shows an uppermost layer with numerous small irregular calcareous nodules and a tendency to crumble, such as is more clearly shown in the lower yellow loess where it comes to the surface.

In the accompanying table of fossils no attempt is made to separate the fossils of these two yellow loesses as the deposits blend almost imperceptibly and the fossils often grade upward gradually from the lower to the upper. The fauna of the upper loess is less rich in both individuals and species, however, and was evidently developed under xerophytic conditions not unlike those which prevail on the loess bluffs today, the few species being identical with those which occur sparingly on these surfaces at the present time.

The upper loess is practically restricted to the Missouri river bluffs and the more abrupt ridges and bluffs bordering the larger tributaries. It soon runs out inland, the lower loess there forming the surface. In a few places, as east of Murray Hill and north of Grant Center, where the sharp, billowy loess ridges extend farther inland, this loess forms their summits even at points quite remote from the bluffs. On the great river benches and on other inland surfaces the uppermost part of the yellow loess, forming an irregular inconspicuous veneer, also probably belongs to this member.

The difference between the two yellow loesses and the reason for their almost complete blending may be better understood by reference to the changes which have taken place in this part of the country since the Kansan ice period.

It is a well-known fact that Iowa geologists recognize three drift-sheets which followed the Kansan.*

The Kansan was followed by an interval in which the bluish gray loess was deposited, as has already been shown.

The Illinoian drift then entered the state, but was restricted to its southeastern part, practically the length of the state from

*For the distribution of the drift-sheets in Iowa see Calvin's map, plate III, in volume XIV of the Report of the Iowa Geological Survey (1904).

Harrison and Monona counties. After another interval the Iowan followed, and though its western boundary has not been exactly determined, it is probable that it did not extend west of the center of the state; and lastly, succeeding another interval, the Wisconsin entered the state and extended westward to Carroll county, reaching a point but little more than the length of Crawford county from the northeast corner of Monona county.

It will thus be seen that none of these later drift-sheets reached our territory, yet it is reasonable to conclude that their proximity produced an effect upon the surface conditions even beyond their borders. There would perhaps follow first a destruction of the original flora and an exposure of the surface; the precipitation of moisture upon these surfaces would be affected; floods would originate in the glaciers and extend into the outlying regions; and finally when the glacier receded large quantities of new materials would be exposed to erosion and carried down the streams into the unglaciated territory, there to form bars from which the supply of loess-dust would be obtained.

The evidence now at hand indicates that during each of the interglacial intervals loess was deposited, and that at least a part of the yellow loess is interglacial. Thus at the point in the Wisconsin drift area which is nearest to our territory, namely in Carroll county, the first cut along the Chicago Great Western railway northeast of Carroll shows the following section near the middle of the south side:

6. Wisconsin drift, 1 to 5 feet.
5. Yellow loess (post-Iowan?), about 10 feet.
4. Bluish gray loess (post-Kansan), 5 to 6 feet.
3. Black, mucky, soil-like band, 1 foot.
2. Heavy, reddish, joint-clay (Loveland), 1 foot.
1. Kansan drift.

Both the loesses are fossiliferous, and they are separated by a strongly oxidized band four to ten inches wide. The lower is typical bluish gray post-Kansan, and the upper is the same as the lower yellow loess of Harrison and Monona counties. It is therefore younger than the post-Kansan loess but older than the Wisconsin drift.

But in the old quarry west of West Amana, Iowa, a similar fossiliferous yellow loess rests directly on the Iowan drift, the section showing the following members:*

4. Yellow loess, 10 feet, the lower 5 or 6 fossiliferous.
3. Iowan drift, 4 feet.
2. Kansan drift, 4 feet.
1. Carboniferous sandstone.

Here the loess is evidently younger than the Iowan drift, and it is probable that at least a part of the more compact lower yellow loess of Harrison and Monona counties is also post-Iowan. It is certainly younger than the post-Kansan loess, and it seems to be identical with a loess which in the Carroll section is clearly below the Wisconsin. It therefore represents the accumulations of one or both of the intervals following the Illinoian and Iowan drift periods. The fact that it is comparatively uniform suggests that it was formed chiefly or wholly within one of these intervals, and since loess essentially like it in Johnson and Iowa counties is post-Iowan, it is probably also post-Iowan. Certainly no variation in this loess which might have been due to two glacial periods has been observed.

The upper light yellow loess appears to be comparatively modern. It is found only in close proximity to the Missouri river, and forms the culminating features of the "snow-drift" topography which characterizes the Missouri bluffs region. It has probably been swept up from the great valley since the Wisconsin period and is evidently being formed very slowly today from the clouds of dust which are carried up by winds from the bars of the Missouri river during the drier seasons of the year.

While the upper loess usually blends with the lower, in some places, as in the east half of section 22, township 82 north, range 44 west, Monona county, and elsewhere, a line or layer of rather large calcareous nodules forms a more or less distinct line of division between the denser lower loess and the more porous upper loess.

In Missouri Valley and elsewhere where English sparrows are abundant, the upper softer loess is often marked by numerous

*Several other sections near the Iowan drift border in northern Johnson and Iowa counties show yellow loess on the Iowan drift.

holes excavated by the birds and used as retreats and probably for nesting. Such holes do not appear in the tougher lower loess.

The yellow loess is probably a composite formation consisting of at least two deposits, the source of the materials of which was affected by different drift-sheets, the materials being carried beyond the limits of the drift-sheet by streams and re-deposited as loess. It is impossible to determine the extent to which the Iowan drift contributed materials of this kind in our territory as its southwestern limits have not been ascertained. It is probable however that the lower yellow loess was derived at least in part from Iowan sources.

The Wisconsin has evidently contributed much material of this kind to the Missouri drainage, and the upper yellow loess is probably largely derived from this source.

The blending of the yellow loesses in Harrison and Monona counties, and in other territory beyond the limits of the later drift-areas, is probably due to their remoteness from the drift-borders and to the similarity of the materials brought down by the later ice-sheets.

YELLOW LOESS SECTIONS.

Nearly 300 sections showing yellow loess were studied in the two counties, and fossils were found more or less abundantly in 127 of them. The sections are distributed throughout the upland areas along wagon-roads and streets, in gullies, on the faces of the steeper bluffs, in sand-pits and brickyards, and along the Chicago, Milwaukee and St. Paul railway, this being the only railway which cuts the uplands. This loess forms the most abrupt portion of the main bluff (as shown in the upper part of plate XXI, figure 1, in plate XXXI, figure 2, and Plate XXXIII, figure 1) where it is also thickest, and in such situations slipping and faulting is common and numerous sections are exposed in this manner.

This slipping and faulting frequently results from the undermining of the underlying Aftonian sand and gravel, though the loess itself slips in wet seasons. Ordinarily however it persists even in vertical walls, and in artificial excavations the sides often remain undisturbed for several years. Such cuts are illustrated in plate XXXI, figure 1, and may be observed in all the Mis-

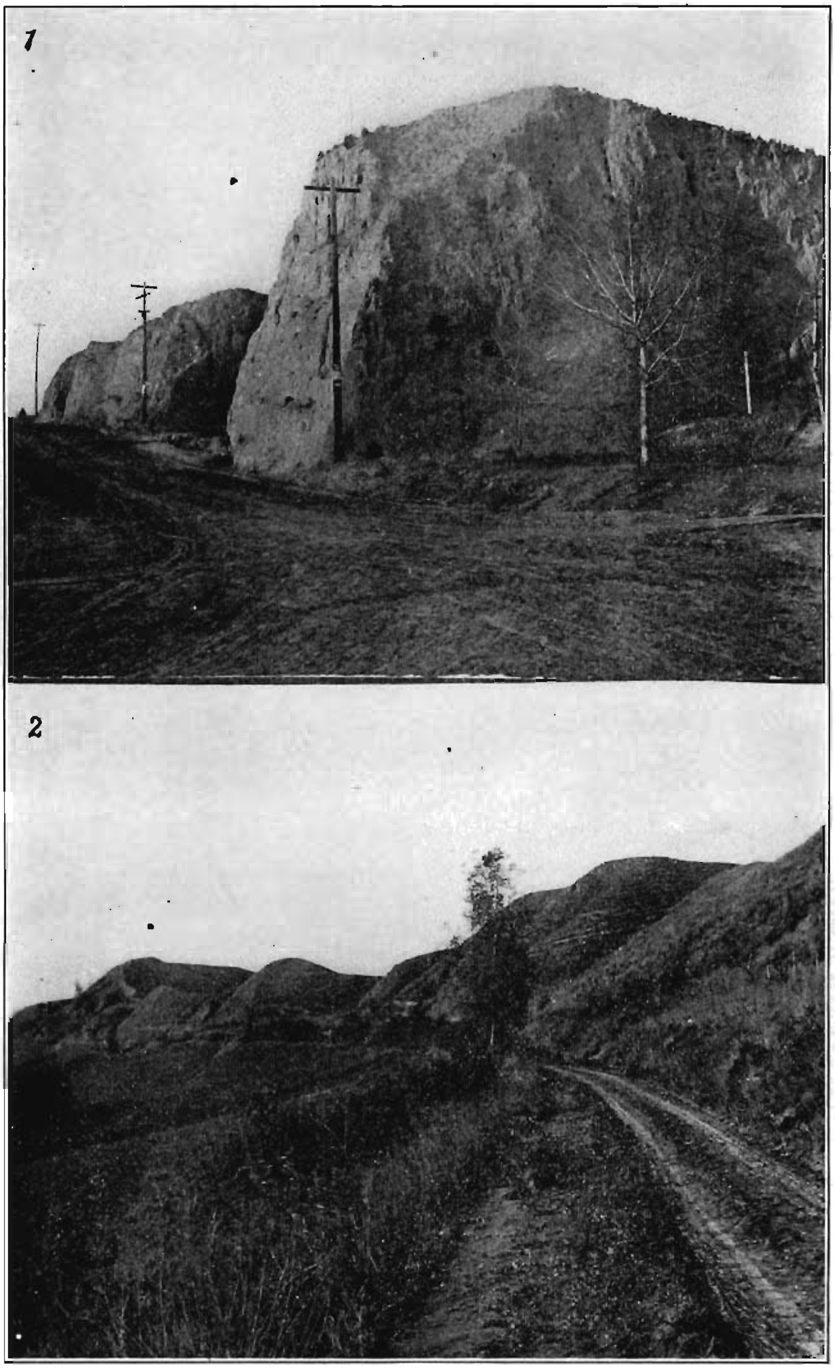


Plate XXXI. — Loess exposures. (1) Looking north on 5th street, Missouri Valley. Street cuts (pp. 309, 392). (2) Loess bluffs in southwest quarter section 3, township 82 north, range 44 west. Loveland and fossiliferous loess (pp. 280, 284, 372, 392, 400, 415).

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souri valley bluff cities and towns in Iowa, Nebraska, Missouri and Kansas.

Missouri Valley is the best locality for the study of the yellow loess within our territory, and one of the best in the entire Missouri valley, being equalled only by Sioux City and Council Bluffs, Iowa, and St. Joseph, Missouri, on the east side of the valley, and perhaps by Omaha, Nebraska, on the west side.

Missouri Valley is located in part on the southerly slopes of the point of highlands which projects southward between the Boyer and Missouri valleys. These highlands descend southward in a series of about five ridges, of which the westernmost one is the shortest and most abrupt, forming a prominent headland, and contains the Smith brickyard section. (See page 369.)

Northward the same highlands form the southern slope of Snyders Hollow, which is shown in plate XXXIII, figure 2.*

Street-cuts and other excavations in this upland mass, to the number of sixty-four, were studied in detail. These sections vary from seven to thirty-five feet in depth, excepting the Smith section which, as already noted, exposes nearly ninety feet of the yellow loess.

On the more easterly ridges the lower yellow loess prevails, but on the western bluffs the lighter upper loess is well developed. Both are typical.

Neither part of the yellow loess is here very fossiliferous, but the lower yielded about twelve species of mollusks, all terrestrial, which were represented by quite a number of more or less scattered individuals. The upper loess yielded only a few individuals of *Succinea ovalis,* a species which is usually found eastward in rather low alluvial woods, but which occasionally occurs on even the treeless portions of the dry Missouri bluffs in western Iowa. In such cases it is uniformly smaller, evidently stunted by exposure to its environment, but identical with the fossil forms of the same species which occur in all the loesses of the region.†

Fossils are much more numerous in other parts of our territory. Perhaps the richest exposure of fossiliferous lower yel-

*The western border of this highland mass, which here forms the Missouri bluffs, is illustrated in plate XXXIII, figure 1.

†The larger form of this *Succinea* is also found on lower grounds in western Iowa, and it is very common in some of the alluvial deposits described in this report.

low loess is that in the Murray Hill section in the Missouri bluffs, and in the cuts along the Chicago, Milwaukee and St. Paul railway east of Mapleton.

In connection with the discussion of the yellow loess sections attention should be called to a number of sections showing the loess of the river benches. These benches are covered with loess, chiefly of the lower yellow type, as is shown by a number of sections. This loess is in every way typical, and, like the underlying formation of the benches already described, it is exactly the same as the corresponding formations described elsewhere in this territory, and simply emphasizes the conclusion that these benches are as old as any part of the inland loess-Kansan territory and that they are not river-terraces.

Some of the best of these loess sections are located as follows:

HARRISON COUNTY BENCH SECTIONS.

1. A street-cut north of the Chicago and North Western railway station at Logan. Fossils.

2. A road-cut west of Dunlap on the north line of section 9, township 81 north, range 41 west. Fossils.

3. A road-cut near the northwest corner of the northeast quarter of section 5, township 80 north, range 41 west. Fossils.

4. A road-cut near the southwest corner of the northwest quarter of the same section. Fossils.

5. A road-cut in the northwest quarter of section 12, township 81 north, range 44 west, near Pisgah.

6. A road-cut in the southwest quarter of section 14 of the same township. Fossils.

7. Two road-cuts in the southeast quarter of section 15 of the same township.

8. A road-cut in section 23 of the same township.

9. Two road-cuts on the east line of the northeast quarter of section 22 of the same township. Fossils.

MONONA COUNTY BENCH SECTIONS.

10. A road-cut in the southeast quarter of section 30, township 84 north, range 43 west. Fossils.

11. A road-cut in the southeast quarter of section 2, township 83 north, range 44 west.

12. Two road-cuts in the east half of section 11 of the same township. Fossils.

13. A road-cut near the middle of the east half of section 4, township 83 north, range 42 west. Fossils.

14. A road-cut near the northwest corner of the northeast quarter of section 31, township 82 north, range 43 west. Few fossils.

Loess Fossils.

The fossils of the loess of this region are all mollusks, and terrestrial forms here as elsewhere vastly predominate.

The following table gives a comparative view of the molluscan faunas of this region, from the Aftonian to the present time. The first column includes the fauna of the Aftonian beds; the second of the somewhat doubtful, though probably Aftonian, bed of manganese dioxide at Missouri Valley; the third of the bluish gray post-Kansan loess; the fourth of the yellow loess; the fifth of the various alluvial deposits described on succeeding pages; and the sixth the modern fauna.

FOSSIL AND MODERN MOLLUSCA OF HARRISON AND MONONA COUNTIES

	Aftonian	MnO_2	Gray loess	Yellow loess	Alluvial	Modern
TERRESTRIAL SPECIES.						
Vallonia gracilicosta Reinh.	+	------	+	+	+	+
Vallonia parvula St.	------	------	------	------	+	+
Polygyra hirsuta (Say) Pils.	------	------	------	------	+	------
Polygyra monodon (Rack.) Pils.	------	+	+	+	+	+
Polygyra multilineata (Say) Pils.	?	+	+	+	+	+
Polygyra profunda (Say) Pils.	------	+	------	------	+	+
Strobilops labyrinthica (Say) Pils.	------	+	------	+	------	+
Strobilops virgo Pils.	------	+	------	+	------	+
Leucocheila fallax (Say) Try.	------	------	------	?	------	+
Pupilla muscorum (L.)	------	------	+	+	------	------
Bifidaria armifera (Say) Sterki.	+	+	------	+	+	+
Bifidaria contracta (Say) Sterki.	------	+	------	------	+	+
Bifidaria holzingeri (Sterki.)	------	------	------	------	------	+
Bifidaria pentodon (Say) Sterki.	------	------	------	------	+	+
Bifidaria procera (Gld.) Sterki.	------	------	------	------	------	+
Vertigo milium (Gld.) W. G. Binn.	------	------	----	------	------	+
Vertigo modesta (Say) Pils.	------	------	+	+	------	------
Vertigo ovata Say	------	------	------	------	+	+
Vertigo tridentata Wolf.	------	------	+	------	+	+
Sphyradium edentulum var. *alticola* (Inger.) Pils.	------	------	+	------	------	------
Cochlicopa lubrica (Muell.)	------	------	------	+	------	+
Vitrea hammonis (Strom.) Pils.	+	+	+	+	+	+
Vitrea indentata (Say) Pils.	------	------	------	------	------	+

FOSSIL AND MODERN MOLLUSCA OF HARRISON AND MONONA COUNTIES
CONTINUED

	Aftonian	MnO_2	Grry loess	Yellow loess	Alluvial	Modern
Euconulus fulvus (Drap.) Reinh	------	+	+	+	+	+
Zonitoides arboreus (Say) Pils	+	+	+	+	+	+
Zonitoides minusculus (Binn.) Pils	------	+	------	+	+	+
Pyramidula alternata (Say) Pils	+	+	+	+	------	+
Pyramidula shimekii (Pils.) Sh	------	------	+	+	------	------
Pyramidula striatella (Anth.) Pils	+	+	+	+	+	+
Helicodiscus parallelus (Say)	------	+	+	+	+	+
Punctum pygmaeum (Drap.) Binn	------	------	------	------	------	+
Succinea avara Say	+	+	+	+	+	+
Succinea grosvenorii Lea	------	------	------	?	------	+
Succinea ovalis Say (=obliqua Say)	+	+	+	+	+	+
Succinea retusa Lea	+	+	------	------	+	+
Agriolimax campestris (L.)	------	------	------	------	------	+
Carychium exiguum Say	------	+	------	------	------	+
Carychium exile Lea	------	+	------	------	------	+
Helicina occulta Say	------	+	+	+	+	------
Eggs of small snails	------	------	+	+	+	+
FRESH-WATER SPECIES.						
Lymnaea caperata Say	+	+	?	------	+	+
Lymnaea humilis Say	+	+	+	------	+	+
Lymnaea obrussa Say	------	------	+	------	+	------
Lymnaea palustris Muell	------	------	------	------	------	+
Lymnaea reflexa Say	+	------	------	------	+	------
Aplexa hypnorum L.	------	+	------	------	+	------
Physa gyrina Say	------	+	------	------	+	+
Physa integra Hald	?	------	------	------	+	+
Planorbis bicarinatus Say	+	------	------	------	+	+
Planorbis dilatatus Gld	+	------	------	------	+	+
Planorbis exacutus Say	------	------	------	------	+	------
Planorbis parvus Say	+	+	------	------	+	+
Planorbis trivolvis Say	------	------	------	------	+	+
Segmentina armigera (Say) H. & A. Adams	+	------	------	------	------	------
Ancylus rivularis Say	+	------	------	------	------	------
Amnicola ———(?)	+	------	------	------	------	------
Bythinella obtusa (Lea) Hald	+	------	------	------	------	------
Valvata tricarinata Say	+	------	------	------	------	------
Valvata bicarinata Lea	+	------	------	------	------	------
Pisidium abditum Hald	+	+	------	------	+	------
Pisidium compressum Prime	+	------	------	------	+	------
Sphaerium striatinum Lam	------	------	------	------	------	+
Sphaerium sulcatum Lam	+	------	------	------	+	------
Musculium truncatum (Linsl.) St	------	------	------	------	+	------
Unio anodontoides Lea	+	------	------	------	+	------
Unio lachrymosus Lea	------	------	------	------	+	------
Unio metanever Raf	+	------	------	------	------	------
Anodonta ———	------	------	------	------	------	+
Anodonta ———	------	------	------	------	------	+

A comparison of the lists of fossils from the two loesses shows very little difference. Even where species occur in one and not in the other the difference is without significance as in each case the species is found in the other loess in some other section of the state. Such differences for the limited territory here considered are simply due to the uncertainties and inequalities of field work.

It will be noticed that with the exception of the Lymnæas which were found in restricted parts of but two sections of post-Kansan loess, the loess species are strictly terrestrial, and with the exception of *Vertigo modesta* and *Pyramidula shimekii** all live within the limits of the state, though three additional species, *Sphyradium edentulum, Pupilla muscorum* and *Helicina occulta*† are not found in the modern fauna of these counties.

Several terrestrial species which are found in the modern fauna of the region were not collected in the loess, or the specimens were doubtfully from the loess. All of these species have been found in the loess of other parts of the state and country. They are:

Vallonia parvula
Succinea grosvenorii
Polygyra profunda
Leucocheila fallax
Bifidaria contracta
Bifidaria holzingeri
Bifidaria pentodon
Bifidaria procera
Vertigo milium
Vertigo ovata
Vitrea indentata
Punctum pygmaeum
Carychium exile

Vallonia parvula and *Succinea grosvenorii* are common on the modern surfaces of this region, but they are not common in the loess and seem to be comparatively recent additions to the fauna. *Limax campestris* is a slug and hence would leave no evidence of its earlier existence. *Succinea retusa* and *Carychium exiguum* though not aquatic prefer very moist places, and they are practically absent from the loess of this country, though at least the *Succinea* extends back to the Aftonian. It will be observed that the same is true of a number of the aquatic species which occur in both the Aftonian and modern faunas but are found very sparingly, or more frequently not at all, in the loess. This fact has an important bearing on the genesis of loess.

*Both of these species live in the dry regions of the southwest. For a more detailed discussion of the *Pyramidula* see the Bulletin from the Laboratories of Natural History of the State University of Iowa, vol. V, part 2, 1901, pp. 139-145.

†For the discussion of the distribution and variation of both fossil and modern forms of this species see the Proceedings of the Davenport Academy of Sciences, vol. IX, 1904, pp. 173-180, and the Journal of Geology, vol. XIII, 1905, pp. 232-237. In our territory this species became extinct before the completion of the deposition of the yellow loess as it does not occur in the upper part of that formation.

None of the species here listed, whether from the Aftonian, the loess, or the alluvium are entirely extinct.

Quite a number of the terrestrial species extend through all the formations included in the table, but in such cases they occur in the Aftonian and more modern alluvium only in comparatively small numbers and were evidently washed down from adjacent land surfaces. A few species of aquatic pulmonates, belonging to the genus *Lymnæa,* and one bivalve, *Pisidium compressum,* are also found in all these formations, but they are rare (the *Pisidium* is very rare) in the loess though common in the water-lain Aftonian and alluvium.

The distribution of the mollusks in all these formations is similar to that of the modern forms. No single exposure will yield all the species in the list, just as no single limited area will support all the modern forms.

Certain species, such as *Vallonia gracilicosta, Pyramidula striatella, Succinea avara, Succinea ovalis* and *Helicina occulta,* are likely to occur in considerable numbers in the loess, just as they do on modern surfaces. Other species, such as *Polygyra monodon, Vitrea hammonis, Euconulus fulvus, Zonitoides arboreus* and *Helicodiscus parallelus,* are less abundant in any given cut or locality but are widely distributed, thus also resembling the modern representatives of the same species. Still others are rare and local in the loess as well as on the surface.

The vertical distribution of the shells in the loess is also very variable, suggesting that as the loess was forming surface conditions and the surface fauna changed, usually more or less gradually.

The distribution of the few aquatic pulmonates of the loess also resembles that of the modern forms. The smaller Lymnæas, which form the greater part of the aquatic pulmonate fauna of all the loess, are now found usually at the edges of ponds and sluggish streamlets, and when they occur in the loess they are usually found in bands or pockets which suggest a similar condition, and which probably represent the edge of a pond long since buried.

Taken collectively the molluscan fauna of the Aftonian and alluvium suggests aquatic and low-ground conditions, while that of the loess suggests terrestrial upland conditions.

The Genesis of the Loess.

The question of the genesis of the American loess has been under discussion for many years, and various hypotheses have been presented to account for the presence and the peculiarities of this deposit.

For many years American geologists quite generally accepted some form of the glacio-fluviatile hypothesis as sufficient to explain the phenomena of the loess, but more recently those who are most familiar with the subject have been inclined to favor the æolian hypothesis.

The writer has presented the æolian side of the case in a more or less fragmentary manner in a series of papers published within the past sixteen years,* and he does not purpose here to enter into a detailed discussion of the genesis of the loess, this being reserved for a more extended paper now in preparation.

However the work in Harrison and Monona counties and in adjacent territory has brought out certain facts which throw light on the genesis of the loess and these are here briefly discussed.

It may be stated at the outset that these facts give support to the æolian hypothesis and are in themselves sufficient to establish it and to show the utter impossibility of the existence of glacio-fluviatile conditions during the deposition of the loess.

Briefly stated they are as follows:

1. The presence and relative position of the several loesses is consistent with the conclusion that they are interglacial (the last post-glacial) and that they were deposited in a comparatively mild climate. This precludes the possibility of a glacial or sub-glacial climate in which shores of ice might at times retain large bodies of water, and increases the difficulty of accounting for the presence of loess on the highest ridges under the glacio-fluviatile hypothesis.

*See the Loess Papers in the Bulletin from the Laboratories of Natural History of the State University of Iowa, vol. V, 1904, pp. 298-381, containing references to earlier papers; the Loess of the Missouri River, Proceedings of the Iowa Academy of Science, vol. XIV, 1908, pp. 237-256; a paper on the Genesis of Loess a Problem in Plant Ecology, loc. cit., vol. XV, 1909, pp. 57-75; the Loess of the Paha and River Ridge, loc. cit., pp. 117-135; and the Nebraska "Loess Man", Bulletin of the Geological Society of America, vol. 19, 1908, pp. 243-254.

2. The topography of the roughest loess-covered areas where the loess is best developed is distinctively wind or snow-drift topography (see plate XXI; plate XXII, figure 1; plate XXIII, figure 2; and plate XXXI, figure 2). In such places the thickest loess always occupies the highest part of the ridge, and was evidently formed from dust which was deposited in much the same manner as snow is whipped up to form drifts. During dry summers the writer has frequently observed little trains of dust thus carried upward between the tufts of the scant vegetation (see figure 34 and plate XXXIII, figure 1) on the loess bluffs along the Missouri valley, and sometimes this was done even by gentle winds or mere intermittent puffs.

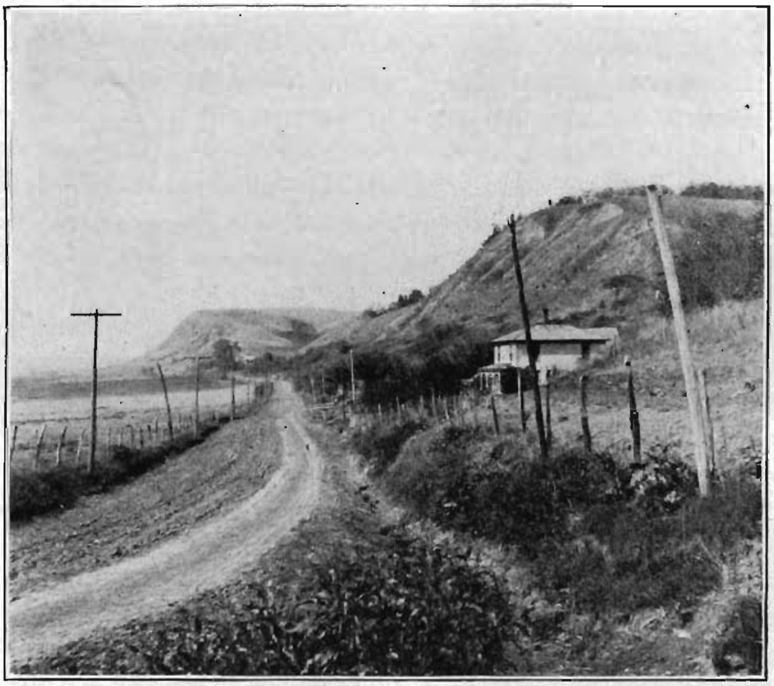


Fig. 32. The abrupt treeless bluffs above Missouri Valley, Iowa. This represents the prevailing type on the east side of the river. (See p. 403.)

The fact that such transportation of material takes place on the very surfaces under discussion is also brought out by figure 2, plate XXIII. This represents the loess ridges north of Turin in Monona county, and the view is taken looking a little west of south, after much of the snow had disappeared. Here the sharp crests of the loess ridges are made still higher by the remnants of snow-drifts *which were deepest at the very top of each crest.* These drifts were built up chiefly by gentle winds for during the winter of 1909-10 (when the photograph was taken) there was very little violent drifting of snow.

3. The source of the loess materials is here plainly discernible. During most of the days of the open warmer parts of the year winds prevail, and even on merely moderately windy days it is possible by looking out across the valley from the loess bluffs to locate all the larger bars along the Missouri river by the columns and clouds of dust which rise from them. There is always more or less of this dust in circulation, but on very windy days the atmosphere is dense with it, and enormous quantities of material are thus transported. On the bars near the Blair railway bridge in Harrison county, and at other points,

Fig. 33. The wooded bluffs above Florence, Neb. These rounded wooded bluffs are the prevailing type on the west side of the Missouri river. (See p. 403.)

the writer has observed the manner in which this dust is often released. Much of the silt carried down and deposited by the Missouri is very fine and is variously mingled and interstratified with sand. Where loose sand is at the surface on the exposed river-bars it is frequently driven by the wind over the dry silt which it reduces to dust, much of which is then carried away to be deposited in part on the uplands as loess. As each succeeding rise in the river brings new burdens of silt the supply of dust material is perpetual and inexhaustible.

4. The loess is greater and more irregular in thickness along the bluffs of the valleys and thins out inland where it also commonly forms a more regular veneer. The bluff-loess is also made up of somewhat coarser material than that which forms the more remote inland loess. Both facts are consistent with the æolian hypothesis for the thickest deposit is nearest to the source of supply, and both suggest that a large part of the dust forming the unequal bluff loess drifted into its present position in the

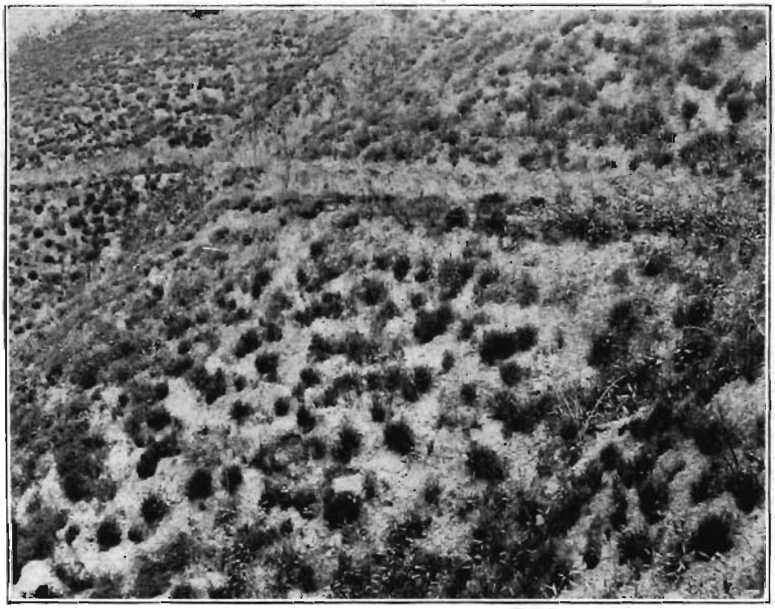


Fig. 34. A portion of the face of the loess bluffs at Council Bluffs, Iowa, showing the tufted xerophytic vegetation with large bare spaces between the plants Dust may therefore be whipped up these abrupt slopes much as snow is driven up the face of a snow-drift. (See p. 400.)

manner already described, while the finer and less abundant dust which remained suspended in the air longer was carried inland to be finally deposited as finer loess in more uniform strata. The loess formed in the shelter of groves would be especially uniform because evenly deposited by settling without drifting.

5. The distribution of the thickest portions of the loess deposits is best explained on the basis of the æolian hypothesis. They are found chiefly on the bluffs on the east side of the Missouri valley, (compare figures 32 and 33) and on the west or northwest bluffs of the larger tributary valleys all of which extend in a general southwesterly direction, thus exposing these bluffs to the prevailing southerly and southwesterly winds of the warmer parts of the year. These thicker deposits do not occur on the rounded bluffs on the southeastern side of the tributary valleys, excepting where the line of the bluffs on this side is so turned that a portion of them is exposed to the southwest. In short the distribution of the thickest loess coincides with that of the abrupt bluffs with cat-steps which have already been described. (Compare figures 1 and 2, plate XXII.)

Similarly the edges of the river-benches where exposed in the same manner show a thicker accumulation of loess on the exposed side. Thus the edge of the Soldier river bench in the southwest quarter of section 29, township 82 north, range 43 west, shows the ordinary abrupt wind-topography with cat-steps, and the southwestern and western edge of the great Belvidere bench (see plate XXIII, figure 1) is similar and averages about fifty feet more in height than the remainder of the bench. Most of this additional height is evidently due to the greater accumulation of the yellow loess.

It should also be noted that the thickest deposits of loess occur along the streams with the broadest valleys and the largest and most numerous bars, and this is true not only of these counties but of the entire Missouri valley.

6. The lamination of the loess, which, when discernible, quite uniformly follows the vertical contours of the hills, also suggests deposition by wind, for it is very similar to the lamination which may be observed in sand-dunes, such as that illustrated in figure 35, which have been built up gradually by comparatively mod-

erate winds. It is wholly unlike the regular, more or less horizontal, continuous lamination exhibited by silts.

Udden has reported horizontal shearing planes in both loess and "gumbo" (Loveland) near their line of contact,* and it is probable that he refers to the ordinary lamination of the lower part of the loess. Inasmuch as this lamination is most pronounced in the lower parts of the thickest deposits it is possible that the pressure of the upper mass is the cause of the lamination, and that shearing planes are produced as suggested by Udden, but the fact that the lamination follows the vertical contours, and the further fact that sand-dunes show lamination of the same type, point rather to an æolian origin.

These shearing-planes may have been produced, however, by the slipping of large masses of loess, etc., on the ridges forming the bluffs, a phenomenon by no means uncommon. In that case all the plastic materials, whether loess, Loveland or drift clay, would show similar effects. Such slipping does not, however, take place where the slopes are less abrupt and could not explain the lamination in the loess which is so common even where creeping or slipping of the loess could not take place.

7. The fossil land shells of the loess of this territory present again one of the strongest arguments in support of the æolian hypotheses. They are abundant and widely distributed, while aquatic shells are almost absent, and the few which were found, less than a dozen specimens, belong to species which ordinarily live in small ponds or along the borders of small sluggish streams. Species belonging to larger bodies of water are notably absent, here as elsewhere, from the loess.

The distribution of the land-shells of the loess has already received attention, and the occurrence of the same species in the modern fauna is brought out in the table of mollusks. It is sufficient here to state that the vertical and horizontal distribution of these species, when compared with the distribution of the modern forms of the same species, suggests that the loess shells were buried *in situ* on old land surfaces which they inhabited. Then as now there were groves in which snails were quite abun-

*From Pottawattamie county, Iowa, in the Journal of Geology, vol. X, 1902, pp. 245-251.

dant, and in such places shells are abundant in the loess; then as now there were mollusk stragglers at the edges of the groves, in the scattered clumps of bushes on the prairie, and rarely on the prairie itself, and in such places the fossils are few and scattered; and then as now there were more xerophytic prairie areas on which no mollusks lived, and when these were covered with loess it contained no shells.

The entire loess fauna suggests surface and climatic conditions not materially different from those which prevail in the same region today. Indeed, if there is any difference it suggests a somewhat drier climate since it contains species such as *Vertigo modesta, Sphyradium edentulum, Pupilla muscorum* and *Pyramidula shimekii* which are today restricted to, or most abundant in, the drier sections of the far west.

THE ALLUVIUM.

The alluvium is by no means the least interesting and important of the surface deposits in Harrison and Monona counties. Not only does it form the great alluvial plain of the Missouri and its tributaries, but it contains animal remains which are deserving of attention because of the light which they throw upon the conditions which have prevailed in the region in comparatively recent time. The great alluvial plain is more or less variable in composition, as has been noted. A large part of its area is covered with a rich black alluvial soil which is sufficiently loose and well drained to make excellent farming land. Here and there in the less readily drained tracts there are areas of "gumbo", a heavy, impervious, usually dark-colored deposit, which may be derived in large part from the Nebraskan till. This gumbo is now farmed to advantage, where not too low, by being cultivated while dry. Large tracts of gumbo border both the West Fork and the Little Sioux, occupying most of the area subject to inundation, and it appears more or less abundantly in other parts of the Missouri plain and its larger tributary valleys.

Sandy tracts, representing old river bars, also appear here and there, and the Missouri river is bordered by interrupted sand-dune areas which are derived from the bars of the great stream. The largest of these dune areas is located near the Blair railway bridge west of California Junction.

The usual organic remains are found in these alluvial deposits. Buried sticks and logs are common, and pond and fluviatile shells belonging chiefly to the genera *Sphærium, Pisidium, Physa, Lymnæa,* and *Planorbis* are found frequently in the alluvium of stream and pond.

However, sections are neither numerous nor deep and only such as are exposed by recent shallow erosion are available for ordinary study. Deeper borings, as in the Missouri Valley wells and elsewhere, indicate that the deeper deposits consist largely of sand and gravels. In the Missouri Valley railway wells sand was found at a depth of thirty-five feet, and rock was reached at ninety feet. Some bowlders were found near the bottom of the deposit. At the Blair bridge, on the Iowa side, bed rock is forty-five feet below low-water, and it dips to the west, being about five feet lower on the west side.*

But while the alluvial deposits of the great valley excel in magnitude and extent, they are in many respects less satisfactory for study than those which in some places border the valley along the bases of the bluffs, or follow the numerous tributaries into the region in which uplands predominate. These border deposits present many more sections, and both their structure and contents can be more thoroughly studied.

Moreover the smaller tributaries have so deeply cut into the alluvium of their own earlier deposition that they have exposed fine sections in all parts of our territory.

These alluvial deposits usually consist of fine silt which is ordinarily dark in color, sometimes blue-black, but occasionally varies to yellowish. It is more or less distinctly laminated and interstratified with various bands and streaks of sand and fine gravel; when wet it becomes very soft and sticky, and in the bottom of the deep gullies cut by the small streams it usually forms a treacherous mire. In the lower part it frequently contains numerous large iron root-tubes similar to those of the post-Kansan loess, and is occasionally marked with ferruginous lines and streaks.

Irregular calcareous nodules are also sometimes present, and

*Reported by Mr. J. S. Wattles.

the shells of mollusks present the usual mixture of land and fresh-water species which is ordinarily found in modern alluvium and in the drift along streams. A list of the species collected from the alluvium of Harrison and Monona counties is given in the table of mollusks. All are living in the state today.

The Bison in Iowa.

The most remarkable feature of the alluvial deposits bordering the smaller creeks, however, is the presence in them of large numbers of skulls and bones of the bison, or buffalo, together with less common remains of the elk and the Virginia deer.

The existence of the bison in considerable numbers in Iowa has long been disputed. The question was again precipitated in recent years by Professor Herbert Osborn* who accepted the evidence as conclusively proving the existence of the bison in Iowa. This conclusion was challenged by Mr. Robert L. Garden, who later published his objections in book form,† and the discussion brought out the fact that isolated skulls and bones of the bison had been frequently found in Iowa. The writer has personal knowledge of such discoveries in Woodbury, Mills, Lyon and Cerro Gordo counties besides a number of cases in Harrison and Monona counties.

Mr. Charles I. Whiting presented a skull of a bison which was taken from the creek alluvium in section 10 of Center township, Monona county; Mr. Edwin Quick reported the discovery of two bison skulls in the southeast quarter of section 30 in Cooper township, Monona county, and the antlers of a Virginia deer in a well in the southeast quarter of section 16 in the same township; Mr. C. G. Kiefer found a part of a bison's skeleton in section 24, township 80 north, range 42 west, in Harrison county; and Smith's History of Harrison county contains an account of other such discoveries and of the killing of a bison in that county (pp. 123-126).

It is also worthy of note that the report of the Long Expedition (loc. cit.) states that on February 22, 1820, several buffaloes were killed near the Sioux river. This was probably the

*January number of the Annals of Iowa, 1905.

†The paper is entitled "Did the Buffalo ever exist in Iowa?", and was published in 1907 by Robert L. Garden in a volume containing in addition a History of Scott Township, Mahaska county, Iowa, and War Reminiscences.

Little Sioux and within our territory.* While the foregoing cases, and many others like them. demonstrated the occasional occurrence of the bison in Iowa at a time not very remote, they did not conclusively prove that the animals were numerous. It remained for Harrison and Monona counties to furnish the conclusive evidence that the bison did occur in Iowa in large numbers. This evidence was furnished by two localities, one in each county, and consists of a large number of skulls and various parts of skeletons of the bison, associated with a few antlers and bones of the elk and the Virginia deer. The collection from the Monona county locality along Beaver creek is represented in plate XXXII, figure 2.

A more detailed description of the two localities mav be of interest.

The Monona county bone beds are located on the farm of Mr. G. F. Struble in Jordan township. They extend along Beaver creek for some distance, the best exposures being located in the northwest quarter of section 17, township 83 north, range 43 west, and in the southeast quarter of section 8 in the same township.

Large numbers of bones had previously been taken from this deposit by Messrs. Struble, Mathiasen and Babcock, and these gentlemen also assisted Professor Calvin and the writer in making further collections and investigations.

In the best part of the exposure, a portion of which is shown in plate XXXII, figure 1, the bones were buried to an average depth of about fifteen feet, and were exposed in the deep gully cut by Beaver creek.

This gully is here about eighteen feet deep, and its greatest width is about thirty-five feet. The lowest four feet of the exposure consists of a tough blue-black alluvial layer containing in some places, especially near the base, a large number of nearly vertical ferruginous root-tubes. Upward the material becomes somewhat lighter in both color and texture. Streaks of sand and fine gravel occur throughout. Bones were found in both the

*In the same report Major Long describes the journey across southwestern Iowa, and records (in volume II, p. 108) the following statement May 24th, 1820: "Remains of bison, as bones, horns, hoofs, and the like are often seen in these plains, and in one instance, . . . we discovered the recent track of a bull; but all the herds of these animals have deserted the country on this side of Council Bluffs. The bones of the elk and deer are very numerous . . . and the living animals are still to be found in plenty."

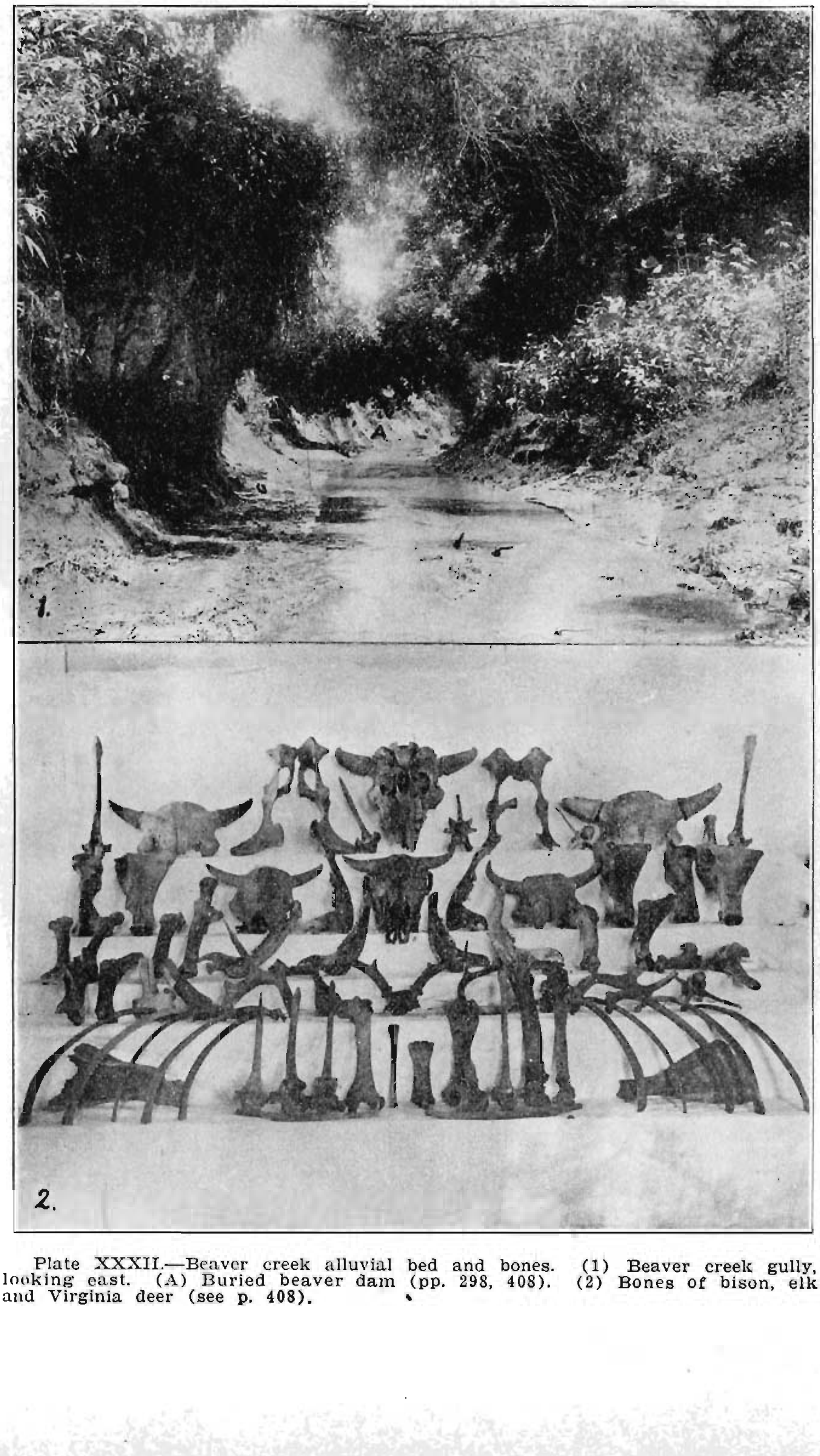


Plate XXXII.—Beaver creek alluvial bed and bones. (1) Beaver creek gully, looking east. (A) Buried beaver dam (pp. 298, 408). (2) Bones of bison, elk and Virginia deer (see p. 408).

Blank faces
pg. 409

upper part of the lowest tough stratum and in the lower part of the upper layer. They were found projecting from the banks, such as the one shown to the left in figure 1, plate XXXII, for a considerable distance, and evidently represent the remains of many animals.

An old beaver-dam, buried to a depth of about twelve feet, was found at the point marked A in the figure. Some of the sticks plainly showed the marks of beavers' teeth. Numerous shells (listed in the alluvial column of the mollusk table) and bits of carbonized wood were associated with the bones.

Mr. Struble reports that thirty years ago there was no gully at this point and that it was possible to drive across the creek. He says that the creek has done most of its cutting in the past ten years.

The Harrison county exposure is located along Hog creek chiefly on the farm of Mr. Lester Adams in the northeast quarter of the southeast quarter of section 14, township 79 north, range 42 west, near Logan, and extends to the adjoining southeast quarter of the same section.

The gully is here cut into alluvium to a depth of from eight to twelve feet. The alluvium presents the same structure as in the Struble section, but the exposed part of the stratum containing the iron root-tubes is at least six feet deep. There are streaks of sand and gravel, ferruginous lines and cloudings, scattered irregular calcareous nodules, and many shells, besides the numerous bones of the bison and elk, which appeared chiefly about half way up the bank.

The alluvium which forms the banks and bed of Beaver and Hog creeks makes a very deep, soft mire when wet, and it is evident that during the period of aggradation by the creek the animals which came down to drink were mired and finally buried in the ooze of the creek-bed.

This explains the excellent state of preservation of the bones, for exposure to the air would have long since caused them to crumble. It also explains the great preponderance of the skulls and bones of males, which is striking wherever bison remains are found in Iowa. Very few skulls of females were found among those examined. The three lower skulls in figure 2, plate XXXII are those of females. The greater number of remains of males is evidently due to the fact that the heavier males had greater difficulty in extricating themselves from the mire and were overwhelmed. This would be especially true of old animals, and it is evident that these skulls belonged chiefly to such individuals.

The abundance of these bones in the alluvial beds warrants the conclusion that the bison was once common in Iowa, for the buried skeletons undoubtedly represent only a small part of the fauna of their time since only those which were buried in mire were preserved, all others disappearing completely.

In addition to the two great exposures here discussed there are numerous alluvial exposures which have yielded shells of mollusks only. These present the usual mixture of land and freshwater forms found in alluvium, and are included in the mollusk table. The best of these exposures were observed at the following points:

IN HARRISON COUNTY.

1. In the deep and narrow gully cut by Stowe creek in the southeast quarter of section 6, township 81 north, range 43 west.

2. North of the county line exposure in section 5, township 81 north, range 44 west. At the base of the bluff along the road shell-bearing alluvium is exposed to a height of ten feet. It contains bivalve shells also.

3. A deep gully in the southwest quarter of section 7, township 79 north, range 43 west. This is the greatest of these gullies, reaching a depth in some places of more than forty feet.

4. A low exposure east of the manganese dioxide bed in Snyders Hollow.

5. The first road-cut south of the Peyton sand-pit south of Pisgah also shows an alluvial deposit with some calcareous nodules, numerous large land shells and a few Unios. The terrestrial shells are *Polygyra profunda, Pyramidula alternata* and *Succinea ovalis.*

IN MONONA COUNTY.

6. Several sections along the road north of the Harrison county line in section 34, north of exposure (2) and similar to it.

7. Along Mucky creek southeast of Mapleton.

8. Along Rock creek south of Ute. The section is eight to ten feet deep.

THE SAND-DUNES.

As has been noted there are sandy areas on the alluvial plain of the Missouri, especially in close proximity to the river. The finest of these sandy areas in our territory is located in Harrison county near the Blair railway bridge.

Fig. 35. A large sand-dune, with cottonwoods, west of California Junction, Harrison Co., Ia. Sections of this dune showed laminated sand clearly. (See p. 411.)

Here the sand has been heaped up into distinct dunes, some of them more than twenty feet high, which are usually formed around a clump of willows or young cottonwoods. At first the dune is bare, as in figure 35, but soon a scant xerophytic vegetation gains a foothold and finally covers the surface, as illustrated in figure 36. The plants which first appear are for the most part *Leguminosæ* which develop root-tubercles with nitrifying bacteria and are thus able to hold their own on the barren sands. All the *Leguminosæ* which are listed in the sand-dune column showed large numbers of root-tubercles. The older dunes and sandy areas are covered with a cottonwood forest which is usually fringed with the Missouri willow and other shrubs.

Fig. 36. A sand-dune on which plants (chiefly *Cassia chamaecrista*) have become established. The dune is now fixed and is beginning to form a finer soil. The trees are cottonwoods, and are responsible for the formation of the dune. Nearly all the plants on these dunes are leguminose, with abundant root-tubercles containing nitrifying bacteria. Harrison county, Iowa. (See p. 411.)

On windy days the loose sand is freely shifted about; clouds of dust rise from the sands and are carried across the valley.

MOUNDS

Practically every prominent point along the loess bluffs on the Iowa side of the Missouri valley between Sioux City and Hamburg, shows one or more burial mounds constructed by the aboriginal inhabitants of this region, and Harrison and Monona counties have their fair share.

It is scarcely the province of this report to take up the discussion of a problem which involves archæological and ethnological questions, but it is proper that attention should be called to the richness of the field which on the Iowa side has remained almost untouched save for the occasional investigations of Mr. Robert F. Gilder of Omaha who has made many interesting discoveries on the Nebraska side of the river, and for the efforts of local amateurs who have not made systematic studies of the mounds, but have contented themselves with making collections of their contents. Several interesting collections of this kind are known in Harrison county, those belonging to Mr. J. D. Hornby and Dr. Weeks of Logan being perhaps most noteworthy.

The mounds seem to have been built up chiefly on the upper yellow loess along the more prominent bluffs of the Missouri and its larger tributaries, and frequently contain human skeletons accompanied by various trinkets, such as beads, shells, occasional pieces of pottery, etc.

They are of special interest because they so frequently contain shells and fragments of shells of freshwater mussels (Unios) and these have been regarded as evidence that the loess (of which the mounds are constructed) is of aqueous origin.

A particularly interesting mound was carefully examined by Mr. George H. Culavin of Missouri Valley. It was discovered on the ridge north of the entrance to Snyders Hollow about eighty-five feet above the valley, and contained the skeleton of an adult male and parts of skeletons of two children.

The large skeleton, which is now in the collection of the State University, was buried in a sitting or reclining posture, facing toward the south. The skull was about three feet below the surface, and above it, evidently intended for protection, was a layer of much decayed bur oak sticks and small logs, some of them reaching more than six inches in diameter. Mussel-shells were found in the upper stratum, and fragments were also strewn on the slope near the mound. The skeleton is almost complete and evidently belonged to an individual whose height exceeded six feet. The limb bones are long and rather slender, like those which are commonly found in the mounds of this region. The right forearm was crippled as the radius was broken and the ends failed to unite. The skull is in fine condition, and contains teeth which are remarkably regular and perfect, though somewhat worn with age.

Various articles of interest accompanied the skeleton. There were two pipestone pipes; more than two dozen perforated bony cores of bears' claws which evidently formed a necklace; a bone scraper; a mass of ochre which was so shaped and situated that it had evidently been carried at the belt in front in a pouch; a badly rusted tube which probably formed the barrel of a short rifle or long pistol; a wooden key of some musical string instrument with flattened head and wrapped with flattened wire; several small hawk-bells; a flint arrow-head; flattened copper tubes, —probably bangles; a mink's skull and two smaller skulls probably belonging to the weasel; the lower mandible of a large bird; and various unidentifiable metallic fragments.

Another interesting mound was found by the writer on the detached ridge south of the Chicago, Milwaukee and St. Paul railway near Grant Center. Shallow excavations and a superficial examination revealed human bones, shell-beads, copper bangles and the ever-present shells of *Unio* which have been so generally carried to the mounds of the loess ridges by human hands.

All the species of fresh-water mussels found in these mounds, which have thus far been identified, are modern, and live today in the streams of western Iowa and eastern Nebraska.

The mounds of western Iowa should be carefully and systematically studied before they are ruined by the haphazard methods of the mere collector.

ECONOMIC PRODUCTS

Soils and their Products

The most valuable products of Harrison and Monona counties, like those of all the prairie counties, are those which are derived from the soils.

The soils of the bottom-lands consist of rich alluvium, with irregular strips of sand and occasional larger areas covered with a heavy gumbo. The better drained alluvium forms a very rich soil and the gumbo is quite productive, and if worked when dry may be very satisfactorily cultivated. The sandy areas are now used to some extent for the cultivation of watermelons, etc., and they should make very satisfactory truck gardens.

The bottom-lands subject to overflow are at present serviceable only for the growth of native hay, of which great quantities are produced. Large areas of this kind have already been reclaimed, and if the drainage operations now under way prove entirely successful still larger additions to the tillable area will be made.

The soil of the uplands consists of loess almost exclusively and in the interior portions where this retains a large amount of humus it forms a rich prairie soil, particularly on the river-benches, which are famed for their fertility. Where the upper yellow loess is developed in the bluff areas but little humus is formed and retained, and the yellow loess appears at the surface. Where not too steep for cultivation even this is very productive, being especially adapted to the cultivation of fruit and alfalfa. The latter can be grown upon all slopes which can be cultivated and while it grows more luxuriantly on well-drained, richer soils it will produce a profitable crop on the drier yellow slopes which will produce but little else. A Monona county alfalfa field is shown on the lower slope, below the road, in plate XXXI, figure 2.

The driest ridges, covered with native grasses, are at present used for pasture.

The cultivation of fruit is proving very successful and should be extended. The sheltered valleys in the bluff territory should largely be devoted to this use.

Perhaps the finest orchard in our territory is that belonging to Mr. C. H. Deur of Missouri Valley (see plate XXV, figure 2) and located in section 1, township 78 north, range 44 west. It covers an area of sixty acres and contains chiefly apple trees set out in 1897, 1898 and 1899. It is located on the slopes bordering the Boyer valley and presents a variety of exposures, but on the whole it is protected from the southwesterly winds. Mr. Deur considers fruit-growing profitable in this section.

Other large fruit growers are Mr. A. L. Haights, south of Missouri Valley, with about twenty acres; Mr. W. A. Fouts, two miles north of Missouri Valley, who uses forty acres for fruit and vegetables, nearly one-half being in fruit; and Messrs. W. T. Worth and A. G. Worth of Raglan township, Harrison county, the former with more than fifty acres and the latter with eighty acres. In addition to apples, pears and peaches small fruits are grown successfully.

It has been amply demonstrated that fruit can be grown in this territory with profit, and with a judicious selection of sheltered slopes and a more general planting of shelter-belts much land scarcely suitable for other purposes may thus be made profitable.

Building Stone

Building stone has been taken from the limited exposures of Missouri limestone between Logan and Woodbine, but none is quarried at present. The small area of these exposures, together with the growing use of cement blocks, make it improbable that the quarrying of this limestone will be resumed within the near future.

Clays

The loess clays of this territory, especially Harrison county, were formerly quite extensively employed in the manufacture of brick, and until quite recently yards were in operation in Missouri Valley, Woodbine, Logan and Dunlap. At present only the Missouri Valley and Woodbine yards are in operation, and there has been a decided falling off in the total value of the product.

The Reports of the Iowa Geological Survey give the value of the clay products (common brick) in Harrison county for the respective years listed, as follows:

For 1897, six yards	$ 5,380.00
For 1898, six yards	10,785.00
For 1903, seven yards	22,345.00
For 1904, six yards	16,260.00
For 1905, six yards	13,870.00
For 1908, four yards	6,300.00

No bricks were burned in the Missouri Valley yards in 1909, and the Logan and perhaps other yards were transformed into cement block works. The latter industry has evidently been the cause of the decline of the former. Clay tile seems to have been entirely crowded out by cement tile.

Sand and Gravel

The widespread deposits of Aftonian sands and gravels furnish an abundant supply of these materials for building and other purposes. They are now extensively used for concrete work, building blocks and tiling, and cement works have, as noted, in large part taken the place of brickyards. The variation in the coarseness of the materials provides for all ordinary uses, and the thickness and extent of the beds insures an abundant supply, while their wide distribution places them within comparatively easy reach of all points within the territory.

Numerous small pits furnish supplies for local use, and some of them have been operated more or less irregularly for seven or eight years. The Cox pit, Peyton pit and Elliott pit are worked on the largest scale, and not only furnish the necessary sand for building purposes but each supplies a cement block and tile factory. The great extent of the bottom-lands, now being tiled as a result of the establishment of a system of drainage ditches, makes the tile manufacturing industry of especial importance.

Road Materials

Few counties equal Harrison and Monona in the quality and abundance of road materials. The coarser gravels and the impure beds of the Aftonian in which silt, sand and gravel are mingled, are admirably adapted to such uses, and their wide distribution makes them available in all the territory within or adjacent to the uplands.

The loess bluffs and hills, together with the belts of exposed Kansan, furnish an abundance of material for building up roads across the lowlands, and the sand and gravel may be used for a top dressing.

Water Supply

The principal water supply for domestic and other uses is obtained on the bottom-lands from wells which reach the sands and gravels which underlie the alluvial plain. On the uplands this supply comes chiefly from the Aftonian beds which, resting on the impervious Nebraskan drift, form a reservoir usually containing an abundance of water. In all the well-sections already recorded which reached the Aftonian a generous supply of water was found in that formation. The fact that springs are numerous where the Aftonian crops out near the bases of the bluffs has also been noted. Several well-sections have already been reported in connection with the Aftonian.

Water Power and Drainage Ditches

While the numerous larger streams have a sufficient fall and an adequate supply of water for the development of great water-power, it is not probable that this will be utilized for some time to come, as the present tendency is toward the removal of dams and other obstructions from the streams to prevent interference with the great drainage projects. These drainage projects have been pushed forward at great expense, and they involve the changing of many miles of the channels of the principal tributaries of the Missouri river and the construction of many more miles of large drainage ditches. The principal changes and the main ditches are represented on the maps.

The Logan dam which supplied mill-power for many years was recently removed as an obstruction, and the Woodbine dam is the only one in our territory the use of which has been continued to the present time. The dam at Dunlap is not now utilized.

METEOROLOGICAL RECORD

It is a privilege to be permitted to present here a remarkable meteorological record furnished by Mr. Glenn H. Stern of Logan. The observations here recorded were commenced by Mr. Stern's grandfather, Mr. Jacob T. Stern, for the Smithsonian Institution and were continued to the time of his death. They were then taken up by his widow who finally passed the work on to the grandson, who is now the official observer at Logan.

It is a unique and valuable record and should be preserved for future ready reference.

TEMPERATURE AND RAINFALL AT LOGAN, IOWA.

From 1866 to 1909.

	1866				1867			
	Temperature High	Temperature Low	Temperature Mean	Precipitation in inches	Temperature High	Temperature Low	Temperature Mean	Precipitation in inches
January	49	—2	22.0	--------	39	—10	15.6	0.26
February	48	—20	20.5	--------	48	—16	23.9	2.60
March	54	1	37.5	--------	44	—16	18.3	2.75
April	72	32	45.0	--------	67	26	44.2	1.60
May	78	33	58.9	1.20	80	29	52.4	4.50
June	85	46	65.1	3.10	85	48	58.1	4.20
July	93	53	76.3	3.00	87	50	70.6	3.80
August	94	46	69.1	1.30	89	55	71.8	2.00
September	82	33	58.0	4.40	89	54	66.0	1.40
October	79	20	51.0	--------	80	28	54.3	2.90
November	71	10	41.0	--------	70	3	42.4	1.00
December	50	—1	22.5	--------	54	—3	27.5	0.80
								27.81

	1868				1869			
January	48	—16	13.0	--------	48	—2	23.1	0.90
February	58	—17	26.0	1.60	50	—4	26.5	1.40
March	74	13	43.5	2.40	66	—5	31.9	0.50
April	76	18	43.7	2.80	76	14	45.0	1.10
May	84	40	60.9	4.00	80	32	58.0	3.50
June	88	45	68.3	6.90	81	35	63.3	9.00
July	100	61	79.6	3.29	86	51	68.9	8.90
August	90	50	63.0	--------	88	52	71.0	7.90
September	83	32	55.4	4.30	83	44	60.6	7.10
October	74	22	49.2	--------	72	12	42.8	0.80
November	60	14	34.0	1.50	64	4	25.7	1.35
December	38	—20	22.5	3.10	48	—4	47.7	2.50
				29.85				44.95

	1870				1871			
January	49	—9	21.2	0.90	50	—8	22.6	0.60
February	55	—15	30.5	--------	68	—11	29.7	3.10
March	58	—7	29.0	1.70	72	20	29.8	--------
April	82	16	50.1	0.40	94	24	54.5	2.70
May	85	39	62.6	2.00	85	33	62.6	1.60
June	93	44	69.3	0.30	93	50	72.4	1.00
July	96	56	75.2	7.00	85	50	70.3	7.30
August	87	42	66.1	1.80	92	50	69.6	2.60
September	84	48	62.4	8.90	88	32	61.5	3.10
October	74	25	42.0	1.10	86	30	53.4	1.80
November	62	8	25.2	--------	64	—8	30.0	3.85
December	58	—17	48.8	0.20	50	—14	17.1	1.30
				25.30				28.95

TEMPERATURE AND RAINFALL AT LOGAN, IOWA.

From 1866 to 1909.

	1872				1873			
	Temperature High	Temperature Low	Temperature Mean	Precipitation in inches	Temperature High	Temperature Low	Temperature Mean	Precipitation in inches
January	40	—16	17.5	0.10	45	—21	14.1	2.20
February	52	—5	25.6	0.30	45	—10	23.2	1.00
March	64	6	29.9	2.50	68	—6	43.5	2.10
April	80	19	48.0	4.20	73	20	55.8	3.60
May	87	31	58.2	6.70	83	38	72.8	7.70
June	88	50	67.9	2.00	92	50	72.9	8.40
July	91	52	72.6	5.00	96	54	74.6	5.10
August	88	55	71.2	3.90	92	47	59.1	8.40
September	88	35	61.5	2.50	90	28	46.7	1.50
October	84	22	52.2	3.10	70	15	37.0	3.20
November	54	—4	28.4	1.50	64	4	30.5	0.00
December	54	—21	14.8	0.30	50	0	23.5	--------
				32.10				43.20

	1874				1875			
January	48	—14	20.2	0.70	45	—16	7.6	0.60
February	43	—8	20.7	2.10	26	—23	12.6	1.80
March	56	0	33.1	2.80	68	—7	28.3	3.80
April	84	16	42.6	1.80	68	16	43.4	2.40
May	92	30	64.2	1.10	92	23	60.5	2.50
June	94	50	96.2	6.30	94	42	68.6	9.90
July	100	60	77.6	2.80	95	52	71.6	7.00
August	101	53	79.0	1.20	85	54	68.2	7.60
September	90	35	63.0	6.20	86	35	61.6	3.50
October	78	13	55.1	1.20	70	23	48.5	1.40
November	70	4	33.6	1.50	62	—10	29.9	0.20
December	50	—12	26.2	0.70	55	—14	32.2	1.30
				28.40				42.00

	1876				1877			
January	50	—10	25.8	0.40	54	—25	17.5	2.30
February	61	—2	28.4	0.60	53	8	35.2	1.20
March	64	—10	29.7	4.50	50	—2	31.9	1.50
April	79	25	49.3	2.70	76	13	47.3	4.90
May	90	34	60.3	1.70	79	30	59.2	11.00
June	94	40	64.5	2.40	86	38	67.9	6.70
July	90	62	72.8	8.30	96	59	73.3	2.90
August	90	60	71.0	1.50	90	50	70.7	4.80
September	86	42	61.3	4.80	87	26	67.8	1.40
October	75	18	48.8	0.90	74	24	50.8	4.00
November	56	3	32.6	0.20	60	—2	35.6	1.40
December	55	—12	16.6	0.20	54	2	34.9	3.00
				28.20				45.10

TEMPERATURE AND RAINFALL AT LOGAN, IOWA.

From 1866 to 1909.

	1878				1879			
	Temperature High	Temperature Low	Temperature Mean	Precipitation in inches	Temperature High	Temperature Low	Temperature Mean	Precipitation in inches
January	48	—3	28.5	1.20	58	—25	21.8	0.40
February	56	4	35.1	0.50	57	—11	26.7	1.10
March	68	20	48.0	2.40	74	12	40.8	4.10
April	76	28	51.8	2.70	78	12	50.9	0.90
May	83	32	56.1	2.60	84	26	63.7	5.80
June	92	44	68.8	10.61	92	44	66.7	5.30
July	94	56	76.4	13.00	94	68	77.0	2.60
August	94	55	74.0	5.10	93	48	74.2	3.50
September	90	38	64.7	1.70	80	32	62.3	2.50
October	76	24	52.7	1.20	84	20	60.7	4.10
November	70	14	21.2	---------	54	4	38.5	2.00
December	54	—10	21.3	0.30	54	—19	15.4	0.80
				46.31				33.10

	1880				1881			
January	60	6	34.4	1.80	42	—28	12.9	3.10
February	56	—4	32.6	0.30	47	—20	16.5	5.30
March	80	—18	36.6	0.60	56	—8	29.5	2.40
April	94	15	51.7	0.70	84	0	45.2	5.40
May	94	46	71.3	4.00	86	36	66.8	7.30
June	92	47	71.0	3.60	94	53	73.6	5.10
July	95	50	75.7	3.70	97	64	79.5	9.50
August	98	50	74.1	5.30	103	60	79.6	1.20
September	84	36	63.4	3.00	98	40	66.9	5.30
October	78	18	49.7	2.30	84	30	54.3	6.60
November	64	—5	27.5	1.33	64	2	35.8	1.50
December	52	—14	18.5	0.70	50	10	34.7	1.90
				27.30				56.60

	1882				1883			
January	50	—2	26.0	1.20	40	—26	10.3	2.50
February	64	—4	33.4	1.30	52	—24	20.2	1.20
March	70	4	39.6	0.60	72	7	33.9	1.40
April	84	28	51.9	3.50	90	32	53.0	2.60
May	82	36	56.6	3.80	90	34	58.5	7.60
June	91	42	72.5	9.60	93	38	68.7	8.50
July	92	50	69.8	7.30	94	56	77.0	3.30
August	92	50	72.1	0.80	96	60	77.2	5.00
September	92	38	66.9	0.20	92	42	63.0	4.10
October	84	29	56.5	3.50	80	24	50.6	2.50
November	56	12	37.4	3.30	70	8	39.3	0.10
December	48	—16	22.8	2.20	60	—2	29.6	1.10
				37.30				39.90

TEMPERATURE AND RAINFALL AT LOGAN, IOWA.

From 1866 to 1909.

	1884				1885			
	Temperature High	Temperature Low	Temperature Mean	Precipitation in inches	Temperature High	Temperature Low	Temperature Mean	Precipitation in inches
January	48	—16	17.8	1.30	56	—28	14.1	---------
February	56	—10	21.3	1.50	52	—22	15.5	1.10
March	70	—4	37.7	1.70	58	6	32.5	0.30
April	72	34	48.4	3.10	76	20	51.8	4.90
May	84	34	64.3	2.10	90	26	61.7	6.00
June	94	52	71.3	3.40	95	42	71.8	9.80
July	96	52	72.8	7.40	101	65	76.9	5.13
August	90	52	70.8	5.00	98	50	70.4	5.40
September	93	44	69.1	5.50	90	54	65.2	1.00
October	86	22	53.7	4.40	78	24	51.0	4.20
November	64	0	38.5	0.10	62	16	39.6	1.00
December	54	—24	17.1	1.10	58	—10	25.6	1.40
				36.60				40.20

	1886				1887			
January	34	—25	7.1	2.60	46	—26	10.9	0.90
February	58	—34	22.0	0.30	60	—16	18.6	0.70
March	64	0	32.2	2.50	68	18	32.2	0.60
April	84	18	52.5	2.10	94	22	52.5	1.40
May	93	40	65.5	1.80	96	34	66.7	1.30
June	98	44	70.7	3.20	100	46	74.4	2.90
July	103	54	77.0	2.20	105	54	77.3	2.40
August	100	58	75.8	2.20	103	48	73.5	4.80
September	92	26	70.2	---------	90	36	66.4	4.20
October	88	26	55.5	3.80	80	17	50.0	0.90
November	74	3	31.3	2.40	75	—16	31.3	0.90
December	50	16	18.1	---------	45	—16	23.8	2.00
				23.10				23.60

	1888				1889			
January	46	—34	7.2	1.50	48	0	24.1	1.49
February	56	—18	20.8	0.90	54	—11	22.9	0.00
March	74	—10	29.0	3.40	70	12	42.1	0.69
April	86	24	53.4	5.44	84	21	54.2	1.35
May	90	38	57.4	5.74	90	28	62.7	3.28
June	98	50	70.8	2.09	98	36	70.7	9.87
July	104	60	79.4	5.09	94	48	74.0	6.28
August	98	50	73.6	6.44	94	48	72.4	3.14
September	92	40	64.4	0.83	87	30	62.2	1.32
October	82	30	50.9	0.73	82	20	52.3	0.46
November	78	14	38.8	0.93	58	3	35.4	0.46
December	66	4	31.5	1.86	65	5	39.6	0.14
				34.02				29.87

TEMPERATURE AND RAINFALL AT LOGAN, IOWA.

From 1866 to 1909.

	1890				1891			
	Temperature			Precipitation in inches	Temperature			Precipitation in inches
	High	Low	Mean		High	Low	Mean	
January	50	—18	19.2	1.09	50	8	30.2	1.79
February	64	—13	26.5	1.10	45	—15	18.7	1.60
March	60	—10	31.6	1.76	53	—7	29.9	2.33
April	82	19	56.2	2.17	86	18	55.2	2.10
May	76	36	59.7	6.29	90	35	61.2	3.93
June	88	32	72.8	14.09	92	48	70.2	3.47
July	96	50	77.0	2.29	90	50	71.7	6.16
August	100	52	70.4	1.19	95	40	72.1	3.31
September	93	46	63.8	1.78	91	41	69.9	1.74
October	92	48	53.8	1.87	77	28	54.0	5.64
November	65	22	41.9	1.87	67	—3	34.7	5.64
December	65	11	38.8	---------	55	—2	34.6	2.73
				34.95				35.39

	1892				1893			
January	50	—29	19.0	0.90	40	—12	15.0	0.40
February	52	—3	32.0	1.14	50	—16	17.0	1.50
March	74	5	36.0	4.58	73	0	31.0	0.84
April	84	24	49.0	4.91	82	20	47.0	2.10
May	80	37	56.0	7.13	86	32	58.0	4.73
June	97	47	71.0	3.16	93	47	72.0	3.97
July	99	51	76.0	4.13	97	53	75.0	3.62
August	97	47	74.0	3.37	94	37	70.0	1.99
September	95	42	68.0	2.00	95	32	67.0	1.36
October	92	22	57.0	1.81	88	22	56.0	0.15
November	60	10	38.0	0.08	72	0	35.0	0.53
December	62	—15	22.0	1.62	60	—11	24.0	1.22
				35.25				22.40

	1894				1895			
January	51	—26	18.0	0.74	58	—16	16.0	0.40
February	50	—15	20.0	0.70	67	—22	21.0	0.72
March	85	3	41.0	0.40	85	0	35.0	0.26
April	78	22	54.0	1.88	89	20	55.0	3.70
May	96	38	64.0	0.55	100	29	64.0	0.84
June	102	50	76.0	3.75	95	44	70.0	5.24
July	103	48	78.0	0.41	99	38	72.0	1.68
August	-----	-----	76.0	1.83	97	46	78.0	9.84
September	-----	-----	65.0	2.22	98	24	67.0	1.71
October	-----	-----	52.0	3.01	74	8	48.0	0.54
November	-----	-----	32.0	0.00	74	—4	35.0	1.09
December	-----	-----	31.0	1.14	48	—1	27.0	0.10
				16.63				26.12

TEMPERATURE AND RAINFALL AT LOGAN, IOWA.

From 1866 to 1909.

	1896				1897			
	Temperature High	Low	Mean	Precipitation in inches	Temperature High	Low	Mean	Precipitation in inches
January	50	—9	23.0	0.64	48	—15	19.0	1.62
February	74	—2	30.0	0.60	55	—14	26.0	0.65
March	70	8	31.0	0.60	62	—8	33.0	2.17
April	88	8	54.0	7.17	82	22	49.0	6.18
May	89	44	64.0	7.93	84	35	60.0	1.80
June	96	44	70.0	7.85	96	36	70.0	2.97
July	99	32	73.0	6.70	105	42	76.0	1.38
August	98	50	72.0	2.33	94	45	69.0	4.98
September	86	30	59.0	4.05	96	34	72.0	0.08
October	78	25	48.0	2.81	90	29	57.0	1.04
November	70	—5	28.0	2.14	71	—10	34.0	0.20
December	56	5	31.0	--------	49	—21	18.0	2.93
				43.82				26.00

	1898				1899			
January	48	—15	25.0	1.30	44	1	18.3	0.10
February	55	—14	26.0	0.80	46	—6	11.8	0.70
March	64	—8	37.0	1.59	68	7	20.7	1.30
April	78	28	48.0	2.86	91	21	50.2	2.08
May	88	35	60.0	4.91	90	35	61.4	3.62
June	89	44	73.0	3.26	98	52	71.0	11.99
July	105	47	74.0	1.50	99	50	73.6	1.83
August	94	45	73.0	2.50	100	46	75.8	5.90
September	96	40	65.0	1.72	98	41	64.0	0.42
October	90	28	48.0	2.93	86	20	55.2	1.39
November	71	—10	35.0	0.90	69	—9	42.4	1.11
December	49	—21	19.0	0.70	39	—14	23.6	1.51
				24.96				31.95

	1900				1901			
January	49	—10	27.1	0.20	56	—11	23.1	0.70
February	47	—24	13.6	1.30	45	—9	20.6	0.90
March	70	—6	33.0	1.95	70	8	37.4	3.00
April	78	30	51.2	3.50	87	24	51.0	1.44
May	90	27	63.0	1.97	92	31	61.6	2.54
June	100	43	70.6	1.27	98	39	71.9	7.97
July	98	50	75.8	7.39	110	57	83.4	0.71
August	95	58	77.5	4.83	98	50	76.2	0.77
September	90	31	63.0	4.09	93	26	62.3	7.66
October	84	24	58.3	4.60	77	22	52.2	2.83
November	67	2	32.4	0.41	67	17	36.4	0.94
December	54	—6	26.4	1.08	50	—20	21.5	1.10
				31.39				30.56

TEMPERATURE AND RAINFALL AT LOGAN, IOWA.

From 1866 to 1909.

	1902				1903			
	Temperature High	Low	Mean	Precipitation in inches	Temperature High	Low	Mean	Precipitation in inches
January	56	—21	24.0	1.30	48	—4	------	0.70
February	55	—15	19.3	0.50	45	—17	------	1.56
March	67	2	40.4	0.43	69	13	------	0.28
April	90	19	51.0	1.08	82	25	------	0.79
May	90	43	65.4	2.88	84	29	------	5.77
June	95	49	66.1	7.52	93	43	------	3.73
July	95	53	73.4	11.34	105	55	------	4.96
August	92	42	71.1	5.36	101	48	------	11.46
September	82	28	59.3	3.40	94	34	------	1.66
October	73	26	54.2	3.26	81	23	------	1.60
November	72	12	39.6	1.53	65	6	------	1.54
December	78	—9	20.2	2.14	46	1	------	0.30
				40.74				30.25

	1904				1905			
January	46	—18	------	1.20	47	—21	------	1.45
February	58	—8	------	0.40	63	—34	------	1.40
March	64	5	------	1.81	80	13	------	1.20
April	71	27	------	5.77	81	20	------	4.23
May	90	34	------	2.02	84	32	------	4.36
June	93	40	------	6.42	95	50	------	2.53
July	95	50	------	0.79	97	46	------	1.76
August	93	44	------	0.99	97	57	------	1.74
September	92	35	------	2.55	85	40	------	6.47
October	85	22	------	1.59	82	19	------	1.85
November	68	12	------	0.20	61	1	------	3.09
December	56	—6	------	0.50	52	—4	------	0.25
				24.14				30.35

	1906				1907			
January	57	—6	------	0.85	44	—10	------	0.50
February	52	—14	------	1.40	55	—17	------	1.63
March	64	—4	------	1.56	89	11	------	0.54
April	92	27	------	3.48	70	15	------	1.89
May	89	31	------	3.73	87	21	------	1.77
June	98	43	------	3.55	92	42	------	4.78
July	94	49	------	6.95	97	52	------	5.04
August	96	50	------	2.80	92	44	------	1.80
September	93	34	------	9.02	92	31	------	0.73
October	78	19	------	2.46	80	15	------	1.18
November	68	13	------	0.89	60	13	------	2.27
December	51	—2	------	1.36	50	0	------	0.60
				38.05				22.73

TEMPERATURE AND RAINFALL AT LOGAN, IOWA.

From 1866 to 1909.

	1908				1909			
	Temperature High	Low	Mean	Precipitation in inches	Temperature High	Low	Mean	Precipitation in inches
January	55	—6	------	0.60	52	—15	------	1.08
February	49	—5	------	2.71	53	—5	------	1.86
March	84	11	------	0.88	67	16	------	0.47
April	86	14	------	0.98	83	24	------	2.09
May	98	30	------	5.95	95	23	------	3.82
June	89	45	------	8.02	90	51	------	6.88
July	93	49	------	2.06	95	52	------	6.83
August	97	45	------	2.33	98	41	------	2.96
September	97	27	------	0.79	89	37	------	6.16
October	84	26	------	2.73	87	17	------	1.02
November	72	14	------	0.85	77	9	------	8.20
December	54	—10	------	0.22	47	—16	------	1.93
				28.12				43.39

BOTANICAL REPORT

The botanical problems presented by Harrison and Monona counties are no less interesting than those which belong to the domain of geology. Moreover they are so intimately connected with some of the latter, and so deeply concern the welfare of the people of this part of the state that some discussion of them should find place in this report.

The most important of these problems concerns the possibility of the cultivation of trees and crops in our territory and this involves the question of the cause, or causes, of the treelessness of the prairies which form so large a part of the surface of these counties. Much light is thrown upon this problem by the study of the native flora, and a report upon this is accordingly included.

The Prairies

TYPES OF PRAIRIES

Few problems of the natural world have attracted as much attention as the cause of the treelessness of the prairies. Layman, amateur and scientific observers have wrestled with it, with the result that the literature of the subject is not only quite voluminous, but exceedingly variable in character and quality.

The pioneers of Iowa found about seven-eighths of the state covered with prairie, but they sought the forested portions for their homes. This was true also of the pioneers of Harrison and Monona counties, for in these counties the first settlements were located in or near the larger groves.

This was done for several reasons: The forest offered building material and fuel so necessary to the home-builder; in it springs were abundant and furnished the indispensable water supply; it provided shelter from the blinding blizzards of the open country and was less likely to be invaded by the fire-fiend that periodically swept the prairies; and finally the pioneer had brought with him the belief that the soils of the forest were more fertile and that because trees did not grow on the prairies the latter would not produce crops.

But the prairie is no longer avoided. Improved methods of transportation and the modern use of artificial building materials have simplified the home-building problem; men no longer depend upon the surface supply of water; the extensive planting of shelter-belts, and the fencing of all lands have removed the horror if not the discomforts of the blizzard; the extensive cultivation of the prairie and the consequent better control of the surface vegetation has minimized the menace of prairie-fires; and man has found that his earlier prejudices against prairie soils were not well founded, that in fact forests grew on the poorest soils and that the rich prairie sustained a flora consisting largely of grasses which are related in structure and by habit to the ordinary cereals which constitute the great bulk of farm crops.

The fact is that the prairies as we knew them in Iowa have become a reminiscence. Their summer splendor and winter terrors have alike disappeared. Over their broad expanse no tinted waves of a varied flora sweep before the summer breeze. for countless acres of grain now cover their surface. The power of the biting blizzard has been largely broken by the groves and shelter-belts which everywhere give comfort and protection to countless happy, prosperous homes.

The prairies have changed, but the climatic causes which brought them about are still in existence, and their influence is largely antagonistic to man's interests and should be heeded.

We hear much during the cycles of moister seasons like that which has blessed our state now for several years, of the change in climate, the increase in rainfall, and the like, for in times of prosperity we easily forget adversity, and many of our people have forgotten the dry seasons which immediately preceded the present cycle of successful years, and which threatened to reduce our fair state to a desert condition. Only a few years ago crops failed for several seasons in succession over a considerable part of our state, and the larger lakes of the state were threatened by the drouth. But there has been no great change in climatic conditions and the net result of the influence of the good and evil conditions in a longer period of time is probably about the same.

In both their scientific and economic aspects the causes of the treelessness of the prairie are of so much interest and importance that they deserve serious consideration.

The prairies of Harrison and Monona counties present an inviting field for the study of the problem of their origin. More than nine-tenths of the area of Harrison county, and about eleven-twelfths of the area of Monona county were originally prairie, and large areas still retain their natural characteristics. The varied topography provides a variety of surface conditions, and the relatively large areas in which the forest and prairie come in contact make comparative studies of especial value and interest.

For these reasons the counties here discussed were selected in part as types of a larger area, and in part for special local studies on the cause of the treelessness of the prairies.

Among scientific observers the problem of the prairie has usually been assigned to, or assumed by the geologists, and Dana, Whitney, White, Alexander Winchell, N. H. Winchell, Foster, Newberry, D. D. Owen, Shaler, Upham, Worthen and other well-known geologists wrestled with it with varying success. White specifically states* that the "question of the origin of the prairie has become more hackneyed perhaps, than any other

*Report on the Geological Survey of Iowa, vol. I, p. 132, 1870.

of the speculative questions which North American geology affords,'' and Willard says* ''their explanation belongs to the science of Landscape Geology.''

Yet the problem is one which belongs in its most striking aspects to plant ecology and falls properly within the province of the botanist, for no matter what may be the variation in the surface characteristics of the prairies there is comparative uniformity in the nature of their floral covering. Not only are prairies striking because of the absence of trees, but they are marked none the less definitely by the presence of a flora which is wholly distinct from the smaller (chiefly herbaceous) flora of the forest.

The areas which were originally covered with a prairie flora in Iowa are of six more or less distinct types:

1. The broad flat plains which characterized the Wisconsin and Iowan drift areas and a part of the un-eroded Kansan drift area such as may be observed in Osceola county and southward. These plains contained large undrained areas the swamps, ponds and lakes of which possessed a rich hydrophytic flora.

2. The more rolling drift surfaces such as are presented by the greater part of the Kansan area and the more or less distinct moraines bordering the Wisconsin and Iowa areas.† In our territory the drift is almost everywhere covered with loess.

3. The very rough loess ridges which border the Missouri valley and which present the most extreme xerophytic conditions in Iowa.

4. The well-drained alluvial plains such as are shown at their best along the Missouri, but which are more or less developed along all the larger streams. The undrained portions of these plains are, of course, hydrophytic.

5. The prairie ridges which appear in all the forested rougher parts of the state, but are most striking in the more heavily timbered eastern parts where they have been known as ''oak openings'' because the surrounding forest usually consists of the hardier oaks and because some of these oaks are

*Willard, Daniel E., The Story of the Prairies, p. 21, 1903.

†For the distribution of the drift areas in Iowa see map plate III, Report of Iowa Geological Survey, vol. XIV, 1904.

sparsely scattered over them. These prairie openings are sometimes mere tongues of greater prairie areas which extend into the forest, but they are frequently completely surrounded by forest and may be several miles from larger prairie tracts. They vary in area down to a few square rods and are developed independently of geological formations except in so far as these determine topography.

6. The sand-dune areas. (See figures 35 and 36.) These are usually considered distinct from the prairie but a comparison of the floras shows that they differ but little.

All but the first of these types are represented in Harrison and Monona counties, though the sixth, including the prairie-openings, so blends with the general prairie that it does not here appear in its most striking detached condition.

These several types of prairie areas present a variety of topographic conditions and they are found upon all the types of geologic formations which come to the surface not only in these counties but in the state at large.

They agree only in two particulars, but these so important that they determine the character of the prairie. The one is the prairie flora which is strikingly uniform on the several types of prairie areas; and the other is exposure to certain climatic influences which are herein more fully discussed.

THE PRAIRIE FLORA.

The general character of the prairie flora is shown in the accompanying table. Specimens were collected at the localities marked (+) and are now in the herbarium of the State University of Iowa. Those marked P were reported by Professor Pammel in the Proceedings of the Iowa Academy of Science, vol. III, 1896, pp. 106-135, and were not found by the writer.

Of the several localities given in the table Missouri Valley, Blair bridge, Logan, Woodbine and Murray hill are in Harrison county and Ute, Grant Center, Mapleton and Onawa are in Monona county.

The species marked in the first column were collected on the loess ridges in the northern part of Missouri Valley in exposed places, chiefly near stations (1) and (3) described in connection with the notes on evaporation, and shown in plate XXXIII, figure 1, plate XXXVIII, figure 1, and plate XXXIX, figure 1.

Those marked in the second column were collected on the better drained portion of the alluvial plain between Missouri Valley and California Junction.

The third column includes the species collected on the sand-dunes near the Blair railway bridge west of California Junction. A portion of this dune area is shown in figures 35 and 36.

The fourth column contains species which were collected on a bit of original prairie in the cemetery grounds at Logan, in loess-Kansan territory. This area lies on the front of the Logan bench, the slope facing east.

The fifth and sixth columns contain lists of the species collected on Murray hill, the first on the upper or loess part of the ridge illustrated in plate XXI, figure 1, and the second on the lower Aftonian surfaces. The intermediate Kansan and Loveland, occupying the vicinity of the basal part of the most abrupt upper portion of the hill showed exactly the same flora as that of the Aftonian, but most of the plants were more vigorous than those of the gravelly Aftonian surfaces. The difference between the two columns is evidently due to the fact that the loess area was a little more exposed than a part of the Aftonian surface. The most exposed parts of the latter yielded the same flora as that which was found on the loess ridge.

The seventh column contains the record of the species reported by Professor L. H. Pammel* from the Woodbine bluffs. The writer found the same species in the vicinity of Woodbine, but *Corydalis aurea* var. *occidentalis, Hypoxis hirsuta, Lactuca pulchella* and *Silene antirrhina* were observed only along the railway and not on the hills.

The Ute column contains plants collected in part by Mr. Boot and in part by the writer on an inland rolling loess-Kansan prairie area northwest of Ute.

At Grant Center the exposed slopes showed Aftonian in the lower part and loess in the upper part. The plants here listed were collected only on the western slope of the detached ridge lying south of the Chicago, Milwaukee and St. Paul railway,

*Proceedings of the Iowa Academy of Sciences, vol. IX, 1902, pp. 152-180.

except those marked O in the loess column which were collected on other loess ridges and slopes near Grant Center.

The Mapleton plants were collected on the rolling loess-Kansan areas chiefly southeast and northwest of Mapleton.

The Turin plants were collected on the loess ridges north of Turin, illustrated in plate XXIII, figure 2. The more or less broken ridge, or series of ridges, extends in a somewhat southwesterly direction, and the surfaces are very xerophytic.

The Onawa collections were made on the alluvial prairie east of Onawa.

Many of the species were found practically in all the areas listed, but where specimens were not collected the species is not checked.

With the exception of a few species which belong to the flora of the dry western plains the species in the following list are, or were, more or less common on all types of prairie represented in the state. *Agoseris cuspidata*, *Anemone patens* var. *Wolfgangiana*, *Astragalus caryocarpus*, *Lithospermum angustifolium* and *Psoralea esculenta* were formerly very widely distributed, but they are becoming noticeably more and more restricted in distribution, and have disappeared from a large part of the state.

The following species belong to the western plains flora:

Aplopappus spinulosus
Astragalus lotiflorus
Astragalus plattensis
Bouteloua hirsuta
Castilleja sessiliflora
Ceanothus ovatus var. *pubescens*
Lygodesmia rostrata
Oxytropis Lamberti
Pentstemon gracilis
Pentstemon grandiflorus
Yucca glauca.

The *Bouteloua, Ceanothus*, and both species of *Pentstemon* are also found on the sand-mound in Muscatine and Louisa counties in eastern Iowa. The remaining species are found only in the western part of the state.

The plants in the prairie list which are marked with an asterisk have been introduced, but are now more or less established on the prairies.

Some of the species are found more commonly on somewhat lower or more sheltered grounds and only exceptionally occur in dry places. Such are *Amphicarpa Pitcheri, Anemone* *canadensis, Erigeron philadelphicum, Helianthus strumosus* var. *mollis, Ranunculus abortivus, Salix longifolia, Silene stellata, Smilacina stellata, Teucrium canadense* and *Carex gravida.*

Cenchrus carolinianus and *Cycloloma atriplicifolia* are usually found in sand but in western Iowa both occur upon the loess hills. On the other hand *Crotalaria sagittalis, Desmodium canadense, Desmodium canescens* and *Hedeoma hispida* were found only in the sandy areas of Harrison county but in other parts of the state they are also found upon dry prairie.

Cyperus Schweinitzii, Paspalum ciliatifolium and *Strophostyles helvola* are found only in sandy places.

PLANTS OF DRY PRAIRIES	Mo. Valley		Blair bridge	Logan	Murray Hill		Woodbine	Ute	Grant Center		Mapleton	Turin	Onawa
	Loess	Alluvial			Loess	Aftonian			Loess	Aftonian			
Acerates floridana (*Lam.*) *Hitch*	+			+		+		+	+				
Acerates viridiflora (*Raf.*) *Eaton*												+	
Acerates viridiflora lanceolata (*Ives*) *Gray*	+			+								+	
Acerates viridiflora linearis *Gray*												+	
Achillea millefolium *L.*		+					+	+					
Agoseris cuspidata (*Pursh*) *Steud.*	+				+	+						+	
Agropyron Smithii *Ryd.*	+								0				+
Agrostis alba vulgaris (*With.*) *Thurb*													+
Allium canadense *L.*									0				+
Amaranthus blitoides *S. Wats*			+									+	
*Amaranthus retroflexus *L.*												+	
Ambrosia artemisiæfolia *L.*	+					+		+	+	+			
Ambrosia psilostachya *DC.*	+		+			+	+						
Ambrosia trifida integrifolia (*Muhl.*) *T. & G.*								+				+	
Amorpha canescens *Pursh*	+	+	+	+	+	+	+	+	+	+	+	+	
Amphicarpa Pitcheri *T. & G.*				+					0				
Andropogon furcatus *Muhl.*	+		+	+		+	+	+	+	+		+	
Andropogon scoparius *Michx.*	+		+	+		+	+	+	+	+		+	
Anemone canadensis *L.*	+							+	+				+
Anemone cylindrica *A. Gray*	+			+			+	+	+	+		+	
Anemone patens Wolfgangiana (*Bess.*) *Koch*	+			+				+	+	+	+	+	
Antennaria neodioica *Greene*	+			+				+	+	+	+	+	
Antennaria plantaginifolia (*L,*) *Rich.*	+						+	+	+	+		+	
Aplopappus spinulosus (*Pursh*) *DC.*	+					+			+	+		+	
Apocynum cannabinum hypericifolium (*Ait.*) *Gray*													+
Aristida basiramea *Engelm.*			+						0				
Artemisia caudata *Michx.*		+											
Artemisia dracunculoides *Pursh.*	+												
Artemisia ludoviciana *Nutt.*	+	+		+		+		+					+
Asclepias purpurascens *L.*				+									
Asclepias Sullivantii *Engelm.*													+
Asclepias syriaca *L.*				+									+

PLANTS OF DRY PRAIRIES	Mo. Valley		Blair bridge	Logan	Murray Hill		Woodbine	Ute	Grant Center		Mapleton	Turin	Onawa
	Loess	Alluvial			Loess	Aftonian			Loess	Aftonian			
Asclepias tuberosa *L.*				+							+		
Asclepias verticillata *L.*	+			+		+	+	+			+	+	
*Asparagus officinalis *L.*				+									
Aster lævis *L.*				+					0				
Aster multiflorus exiguus *Fernald*	+			+		+	+	+		+			
Aster novæ-angliæ *L.*		+				+						P	
Aster oblongifolius *Nutt.*	+				+	+			+	+		P	
Aster sericeus *Vent.*	+			+	+	+	+	+	+	+		+	
Astragalus canadensis *L.*				+				+				+	
Astragalus caryocarpus *Ker.*	+			+	+	+	+	+	+	+		+	
Astragalus lotiflorus *Hook.*					+				+	+		+	
Astragalus plattensis *Nutt.*	+											+	
Baptisia leucantha *T. & G.*													+
Bouteloua curtipendula *(Michx.) Torr.*	+			+		+	+	+	+	+		+	
Bouteloua hirsuta *Lag.*												+	
*Brassica arvensis *(L.) Ktze.*													+
*Brassica nigra *(L.) Koch.*	+												
Brauneria angustifolia *(DC.) Heller.*	+			+			+	+	+	+	+	+	
Cacalia suaveolens *L.*							+						
Cacalia tuberosa *Nutt.*				+				+	0			+	
*Cannabis sativa *L.*			+	+									
*Capsella bursa-pastoris *(L.) Medic.*	+	+						+	0			+	
Carex festucacea *Schk.*	+	+		+		+			0			+	
Carex gravida *Bailey*		+		+									
Carex pennsylvanica *Lam.*				+				+			+		
Cassia chamæcrista *L.*	+		+	+			+						
Castilleja sessiliflora *Pursh.*	+						+		0			+	
Ceanothus americanus *L.*				+							+		
Ceanothus ovatus pubescens *T. & G.*	+			+	+	+	+	+	+	+	+	+	
Cenchrus carolinianus *Walt.*	+		+	+		+						+	
*Chenopodium album *L.*			+			+		+	+				+
Chrysopsis villosa *(Pursh) Nutt.*	+								+	+		+	
Cirsium discolor *(Muhl.) Spreng.*							+	+	0		+	+	
Cirsium iowense *(Pam.) Fern.*	+	+	+	+		+		+					
Cleome integrifolia *T. & G.*		P									+		P
Comandra Richardsoniana *Fern.*	+												
Comandra umbellata *(L.) Nutt.*	+					+						+	
Convolvulus sepium *L.*		+				+	+	+	0				+
Coreopsis palmata *Nutt.*				+			+						
Corydalis aurea occidentalis *Engelm.*		+					+						
Crotalaria sagittalis *L.*			+										
Cycloloma atriplicifolium *(Spreng.) Coult.*	+		+										
Cyperus Schweinitzii *Torr.*			+										
Dalea alopecuroides *Willd.*	+								+	+		+	
Dalea enneandra *Nutt.*		+	+										+
Delphinium Penardi *Huth.*	+	+		+	+	+	+		+	+	+	+	
Desmanthus illinoensis *(Michx.) MacM.*		+	+										
Desmodium canadense *(L.) DC.*			+					+					
Desmodium canescens *(L.) DC.*			+										
Desmodium paniculatum pubens *T. & G.*			+										
Dyssodia papposa *(Vent.) Hitch.*	+			+		+		+	+	+		+	
Ellisia nyctelea *L.*		+							0				
Elymus canadensis *L.*			+	+							+		

PLANTS OF DRY PRAIRIES	Mo. Valley		Blair bridge	Logan	Murray Hill		Woodbine	Ute	Grant Center		Mapleton	Turin	Onawa
	Loess	Alluvial			Loess	Aftonian			Loess	Aftonian			
*Equisetum arvense *L*		+		+									
Equisetum hyemale *L*	+	+	+	+									+
Equisetum hyemale intermedium *A. A. Eaton*				+									
Equisetum lævigatum *A. Br*		+	+	+	+				0				+
*Eragrostis megastachya (*Koel.*) *Link*			+					+					
Erigeron canadense *L*			+	+		+		+	0				
Erigeron philadelphicum *L*		+											
Erigeron ramosus (*Walt.*) *B. S. P*			+	+	+	+	+		+	+		+	+
Eupatorium altissimum *L*				+		+							
Euphorbia corollata *L*		P		+			+	+				+	
Euphorbia glyptosperma *Engelm*	+											P	
Euphorbia maculata *L*	+						+					+	
Euphorbia marginata *Pursh*	+					+	+		+	+		+	
Euphorbia Preslii *Guss*	+		+	+		+		+					P
Euphorbia serpens *H. B. K*	P		+										
Euphorbia serpyllifolia *Pers*	P					+						+	
Festuca octoflora *Walt*	+												
Fragaria virginiana *Duchesne*	+	+	+	+		+		+	0		+	+	
Gaura coccinea *Pursh*	P					+			+	+		+	
Gaura parviflora *Dougl*	+	P											
Gerardia aspera *Dougl*	+											+	
Glycyrrhiza lepidota *Pursh*		P		P								P	+
Grindelia squarrosa (*Pursh*) *Dunal*	+												
Hedeoma hispida *Pursh*			+										
Helianthemum canadense (*L.*) *Michx*								+		+			
Helianthus annuus *L*	+		+			+			+			+	P
Helianthus hirsutus *Raf*								+					
Helianthus Maximiliani *Schrad*		+					+						
Helianthus scaberrimus *L*	+			+		+			+	+		+	
Helianthus strumosus var. mollis *T. & G*		+											
Heliopsis scabra *Dunal*				+			+	+	0				
Heuchera hispida *Pursh*	+												
Hordeum jubatum *L*	+					+			+	+		+	+
Houstonia angustifolia *Michx*	+			+	+	+		+	+	+		+	
Hypoxis hirsuta (*L.*) *Coville*							+						
Isanthus brachiatus (*L.*) *B. S. P*						+						+	
Iva xanthiifolia (*Fresen.*) *Nutt*									+				
Kœleria cristata (*L.*) *Pers*	+			+	+				+	+		+	
Kuhnia eupatoroides var. corymbulosa *T. & G.*	+			+		+		+	+	+		+	
Lactuca canadensis *L*			+	+				+					
Lactuca ludoviciana (*Nutt.*) *Rid*	+			+				+					
Lactuca pulchella (*Pursh*) *DC*							+						+
Lactuca sagittifolia *Ell*												+	
*Lactuca scariola *L*		+										P	P
Lappula Redowskii var. occidentalis (*Wats.*) *Ryd.*	+					+			0				
Lepachys pinnata (*Vent.*) *T. & G*				+			+	+			+		
Lepidium apetalum *Willd*	+	+				+			+	+		+	+
Lespedeza capitata *Michx*	+		+	+				+	0				
Liatris punctata *Hk*	+							+	+	+			
Liatris scariosa *Willd*	+			+				+					
Liatris squarrosa *Willd*				+									
Linum sulcatum *Riddell*	+			+		+		+	+	+		+	

PLANTS OF DRY PRAIRIES	Mo-Valley		Blair bridge	Logan	Murray Hill		Woodbine	Ute	Grant Center		Mapleton	Turin	Onawa
	Loess	Alluvial			Loess	Aftonian			Loess	Aftonian			
Lithospermum angustifolium *Michx*	+	+		+			+	+	0			+	
Lithospermum canescens (*Michx.*) *Lehm*	+	+	+	+			+		0				
Lobelia spicata *Lam*							+						
Lygodesmia juncea (*Pursh*) *D. Don*	+				+	+			+	+		+	
Lygodesmia rostrata *Gray*			+										
Malvastrum coccineum (*Pursh*) *Gray*					+								
*Medicago sativa *L*	+	+											
*Melilotus alba *Desv*	+		+	+					0			+	+
*Melilotus officinalis (*L.*) *Lam*		+							0				+
Monarda mollis *L*	+			+			+	+	0			+	
Muhlenbergia racemosa (*Michx.*) *B. S. P*			+									+	
Muhlenbergia sobolifera (*Muhl.*) *Trin*	+												
*Nepeta cataria *L*									0			+	
OEnothera biennis *L*	+		+	+		+	+	+	+	+			
OEnothera serrulata *Nutt*									+	+		+	
Onosmodium occidentale *Macken*	+			+		+		+	+			+	
Oxalis stricta *L*	+	+						+	0			+	P
Oxalis violacea *L*	+	+		+			+					+	
Oxybaphus nyctagineus (*Michx.*) *Sweet*		+											
Oxytropis Lamberti *Pursh*	+				+	+			+			+	
*Panicum capillare *L*	+		+	+		+		+	+	+			
Panicum Scribnerianum *Nash*	+		+	+	+	+	+	+	+	+		+	
Panicum virgatum *L*		+	+	+			+						
Paspalum ciliatifolium *Michx*			+										
Pedicularis canadensis *L*		+											
Pentstemon gracilis *Nutt*	+												
Pentstemon grandiflorus *Nutt*	+				+	+			+	+		+	
Petalostemum candidum *Michx*	+			+		+	+	+	+	+	+	+	
Petalostemum purpureum (*Vent.*) *Ryd*	+		+	+		+	+	+	+	+	+	+	
Phlox pilosa *L*					+				0		+		
Physalis heterophylla *Nees*			+	+									
Physalis pubescens *L*	+			+	+	+		+	+	+		+	P
Plantago aristata *Michx*	+												
*Plantago lanceolata *L*	+										+		
Plantago Rugelii *Dec*	+												
Poa compressa *L*	+						+	+	+	+			
Poa pratensis *L*	+	+		+		+	+					+	+
Polygala verticillata *L*	+												
*Polygonum convolvulus *L*								+				+	
Polygonum pennsylvanicum *L*			+					+					
Polygonum ramosissimum *Michx*		+				+							
Potentilla arguta *Pursh*				+			+	+					
Potentilla canadensis *L*	+												
Potentilla monspeliensis *L*								+	+	+		+	+
Potentilla paradoxa *Nutt*		+											
Prenanthes aspera *Michx*	+			+									
Psoralea argophylla *Pursh*	+			+	+	+	+					+	
Psoralea esculenta *Pursh*	+				+	+		+	0			+	
Quercus macrocarpa var. olivæformis *A. Gray*	+			+				+			+	+	
Ranunculus abortivus *L*	+		+					+					
Rhus glabra *L*	+	+		+		+	+	+	0			+	
Rhus toxicodendron *L*			+										

PLANTS OF DRY PRAIRIES	Mo. Valley		Blair bridge	Logan	Murray Hill		Woodbine	Ute	Grant Center		Mapleton	Turin	Onawa
	Loess	Alluvial			Loess	Aftonian			Loess	Aftonian			
Rosa pratincola *Greene*	+	+	+	+	+	+	+	+	+	+		+	
Rosa Woodsii *Lindl*	+	+		+		+							
Rubus occidentalis *L*	+	+	+									+	
*Rumex crispus *L*	+		+						0	+			+
Salix humilis *Marsh*	+								0			+	
Salix longifolia *Muhl*	+		+										
Salix missouriensis *Bebb*		+	+										
*Salsola kali var. tenuifolia *G. F. W. Meyer*			+					+	+	+			
Scrophularia leporella *Bickn*								+				+	
Senecio plattensis *Nutt*	+							+		+			
*Setaria viridis (*L.*) *Beauv*	+		+	+		+		+					
Silene antirrhina *L*							+						
Silene stellata (*L.*) *Ait*											+		
Silphium integrifolium *Michx*				+									
Silphium laciniatum *L*	+			+	+	+			+	+		+	
Sisymbrium canescens *Nutt*		+	+				+						
Sisyrinchium campestre *Bickn*	+	+		+	+	+	+	+	+	+		+	
Smilacina stellata (*L.*) *Desf*	+								0			+	
*Solanum nigrum *L*								+	+				
Solidago canadensis *L*	+		+	+		+						P	P
Solidago missouriensis *Nutt*	+						+		0			P	
Solidago nemoralis *Ait*	+			+		+		+				+	
Solidago rigida *L*	+			+		+	+	+	+	+		+	
Solidago serotina *Ait*	+		+	+					0				
Solidago speciosa var. angustata *T. & G.*	+					+		+	+	+		+	
Sorghastrum nutans (*L.*) *Nash*	+	+		+		+	+	+					
Stipa spartea *Trin*	+			+	+	+	+		+	+		+	
Strophostyles helvola (*L.*) *Britt*			+										
Strophostyles pauciflora (*Benth.*) *S. Wats*	+		+					+					
Symphoricarpos occidentalis *Hook*	+			+		+	+	+	+	+		+	
Symphoricarpos orbiculatus *Moench*		+						+					
*Taraxacum officinale *Weber*	+		+					+	0	+		+	
Teucrium canadense *L*				+									
Tradescantia bracteata *Small*	+	+						+					+
*Trifolium hybridum *Muhl*	+												+
*Trifolium pratense *L*		+											
Trifolium repens *L*	+							+					+
*Verbascum thapsus *L*								+	0			+	
Verbena bracteosa *Michx*							+		+	+		+	
Verbena hastata *L*	+			+				+					
Verbena stricta *Vent*	+		+	+		+	+	+	+	+		+	
Vernonia noveboracensis (*L.*) *Willd*	+			+									
Vicia americana *Muhl*		+											
Vicia americana var. linearis *Nees*	+				+	+							
Viola cucullata *Ait*		+	+				+						
Viola palmata *L*	+	+											+
Viola papilionacea *Pursh*	+		+					+					
Viola pedatifida *Don*	+	+		+	+		+	+			+	+	
Vitis vulpina *L*		+	+	+					+				
Xanthium commune *Britt*			+					+					
Yucca glauca *Nutt*	P				+	+			+	+		+	
Zanthoxylum americanum *Mill*			+										
Zizia aurea (*L.*) *Koch*		+											

In addition to the species included in the list the following forms were found on dry prairie or sand-dune surfaces at the localities cited:

At Blair bridge on sand-dunes:

**Digitaria humifusa* Pers.
Eragrostis pilosa (L.) Beauv.
Euphorbia dentata Michx.
**Panicum huachucae* var. *silvicola* Hitch. & Chase.

At Pisgah, on dry banks:

Carex gravida Bailey.
Lithospermum canescens (Michx.) Lehm.
Rosa pratincola Greene.
Silene antirrhina L.
Vicia americana Muhl.
Zizia aurea (L.) Koch.

At Orson, on dry banks:

Agropyron Smithii Ryd.
Artemisia ludoviciana Nutt.

Pammel (loc. cit.) reports the following:

Aster ericoides L. Turin.
Aster sagittifolius Wedem. Turin.
Euphorbia Geyeri Engelm. Missouri Valley.
Euphorbia hexagona Nutt. Missouri Valley.
Helianthus Maximiliani Schrad. Whiting.
Martynia proboscidea Glox. Missouri Valley.

Woodbine bluff flora, reported by Pammel (loc. cit.).

Erigeron annuus (L.) Pers.
Euphorbia dictyosperma F. & M.
Polytaenia Nuttallii DC.
**Rumex acetosella* L.
Sporobolus cuspidatus (Torr.) Wood.

Pammel also reports *Elymus robustus* S. & S. from the Boyer valley.

This flora of the prairies possesses the ordinary xerophytic characters to a greater or lesser degree. Many of the species have small tops and relatively large roots; some are hairy, scaly or even spiny; cutin and other hard protective structures are developed; poisonous or disagreeable properties are sometimes found; and the stomata are sunken or otherwise protected.

In order that the contrast between the prairie flora and that of other habitats may be brought out more prominently lists of plants which were collected in Harrison and Monona counties in upland and alluvial woods and in swamps, etc., are added. For convenience in making comparisons all the lists are alphabetical.

PLANTS OF UPLAND WOODS

Actinomeris alternifolia (L.) DC. Calhoun.
Adiantum pedatum L. Maidenhair Fern. Grant Center.
Agrimonia mollis T. & G. Ute, Grant Center.
Agrostis perennans (Walt.) Tuck. Thin-grass. Ute.
Allium tricoccum Ait. Leek. Ute.
Amelanchier canadensis (L.) Medic. June-berry. Calhoun.
Amphicarpa Pitcheri T. & G. East of Missouri Valley, Ute.
Apios tuberosa Mœnch. Ute.
Aquilegia canadensis L. Columbine. Missouri Valley, Pisgah, Calhoun, Ute, Grant Center.
Arabis canadensis L. Missouri Valley.
Arabis dentata T. & G. Missouri Valley.
Arisaema triphyllum (L.) Schott. Indian Turnip. Calhoun, Ute, Grant Center.
Aster cordifolius L. Ute.
Botrychium virginianum (L.) Sw. Calhoun.
Campanula americana L. East of Missouri Valley, Missouri Valley, Ute.
Carex Davisii Schwein. Calhoun.
Carex gravida Bailey. Calhoun.
Carex grisea var. *angustifolia* Boott. Ute.
Carex laxiflora Lam. Missouri Valley.
Carex laxiflora var. *blanda* (Desv.) Boott. Calhoun, Ute, Grant Center.
Carex rosea Schk. Missouri Valley, Ute, Grant Center.
Carex scirpoides Schk. Ute.
Carex sparganioides Muhl. Calhoun.
Carya glabra var. *villosa* (Sarg.) Rob. Pig-nut Hickory. Calhoun, Missouri Valley, Turin, Ute.
Celastrus scandens L. Bittersweet. Pisgah, Ute.
Celtis occidentalis var. *crassifolia* (Lam.) Gray. Hackberry. Grant Center, Missouri Valley, Ute.
Chenopodium hybridum L. Turin, Onawa, Missouri Valley.
Circaea lutetiana L. Enchanter's Nightshade. Ute.
Cirsium altissimum (L.) Spreng. Tall Thistle. Pisgah, Ute, Grant Center.
Cornus asperifolia Michx. Dog-wood. Logan.
Cornus paniculata L'Her. Dog-wood. Ute, Grant Center.
Cornus stolonifera Michx. Red Osier. Calhoun, Ute.
Corylus americana Walt. Hazel. Missouri Valley, Ute.
Crataegus mollis (T. & G.) Scheele. Red Haw. Turin, Missouri Valley, Grant Center, Ute.
Cryptotaenia canadensis (L.) DC. Ute, Grant Center.
Cynoglossum officinale L. Calhoun.
Cystopteris fragilis (L.) Bernh. Bladder-fern. Missouri Valley, Grant Center.
Delphinium tricorne Michx. Larkspur. Ute.
Dentaria laciniata Muhl. Turin.
Desmodium Dillenii Darl. Beggar-ticks. Ute.
Desmodium gradiflorum (Walt.) DC. Beggar's-ticks. Calhoun, Ute.
Dicentra cucullaria (L.) Bernh. Dutchman's Breeches. Turin, Missouri Valley, Ute.

Ellisia nyctelea L. Turin, Missouri Valley, Grant Center.
Elymus striatus Willd. Wild Rye. Missouri Valley, Ute.
Equisetum hyemale var. *robustum* (A. Br.) A. A. Eaton. Scouring Rush. Magnolia.
Equisetum laevigatum A. Br. Scouring Rush. Missouri Valley.
Erigeron philadelphicus L. Fleabane. Calhoun, Grant Center.
Erigeron pulchellus Michx. Daisy. Missouri Valley.
Erythronium albidum Nutt. Dog's-tooth Violet. Turin, Ute.
Evonymus atropurpureus Jacq. Wahoo. Ute, Grant Center.
Eupatorium purpureum L. Purple Boneset. Ute.
Eupatorium urticaefolium Reich. White Snake-root. East of Missouri Valley, Ute.
Festuca nutans Willd. Missouri Valley, Pisgah, Calhoun.
Fragaria vesca var. *americana* Porter. Ute.
Fragaria virginiana Duches. Wild Strawberry. Missouri Valley, Calhoun, Ute, Grant Center.
Fraxinus pennsylvanica Marsh. Green Ash. Missouri Valley, Ute, Grant Center.
Galium aparine L. Bed-straw. Turin, Missouri Valley, Calhoun, Ute, Grant Center.
Galium circaezans Michx. Calhoun.
Galium triflorum Michx. Sweet-scented Bed-straw. Ute.
Geum virginianum L. Ute, Logan, Grant Center.
Glyceria nervata Willd. Manna Grass. Turin.
Gymnocladus dioicus (L.) Koch. Kentucky Coffee-bean. Missouri Valley, Grant Center.
Helianthus tuberosus L. Artichoke. Missouri Valley, Ute.
Heliopsis helianthoides (L.) B. S. P. Ute.
Heracleum lanatum Michx. Cow-parsnip. Calhoun, Missouri Valley.
Humulus lupulus L. Hop. Turin, Grant Center.
Hydrophyllum virginianum L. Water-leaf. Turin, Missouri Valley, Calhoun, Ute.
Hystrix patula Mœnch. Ute.
Impatiens pallida Nutt. Pale Touch-me-not. East of Missouri Valley, Ute. Grant Center.
Juglans nigra L. Black Walnut. Ute, Missouri Valley, Grant Center.
Lactuca floridana (L.) Gærtn. Ute.
Laportea canadensis (L.) Gaud. Ute.
Lappula virginiana (L.) Greene. Ute, Grant Center.
Lonicera glaucescens Rydb. Yellow Honey-suckle. Pisgah.
Lonicera Sullivantii Gray. Yellow Honey-suckle. Missouri Valley, Calhoun.
Menispermum canadense L. Moonseed. Missouri Valley, Ute, Grant Center.
Mnium cuspidatum Hedw. Calhoun.
Monotropa uniflora L. Indian Pipe. Magnolia.
Morus rubra L. Mulberry. Calhoun.
Osmorrhiza longistylis (Torr.) DC. Sweet Cicely. Missouri Valley, Calhoun, Ute.
Osmorrhiza longistylis var. *villicaulis* Fern. Turin, Calhoun, Ute, Grant Center.

Ostrya virginiana (Mill.) K. Koch. Iron-wood. Missouri Valley, Grant Center, Pisgah, Ute, Logan.
Oxalis filipes Small. Ute, Grant Center.
Oxalis stricta L. Yellow Wood Sorrel. Missouri Valley, Calhoun, Grant Center.
Parietaria pennsylvanica Muhl. Turin, Grant Center.
Phlox divaricata L. Wild Sweet William. Turin, Missouri Valley, Grant Center, Calhoun, Ute.
Phryma leptostachya L. Ute.
Pilea pumila Gray. Logan, Ute, Grant Center.
Poa pratensis L. Blue grass. Calhoun, Grant Center.
Polygonatum biflorum (Walt.) Ell. Smaller Solomon's Seal. Pisgah.
Polygonatum commutatum (R. & S.) Dietr. Solomon's Seal. Turin, Missouri Valley, Grant Center, Calhoun, Ute.
Polygonum dumetorum L. Calhoun, Ute.
Prunus americana Marsh. Wild Plum. Turin, Ute, Grant Center.
Prunus virginiana L. Choke Cherry. Turin, Missouri Valley, Grant Center, Calhoun, Ute, Logan.
Psedera quinquefolia (L.) Greene. Virginia Creeper. Ute, Grant Center.
Quercus macrocarpa Michx. Bur-oak. Turin, Missouri Valley, Ute, Grant Center.
Quercus macrocarpa var. *olivaeformis* (Michx. f.) Gray. Missouri Valley, Mapleton.
Quercus velutina Lam. Yellow Oak, Black Oak. Near Logan.
Ranunculus abortivus L. Turin, Missouri Valley, Ute, Grant Center.
Rhamnus lanceolata Pursh. Buck-thorn. Calhoun, Logan.
Rhus glabra L. Smooth Sumac. Missouri Valley, Ute.
Rhus toxicodendron L. Poison Ivy. Ute, Grant Center.
Ribes Cynosbati L. Prickly Gooseberry. Ute.
Ribes floridum L'Her. Ute.
Ribes gracile Michx. Wild Gooseberry. Turin, Missouri Valley, Ute, Grant Center.
Rosa Woodsii Lindl. Wild Rose. Calhoun.
Rubus allegheniensis Porter. Black-berry. Pisgah, Calhoun.
Rubus occidentalis L. Wild Raspberry. Missouri Valley, Calhoun, Grant Center.
Rudbeckia triloba L. Calhoun, Onawa.
Salix discolor Muhl. Pussy Willow. Turin.
Sanguinaria canadensis L. Blood-root. Ute, Grant Center.
Sanicula marilandica L. Missouri Valley, Pisgah, Calhoun, Ute, Grant Center.
Scrophularia marilandica L. Ute.
Silene stellata (L.) Ait. f. Starry Campion. Missouri Valley, Ute.
Smilax ecirrhata Englm. Ute.
Smilax herbacea L. Carrion-flower. Turin, Calhoun.
Smilax hispida Muhl. Green-brier. Missouri Valley, Ute, Grant Center.
Solanum nigrum L. Black Night-shade. Missouri Valley.
Symphoricarpos orbiculatus Mœnch. Indian Currant. Missouri Valley, Turin.

Symphoricarpos occidentalis Hook. Wolf-berry. Turin, Ute, Grant Center.
Taraxacum officinale Weber. Dandelion. Missouri Valley, Ute, Grant Center.
Thalictrum revolutum DC. Turin, Calhoun, Grant Center.
Tilia americana L. Bass-wood. Missouri Valley, Ute, Turin, Grant Center.
Triosteum perfoliatum L. Horse-gentian. Calhoun, Ute, Grant Center.
Ulmus americana L. White Elm. Missouri Valley, Ute, Grant Center.
Ulmus fulva Michx. Red Elm. Missouri Valley, Ute, Grant Center.
Ulmus racemosa Thomas. Cork Elm. Missouri Valley.
Viola cucullata Ait. Blue Violet. Turin, Grant Center.
Viola pubescens Ait. Yellow Violet. Ute.
Viola scabriuscula Schw. Smooth Yellow Violet. Mapleton, Ute, Grant Center.
Viola sororia Willd. Blue Violet. Turin, Missouri Valley, Ute.
Vitis vulpina L. Wild Grape. Missouri Valley, Ute, Grant Center.
Zanthoxylum americanum Mill. Prickly-ash. Missouri Valley, Ute, Grant Center.

PLANTS OF ALLUVIAL GROVES

Acer negundo L. Box Elder. Logan, California Junction, Blair bridge.
Acer saccharinum L. Soft Maple. Logan.
Amorpha fruticosa L. Wild Indigo. Calhoun, Little Sioux, Blair bridge.
Aster lateriflorus L. Britt. Wild Aster. Little Sioux.
Celtis occidentalis var. *crassifolia* (Lam.) Gray. Hackberry. Pisgah, Modale.
Cornus paniculata L'Her. Dog-wood. California Junction, Blair bridge.
Crataegus mollis (T. & G.) Scheele. Red Haw. California Junction, Blair bridge.
Echinocystis lobata (Michx.) T. & G. Wild Cucumber. Logan, Turin.
Evonymus atropurpureus Jacq. Wahoo. Little Sioux.
Eupatorium urticaefolium Rich. Onawa.
Festuca nutans Spreng. Fescue Grass. Onawa.
Fraxinus pennsylvanica Marsh. Green Ash. California Junction.
Gleditsia triacanthos L. Honey Locust. California Junction.
Gymnocladus dioica (L.) Koch. Kentucky Coffee-bean. Logan.
Juglans nigra L. Black Walnut. Missouri Valley, Turin, etc.
Leersia virginica Willd. White Grass. Logan.
Morus rubra L. Mulberry. Pisgah.
Pilea pumila (L.) Gray. Rich-weed. Logan.
Polygonum lapathifolium L. Smart-weed. Logan, Ute.
Populus deltoides Marsh. Cotton-wood. Logan, California Junction, Blair bridge, etc.
Prunus americana Marsh. Wild Plum. California Junction.
Psedera quinquefolia (L.) Greene. Virginia Creeper. California Junction, Blair bridge.
Quercus macrocarpa Michx. Bur-oak. California Junction.
Radicula palustris (L.) Mœnch. Marsh Cress. Logan.
Ranunculus septentrionalis Poir. Butter-cup. Turin.
Rhus glabra L. Smooth Sumac. Missouri Valley, etc.
Rhus toxicodendron L. Poison Ivy. Missouri Valley, etc.
Ribes floridum (L.) L'Her. Flowering Currant. California Junction.

Ribes gracile Michx. Wild Gooseberry. California Junction.
Rudbeckia laciniata L. Cone-flower. Logan.
Rumex altissimus Wood. Tall Dock. Missouri Valley, Onawa.
Salix amygdaloides Anders. Peach-leaved Willow. Missouri Valley, California Junction, Logan, Blair bridge.
Salix discolor Muhl. Pussy Willow. Logan.
Salix longifolia Muhl. Sand-bar Willow. Logan.
Salix missouriensis Bebb. Missouri Willow. Missouri Valley, etc.
Salix nigra Marsh. Black Willow. Logan.
Sambucus canadensis L. Elder-berry. California Junction, Missouri Val-
Sambucus canadensis L. Common Elder-berry. California Junction, Missouri Valley.
Sanicula marilandica L. Black Snake-root. California Junction.
Sicyos angulata L. Bur Cucumber. Little Sioux.
Silphium perfoliatum L. Cup-plant. Logan.
Solidago serotina Ait. Golden-rod. Logan.
Stachys palustris L. Wound-wort. Blair bridge.
Stachys tenuifolia Willd. Logan.
Ulmus americana L. White Elm. California Junction, Blair bridge, etc.
Ulmus fulva Michx. Red Elm. Logan.
Urtica gracilis Ait. Nettle. Logan, Mapleton.
Vitis vulpina L. Wild Grape. Logan, Missouri Valley, etc.
Zanthoxylum americanum Mill. Prickly Ash. Modale.

PLANTS OF LOW GROUNDS, MARSHES, ETC.

Acnida tuberculata Moq. Onawa. Low grounds.
Ammania coccinea Rottb. Blair bridge, Modale. Swamps.
Artemisia biennis Willd. Pisgah. Low grounds.
Bidens cernua L. Pisgah. Borders of ponds, etc.
Bidens vulgata Greene. Spanish Needles. Ute. Moist grounds.
Boltonia asteroides (L) L'Her. Turin, Missouri Valley. Low places.
Calamagrostis canadensis (Michx.) Beauv. Blue Joint-grass. Onawa. Low grounds.
Carex Bebbii Olney. Missouri Valley, Onawa. Low grounds.
Carex crus-corvi Shuttlw. Onawa, Modale. Swamps.
Carex lanuginosa Michx. California Junction, Denison. Low grounds.
Carex riparia W. Curtis, California Junction. Low grounds.
Carex scoparia Schk. California Junction. Low grounds.
Carex stricta Lam. Missouri Valley. Low grounds, swamps.
Carex stricta var. *angustata* (Boott) Bailey. California Junction. Low places.
Carex trichocarpa Muhl. California Junction. Low places.
Carex tribuloides Wahl. Missouri Valley. Borders of swamps.
Carex vulpinoidea Michx. Missouri Valley, Onawa, Pisgah. Low grounds.
Cornus stolonifera Michx. Red Osier. Modale. Borders of swamps.
Cyperus acuminatus Torr. & Hk. Blair bridge. Wet places.
Cyperus aristatus Rottb. Blair bridge. Wet places.
Cyperus erythrorhizos Muhl. Modale. Wet grounds.
Cyperus esculentus L. Onawa. Wet grounds.
Cyperus rivularis Kunth. Blair bridge, Modale. Low grounds.
Cyperus strigosus L. Blair bridge. Low places.

Echinodorus cordifolius (L.) Griseb. Missouri Valley, Blair bridge. Ponds.
Eleocharis palustris (L.) R. & S. Onawa. Swamp borders.
Eleocharis tenuis (Willd.) Schultes. Pisgah. Swamp borders.
Eupatorium perfoliatum L. Boneset. Missouri Valley. Low places.
Gerardia tenuifolia Vahl. Missouri Valley. Swamp borders.
Helenium autumnale L. Sneeze-weed. Missouri Valley. Low grounds.
Helianthus grosseserratus Mart. Saw-tooth Sunflower. Onawa, Logan. Low places.
Iris versicolor L. Blue Flag. Missouri Valley. Swamps and wet grounds.
Lippia lanceolata Michx. Missouri Valley. Low places.
Lobelia siphilitica L. Blair bridge. Low grounds, borders, etc.
Lycopus americanus Muhl. Water Hoarhound. Blair bridge. Bogs.
Lythrum alatum Pursh. Modale. Wet places.
Mentha arvensis var. *canadensis* (L.) Briq. Pisgah. Bogs.
Nelumbo lutea Pers. Yellow Nelumbo. Onawa. Ponds.
Panicum huachucae var. *silvicola* Hitch & Chase. Blair bridge. Low grounds.
Phalaris arundinacea L. Missouri Valley, Little Sioux. Wet places.
Poa triflora Gilib. Onawa, Blair bridge. Low grounds.
Polygonum lapathifolium var. *incarnatum* Wats. Turin. Low grounds.
Polygonum Muhlenbergii (Meisn.) Wats. Missouri Valley, Modale. Ponds.
Potamogeton illinoiensis Morong. Blair bridge. Ponds.
Potamogeton pectinatus L. Mapleton. Ponds.
Potentilla paradoxa Nutt. Blair bridge. Borders of ponds, etc.
Radicula palustris (L.) Mœnch. Missouri Valley, Pisgah. Swamps.
Radicula sinuata (Nutt.) Greene. California Junction, Little Sioux. Swamps.
Ranunculus cymbalaria Pursh. Blair bridge, Pisgah. Wet borders.
Rumex altissimus Wood. Onawa, Missouri Valley. Low grounds.
Sagittaria latifolia Willd. Missouri Valley. Swamps.
Salix amygdaloides Anders. Peach-leaved Willow. Blair bridge. Low grounds.
Salix cordata Muhl. Heart-leaved Willow. Mapleton. Low grounds.
Salix discolor Muhl. Pussy Willow. Pisgah. Bogs, etc.
Salix longifolia Muhl. Sand-bar Willow. Missouri Valley. Wet borders.
Salix missouriensis Bebb. Missouri Willow. Blair bridge. Low places.
Scirpus americanus Pers. Blair bridge. Borders of ponds and swamps.
Scirpus atrovirens L. Missouri Valley, Grant Center, Modale. Ponds and swamps.
Scirpus validus Vahl. Missouri Valley, Blair bridge. Ponds and swamps.
Scutellaria lateriflora L. Mad-dog Skull-cap. Turin. Wet places.
Sphenopholis pallens (Spreng.) Scrib. Missouri Valley. Low grounds.
Spiranthes cernua (L.) Rich. Blair bridge. Low places, in sand.
Sporobolus heterolepis Gray. Blair bridge. Low sandy places.
Stachys palustris L. Blair bridge. Low grounds.
Stachys palustris var. *homotricha* Fern. Onawa. Low grounds.
Steironema ciliatum (L.) Raf. Calhoun. Wet places.
Typha latifolia L. Cat-tail. Missouri Valley, Blair bridge. Ponds and swamps.
Vernonia fasciculata Michx. Iron-weed. Missouri Valley, Modale, Turin. Low grounds.

Cratty also reports the following species in the Bulletin from the Laboratories of Natural History, State University of Iowa, vol. III, from the localities cited:

Eleocharis palustris (L.) R. & S. Missouri Valley, p. 325.
Scirpus atrovirens Muhl. Woodbine, p. 330.
Carex lanuginosa Michx. Missouri Valley, p. 341.
Carex vulpinoidea Michx. Missouri Valley, p. 354.

The foregoing lists contain all the plants which were collected in the respective habitats, and while they are probably not complete they present a comparative view of the flora of our territory which will not be materially affected by any additions which may be made to any of the lists. The prairie flora is distinctly set apart from the others and is the most constant and most characteristic feature of the prairies of whatsoever type.

EXPOSURE TO EVAPORATION

Another common characteristic of all prairie is exposure to the two great factors which control evaporation, the sun and wind. The maximum heat of the day is reached at about two o'clock in the afternoon. The "two o'clock sun" beats down upon the southerly and southwesterly slopes of rough areas, and equally affects uniformly flat areas; the prevailing winds of summer to which the prairie flora is exposed are from the south or southwest, and the sun-scorched southwesterly slopes are also most exposed to these winds, the flat prairie again suffering almost equally. Countless illustrations of the effect of this exposure may be observed throughout Iowa and neighboring states, but none are finer than those which may be seen in Harrison and Monona counties.

The contrast between the exposed Missouri bluffs and the inland sheltered valleys is almost everywhere sharp. This is well illustrated by the two figures on plate XXXIII. Figure 1 shows the faces of the bluffs just above Missouri Valley. They are here fully exposed to the west and southwest, and both sun and wind have free play. The result is that only the xerophytic flora of the prairie can exist under the trying conditions. Figure 2 shows the sheltered valley on the east side of the same ridge. Neither sun nor wind can operate as effectively in the sheltered valley and the result is the development of the mesophytic flora of the forest. Plate XXXIV also furnishes a fine illustration. Here the two views were taken from the same point,—figure 1 looking southeast toward the prairie ridge which has its side exposed to the west and southwest; and figure 2 looking southwest toward the sheltered slope which is covered with forest growth.

The ridge at Turin, plate XXIII, figure 2, extends in a southwesterly direction and both of its sides are exposed and both are covered with a prairie flora.

Illustrations of this kind may be multiplied indefinitely both in and outside of our territory, and several are furnished by the illustrations of this report. Thus, plate XXI, figure 1, shows the exposed faces of Murray hill, which are covered wholly with a typical prairie flora; plate XXII, figure 1, shows similar surfaces near Pisgah; plate XXXI, figure 2, illustrates the exposed Missouri bluffs in southern Monona county; plate XXXVI, figure 1, shows a series of short ridges projecting into a valley which opens to the southwest, the exposed top of each ridge being prairie and each valley sheltering a bur-oak grove; and figures 32 and 33 bring out the contrast between the prairie slopes on the exposed bluffs of the Missouri above Missouri Valley, and the sheltered forested bluffs nearly opposite, above Florence, Nebraska.

In many places there are northern and eastern slopes which are also devoid of groves. Sometimes this is due to the fact that local topography causes a lateral deflection of the prevailing winds in such manner that these slopes are more freely swept by them. The deflection is sometimes downward, as along surfaces which slope downward gradually toward the north. In such cases the currents of air follow the sloping surface in accordance with the well-known tendency of moving gasses to follow somewhat irregular surfaces,* whereas when the northern slope is more abrupt the prevailing southwesterly winds often pass over without following it. In the latter case, however, there is sometimes a division of the current as illustrated

*Plate XXXVI, figure 2, illustrates such prairie areas on gradual northern slopes.

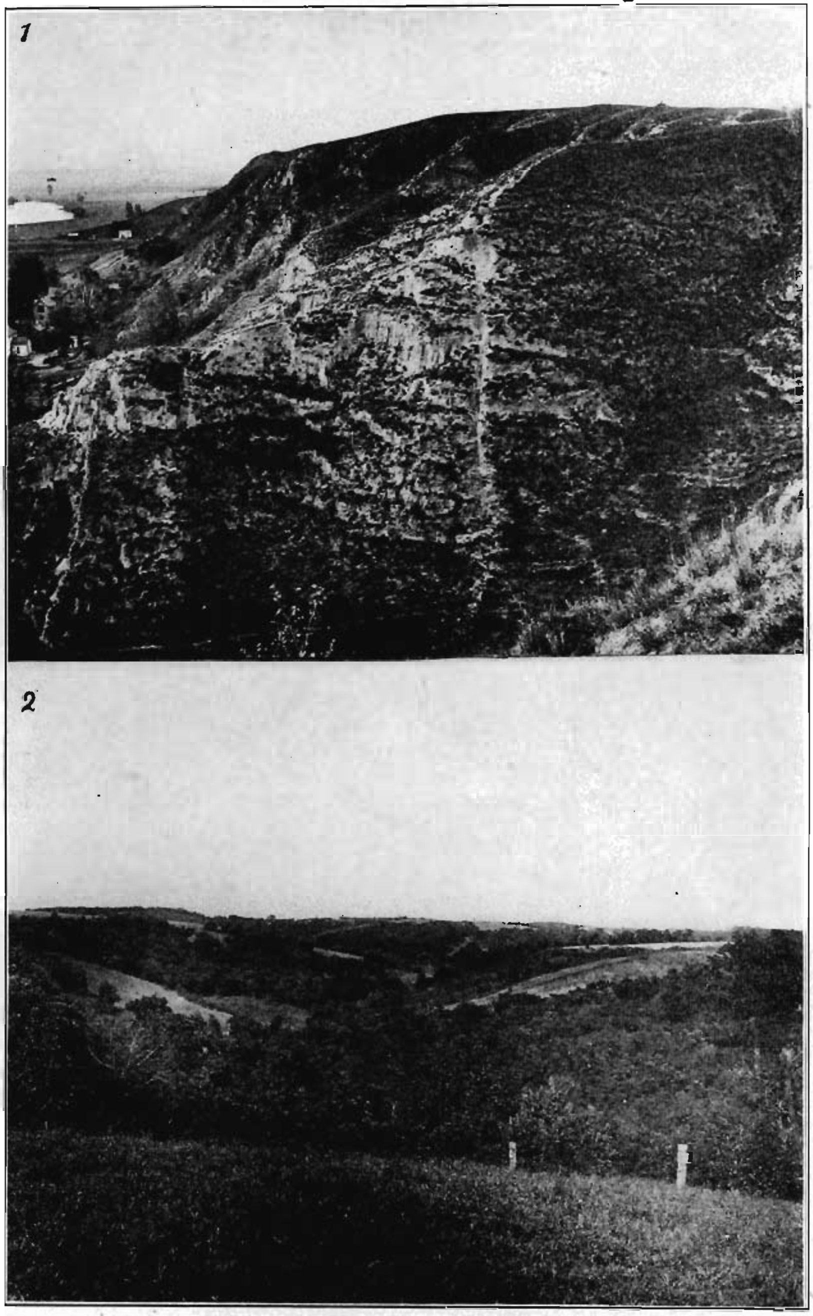


Plate XXXIII.—Missouri Valley topography and groves. (1) Looking north along main bluffs in Missouri Valley (pp. 284, 392, 400, 431, 445). (2) Snyder's Hollow. Looking northeast from top of ridge in (1). (See pp. 393, 445.)

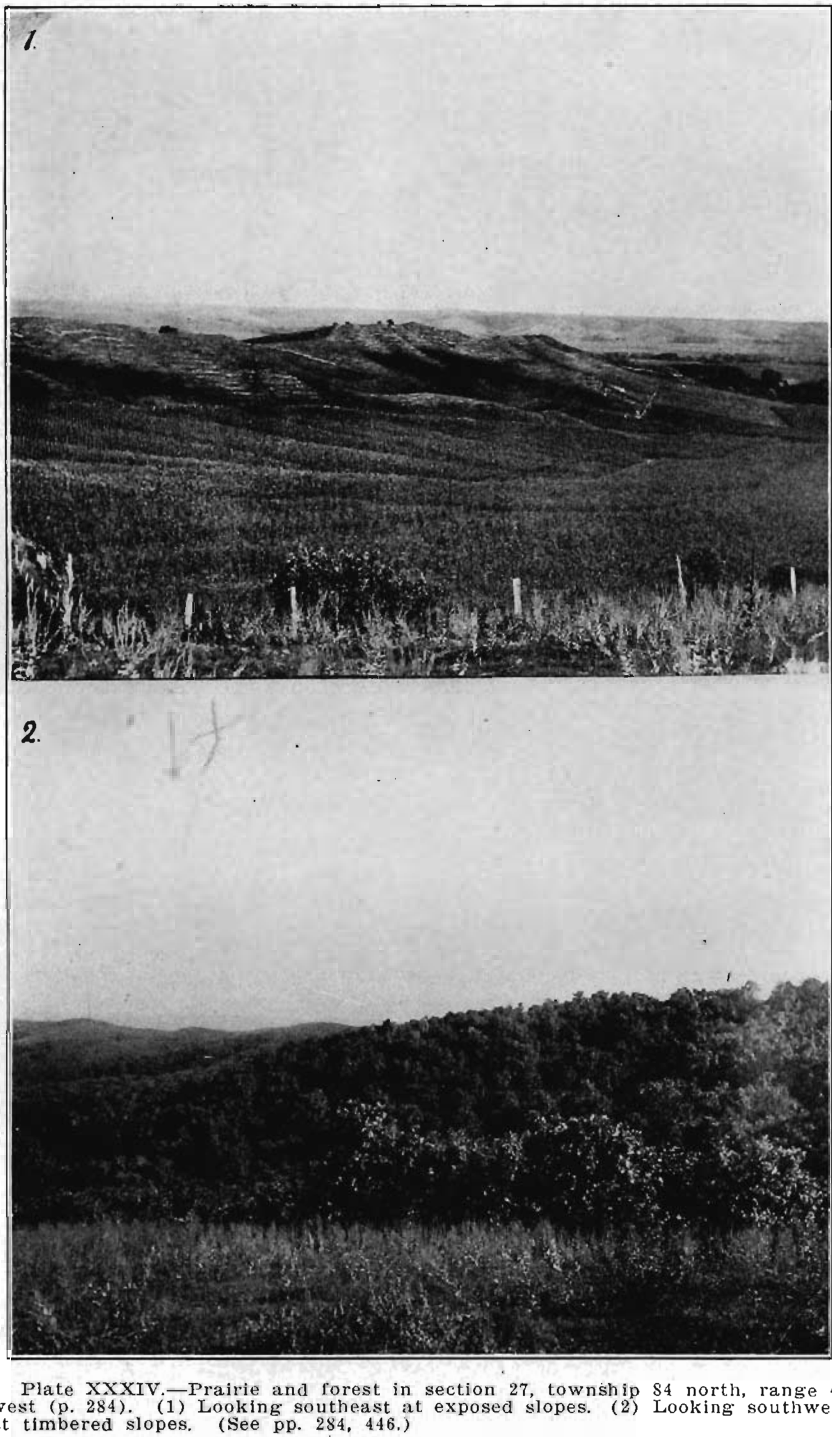


Plate XXXIV.—Prairie and forest in section 27, township 84 north, range 44 west (p. 284). (1) Looking southeast at exposed slopes. (2) Looking southwest at timbered slopes. (See pp. 284, 446.)

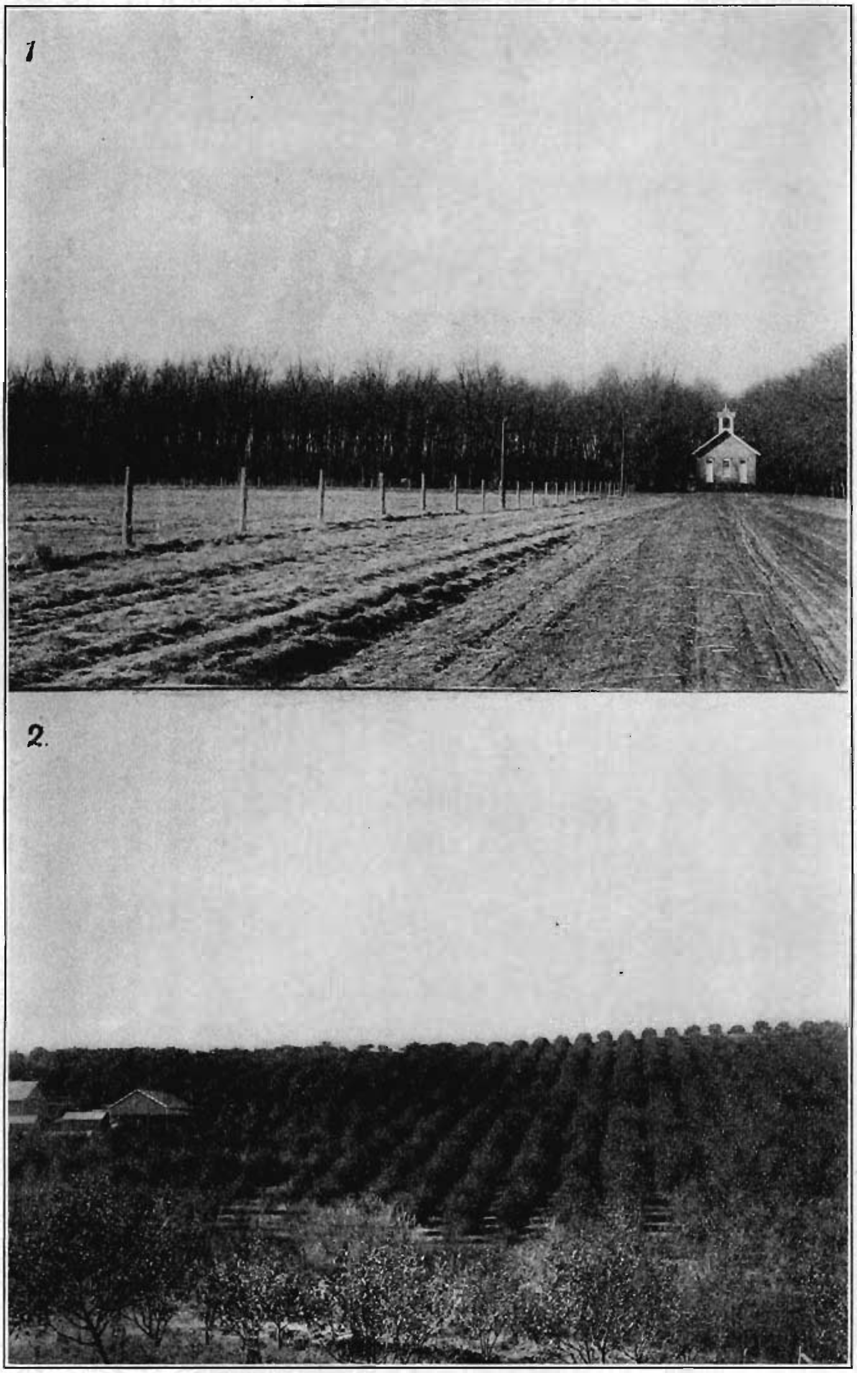
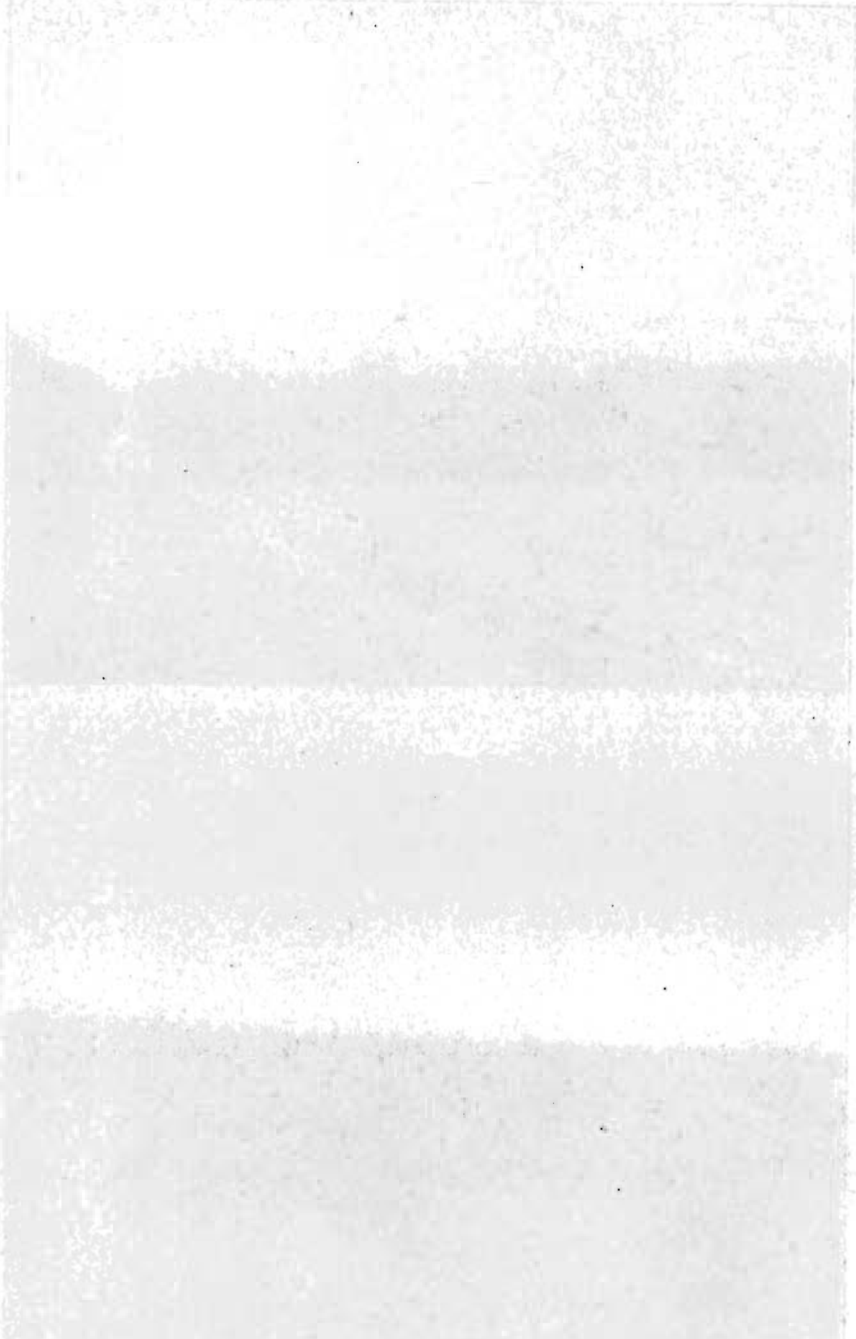


Plate XXXV.—Artificial groves. (1) Whiting grove in northeast quarter section 25, township 85 north, range 46 west. Looking west (p. 475). (2) Deur orchard, section 1, township 78 north, range 44 west. (See p. 415.)



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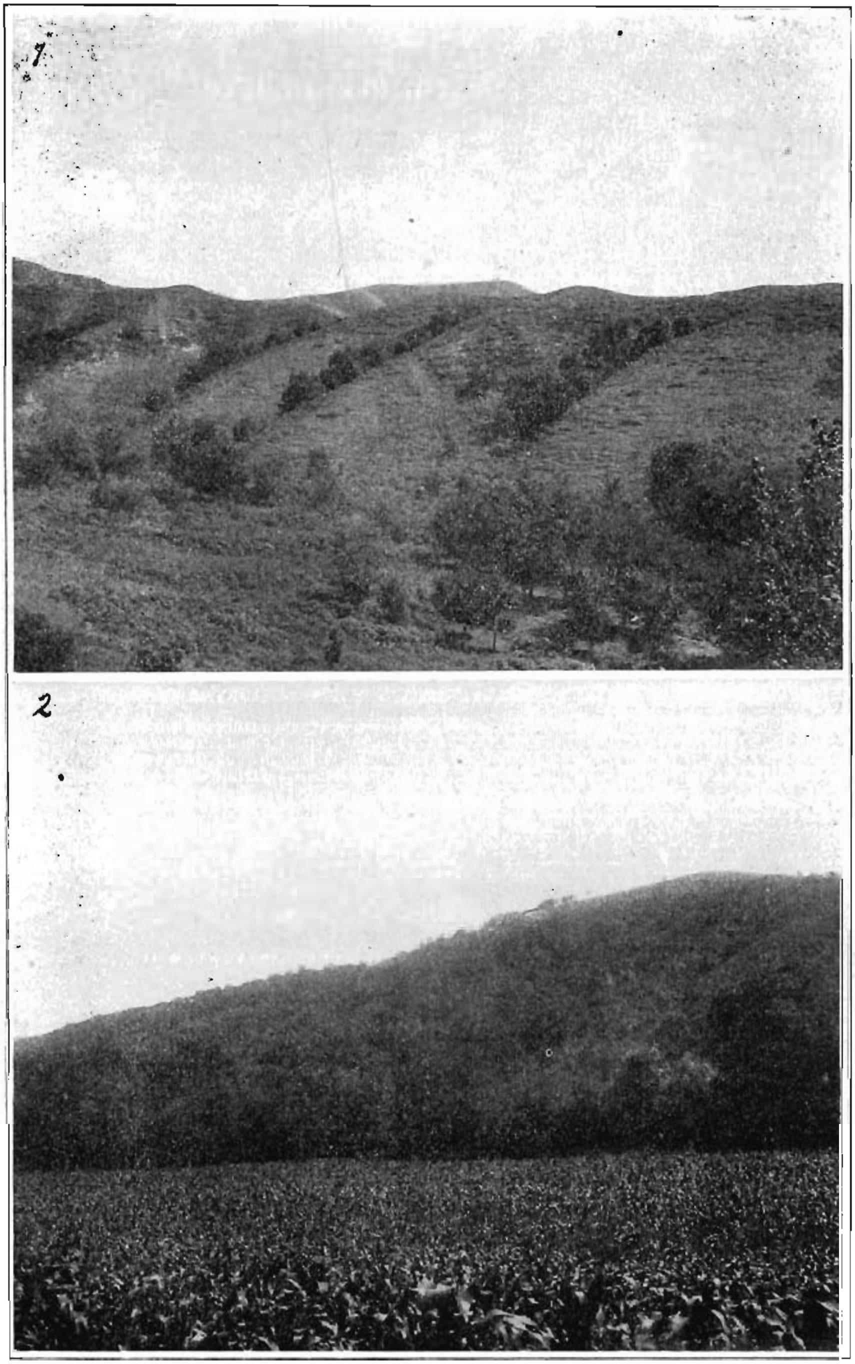

Plate XXXVI.—Prairie ridges. (1) Sheltered ravines with buroaks, looking south from Murray Hill. (2) Looking southeast in section 15, township 84 north, range 44 west. (See p. 446.)

in figure 37, in which case a part of the current sweeps back up the leeward slope. This occurs in rough territory where ridge after ridge intercepts the air-currents and causes disturbances in their lower strata, and was observed only where ridges in front (to the right in the figure) caused this deflection. The writer has frequently tested this by releasing bits of paper, the pappus of composites and other light objects from the summits of such ridges, and invariably when strong winds were blowing most of these objects were swept upward again, often to the feet of the experimenter. In such cases the leeward slope is

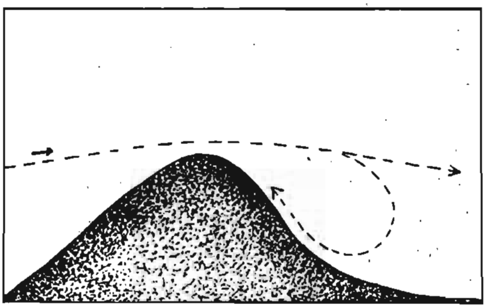

Figure 37. Arrows show the direction of the wind. On the leeward side a part of the current sweeps back up the hill.

almost as much exposed to the dry winds as the windward side, and it is then wholly or largely prairie. In all the preceding cases the prairie areas are distinctly exposed to the prevailing summer winds.

In all cases where the topography of the prairie is rough the rapid run-off of the rains precipitated upon the steep slopes assists in more rapidly making the surfaces xerophytic. That this is not the prime cause however is evident from the fact that steep slopes (especially those facing the north or northeast) are densely covered with a mesophytic forest-growth where sheltered from the winds. Excellent illustrations are furnished by Snyders Hollow at Missouri Valley and Woodwards Glen at Grant Center, where prominent ridges cut off the prevailing summer winds, and by practically every timbered hollow or valley in our territory, for all are similarly situated. The fact that the groves are practically restricted in this and similar territory to the roughest areas is also worthy of consideration.*

That other obstructions than those produced by topographic features have a similar influence upon vegetation is illustrated by plate XXXVII which shows two views of a prairie grove near George, Iowa. Figure 1 shows the sheltered interior of the grove (looking east), here cut by a road. The walnuts on the south side of the road are prospering in the shelter of their companions which form the southern part of the grove. Figure 2 shows the southwest corner of the same grove, growing on the same kind of surface, but at this point exposed fully to the sun and wind from the southwest because lacking the protection of other trees. The walnuts in this part of the grove are stunted and dying out.

The striking distribution of the groves on rougher lands in the western part of Iowa and elsewhere suggested a series of observations on the relative rate of evaporation from the sheltered and protected slopes. The bluffs and ridges bordering the Missouri valley on the east side are especially well suited for such observations as the exposure of the faces of the bluffs is extreme, and as the ridges are often very sharp so that the transition from prairie to forest is very abrupt.

EVAPORATION.

In order that all the conditions affecting evaporation might be properly taken into account a series of meteorological observations was undertaken at Missouri Valley in the summer of 1908. This work included observations on evaporation, temperature and relative humidity, velocity and direction of wind, clearness of sky, barometric pressure, and in a general way on rain-fall.

Evaporation. An effort was made to employ three kinds of evaporimeters. An open tin pan, one foot in diameter, and with upright sides, was buried to the rim at each of the four stations described below.

*The clumps and narrow belts of trees along the larger streams on the alluvial plain form an exception to the rule. The diffusion of moisture from the stream in both soil and air evidently makes this possible as the plants in these belts are all mesophytic with the possible exception of the partly xerophytic cottonwood which thrives in larger groves on the sandy areas bordering the Missouri because its extensive root-system is developed largely in the water-laden sand-beds of the bottomlands.

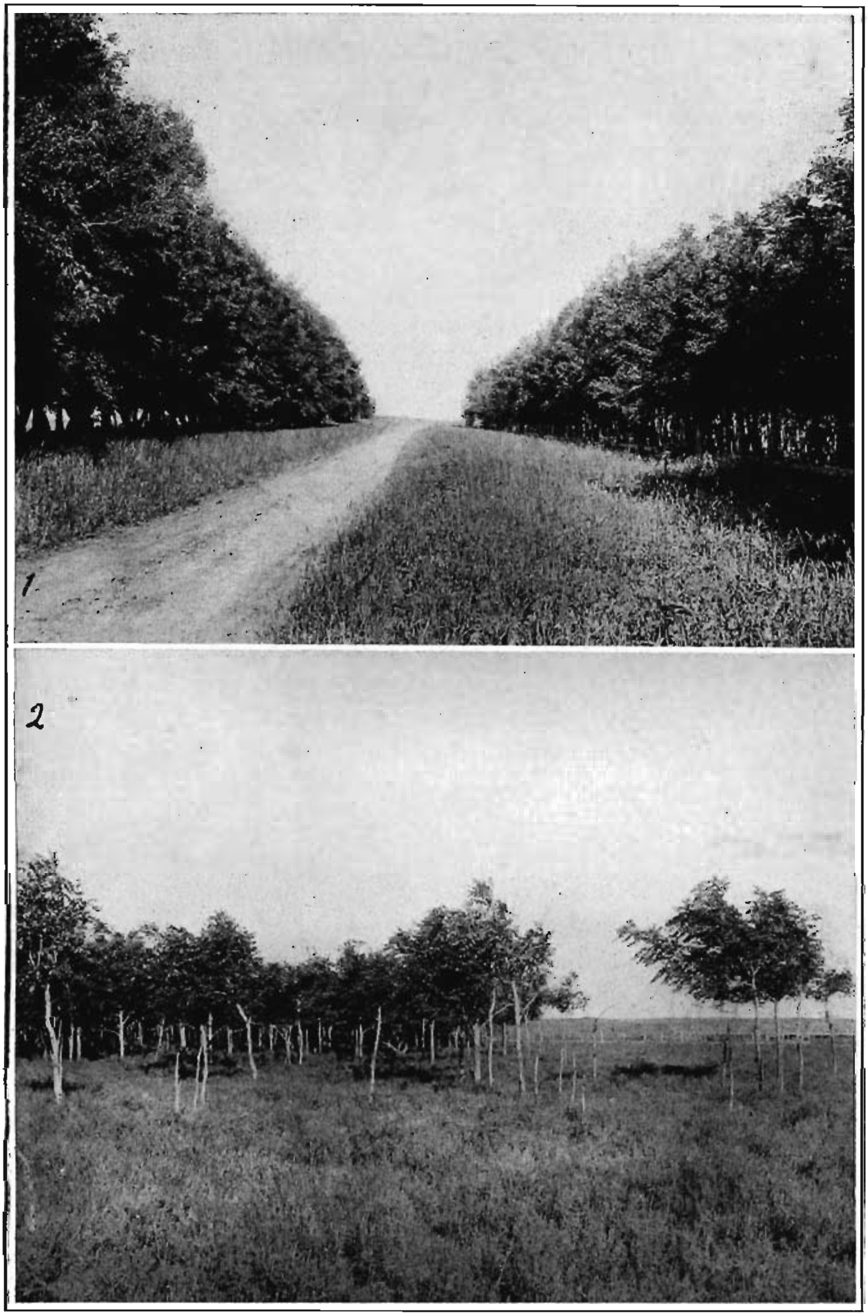

Plate XXXVII.—**Walnut grove near George, Iowa. 1.—Looking east through the** sheltered part. 2.—Looking east at the exposed southwest corner. (See p. 450).

At two of the stations Piche evaporimeters, graduated to hundredths of a cubic inch, were suspended eight inches above the surface of the soil on iron rods driven into the ground. These evaporimeters were frequently tested and worked together perfectly.

An effort was also made to employ porous cup-evaporimeters at these two stations,* but owing to various accidents they failed several times.

Temperature and relative humidity. For this purpose a Marvin Sling Psychrometer with the Fahrenheit scale (the U. S. standard) was employed, rain-water being used for the wet-bulb. Readings were also taken from two Centigrade psychrometers as an additional check.

Wind velocity. The velocity of the wind was measured at one of the stations (number one) by a Green's cup anemometer which was set up at this station throughout each of the observation days. A small mill anemometer (air-meter) was also employed for short periods at various intervals at all the stations.

Barometric pressure. This was measured by an Aneroid barometer.

Rain-fall. No effort was made to measure the rainfall, but during August and September, 1908, when these observations were made, Mr. Stern reported the rainfall at Logan, eight miles away, as follows:

	INCHES.
August	2.03
September	.79

This also probably approximately measured the rainfall at Missouri Valley, and by far the greater part of this was precipitated during the first half of August, which was decidedly rainy. The latter half of August and the first half of September were very dry. By the middle of September the hills were dry and brown, and in the more exposed places only a few of the more pronounced xerophytes were in flower. The following were observed in flower at that time near stations (1) and (3):

Aster oblongifolius
Aster sericeus
Chrysopsis villosa
Grindelia squarrosa
Helianthus scaberrimus
Kuhnia eupatoroides var. *corymbulosa.*
Liatris punctata
Solidago speciosa var. *angustata*
Solidago rigida

*These were kindly furnished for the purpose by Dr. Forrest Shreve of the Carnegie Desert Botanical Laboratory.

By this time even the leaves on the bur-oaks curled, and during the day most plants which still retained leaves were wilted.

The stations. Four stations were selected for the observations.

Station 1 was located at an elevation of 140 feet above the alluvial plain on the west side of the ridge forming the bluffs of the Missouri valley just above Missouri Valley. It was fully exposed to the southwest and west, but was somewhat sheltered by the ridge to the south and southeast. Its vicinity was covered with a typical prairie flora. This station, with some of the apparatus in place is shown in the foreground in plate XXXVIII, figure 1, looking south, and at the point marked (1) in plate XXXIX, figure 1, looking east.

Station 2 was located in the grove on the leeward side of the same ridge at the same altitude as station (1), and ninety-five feet east of it. It was stationed fifty feet east of the west edge of the grove shown to the left in plate XXXIX, figure 1, and also in plate XXXVIII, figure 2. The latter figure also shows in the foreground the border strip, about twenty-five feet wide, which separates the grove in which this station is located from the typical prairie surrounding station (1). The latter station is located about twenty feet west of the west side of this border strip. The border strip follows the very top of the ridge between stations (1) and (2), and the latter station is sheltered partly by this intervening low ridge and to a greater extent by the higher ridge to the south, besides being under cover of the forest.

The observations at stations (1) and (2) should be compared to show the combined influence of the protecting ridge and grove on evaporation.

The floras of the two stations were very distinct. That of the prairie at stations (1) and (3), which is essentially one, is recorded in the first (or loess) column of the table of prairie plants. In the immediate vicinity of station (2) the following plants were collected, practically all, excepting the introduced weeds, belonging to the flora of the forest:

Aquilegia canadensis
Arabis canadensis
Campanula americana
Chenopodium album (introduced)

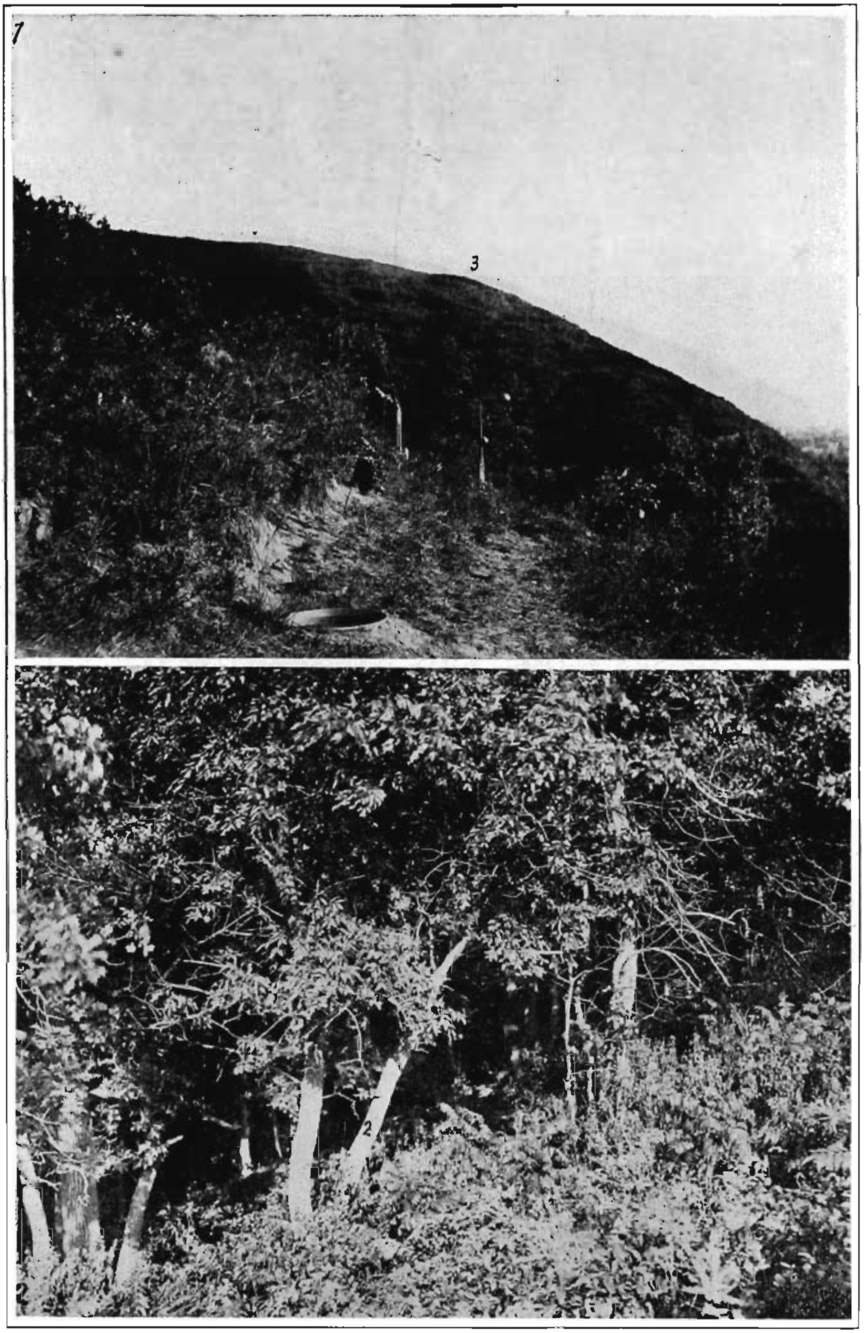

Plate XXXVIII.—Meteorological stations, Missouri Valley. (1) Looking south across stations (1) and (3). (2) Looking east toward station (2) in grove in line with buroak marked (2). (See pp. 454 and 459.)

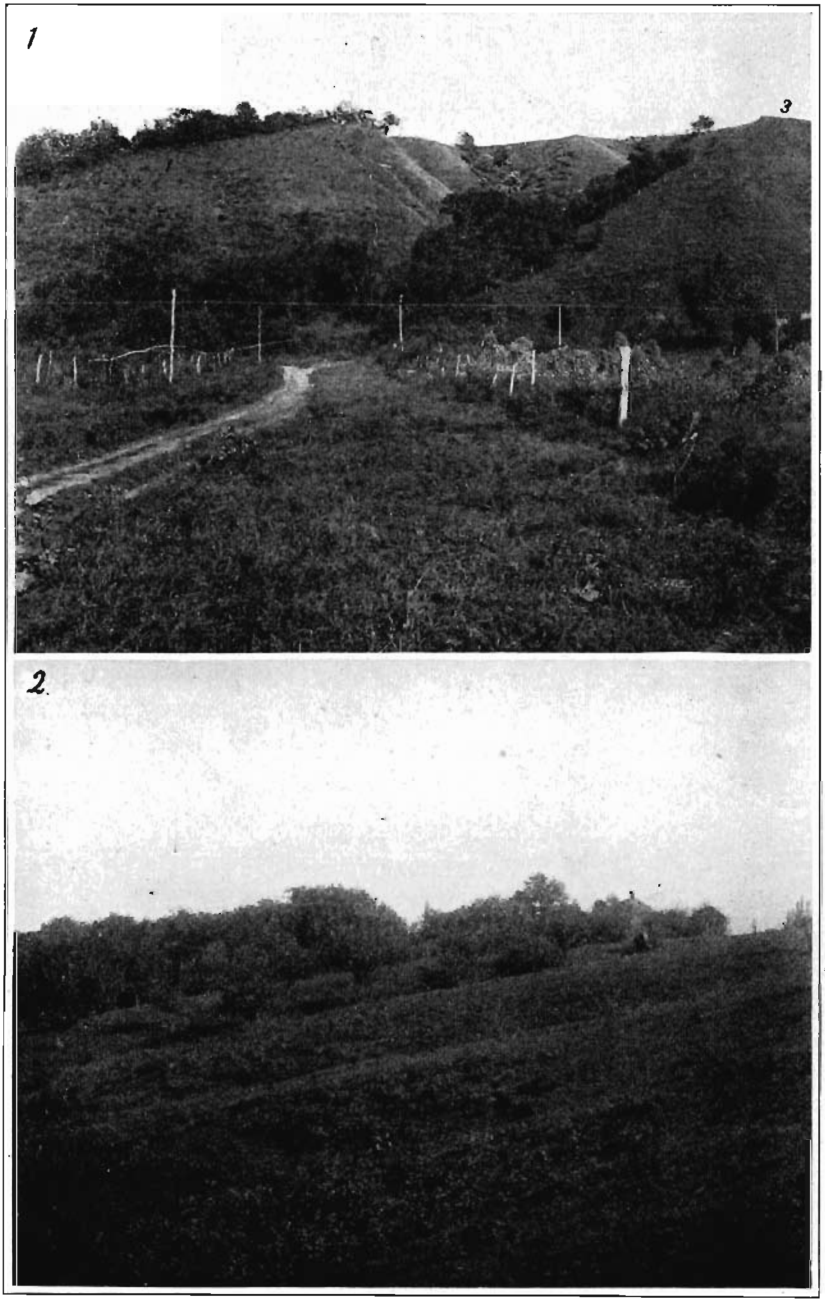

Plate XXXIX.—Meteorological stations, Missouri Valley. (1) Looking east toward stations (1) and (3). (2) Looking east of south toward station (4). (See pp. 454 and 459.)

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Corylus americana
Crataegus mollis
Cystopteris fragilis
Dicentra cucullaria
Ellisia nyctelea
Elymus striatus
Eupatorium urticaefolium
Festuca nutans
Fraxinus pennsylvanica
Hydrophyllum virginianum
Ostrya virginiana
Polygonatum commutatum
Prunus virginiana
Psedera quinquefolia
Quercus macrocarpa
Ranunculus abortivus
Rhus glabra (large)
Ribes gracile
Silene stellata
Smilax hispida
Solanum nigrum (introduced)
Symphoricarpos orbiculatus
Taraxacum officinale (introduced)
Tilia americana
Ulmus americana
Ulmus fulva
Viola sororia
Vitis vulpina
Zanthoxylum americanum

The following plants were collected on the border strip between stations (1) and (2). They present a mixture of species of both forest and prairie, the latter predominating:

Amorpha canescens
Anemone cylindrica
Aster sericeus
Ceanothus ovatus var. *pubescens*
Eupatorium altissimum
Fragaria virginiana
Fraxinus pennsylvanica (small)
Gerardia aspera
Helianthus scaberrimus
Monarda mollis
Onosmodium occidentale
Poa pratensis
Quercus macrocarpa var. *olivaeformis*
Rhus glabra (small)
Sanicula marilandica
Symphoricarpos occidentalis

Station 3 was located on the most prominent point on this side of the bluffs, and fully exposed to the south and west. It was about 350 feet almost due south of station (1), and like the latter was surrounded by a distinct prairie flora. Its position is shown at the point marked (3) in plate XXXVIII, figure 1, and plate XXXIX, figure 1.

This was the most exposed station of the series.

Station 4 was located on the east side of the same ridge, at a point 375 feet east and 220 feet south of station (3) and at the same altitude as that station. The ridge between stations (3) and (4) rises about twenty-five feet above them and its slope on the east side is sufficiently steep to afford protection from excessive evaporation on that side. The eastern slope was formerly covered with forest, but this had been removed and a young orchard has been set out on a part of the slope. Station (4) was in an open place sheltered only by the ridge but in an area which had been but recently forested. This station is shown at the point marked (4) in plate XXXIX, figure 2, looking south along the cleared slope.

The observations at stations (3) and (4) should be compared to bring out the protective influence of the ridge alone.

Care was exercised in placing the pieces of apparatus required for these observations in such manner that they did not interfere with each other.

The observations were continued for a whole day at intervals of about a week from the 13th of August to the 12th of September. Each observation day was given wholly to this work and hourly readings (excepting those of the evaporating pans) were made from 7 o'clock A. M. to 7 o'clock P. M. Earlier and later readings were also at first taken but they could not be continued as the days grew shorter and they are not here included. So far as made they did not in any way modify the results obtained.

Notwithstanding the care which was exercised in making these readings it is probable that occasional errors were made, the possibility of which will be appreciated by those who have ventured to face the tedium of such work in midsummer in a rough territory. The results which were obtained, however, are so generally consistent, and they agree so well with observations made at other points, notably at Ute by Superintendent D. H. Boot under the writer's direction, and at Omaha and Council Bluffs and in the vicinity of Lake Okoboji, Iowa, by the writer himself, that they are here offered with the confident conviction that such errors as may have occurred are rare or insignificant and would not materially affect the general results.

Rate of Evaporation.

The several types of evaporimeters did not show the same relative rate of evaporation at the several stations, but this was evidently due largely to the difference in position and altitude above the surface. In all cases, however, evaporation was shown to be much greater at the exposed stations (1) and (3) than at the more or less sheltered stations (2) and (4).

Evaporating pans. The evaporating pans were filled to the index (a pointed wire) at 7 o'clock A. M. Readings were then taken at 2 and 7 o'clock P. M. During the nights of the 13th and 14th days of August and 28th and 29th of August, the pans were also left in the field and readings were taken at 7 o'clock A. M. On the 28th of August observations were also made from 4 to 7 o'clock P. M. and were continued on the following day.

The following table gives the totals for the times indicated:

Amount of Evaporation from Evaporating Pans.

Date 1908	Hours	Stations			
		1-Prairie	2-Grove	3-Prairie	4-Cleared
Aug. 13.............	6 A. M.-7 P. M.	221 cc.	98 cc.	360 cc.	296 cc.
	7 P. M.-6 A. M.	131 cc.	57 cc.	144 cc.	111 cc.
Aug. 21.............	7 A. M.-7 P. M.	212 cc.	46 cc.	283 cc.	181 cc.
Aug. 28.............	4 P. M.-7 P. M.	84 cc.	9 cc.	118 cc.	58 cc.
	7 P. M.-7 A. M.	63 cc.	20 cc.	89 cc	36 cc.
Aug. 29.............	7 A. M.-7 P. M.	348 cc.	66 cc.	456 cc.	227 cc.
Sept. 5.............	7 A. M.-7 P. M.	250 cc.	47 cc.	375 cc.	139 cc.
Sept. 12............	7 A. M.-7 P. M.	357 cc.	116 cc.	500 cc.	213 cc.

Cup evaporimeters. At the same time the cup evaporimeters at stations (1) and (2) showed the following losses:

Date	Hours	Station 1	Station 2
August 13..............................	6 A. M.-6 P. M.	37 cc.	24.5 cc.
August 21..............................	7 A. M.-7 P. M.	27 cc.	10 cc.
August 28..............................	4 P. M.-7 P. M.	9 cc.	6 cc.
	7 P. M.-7 A. M.	2.5 cc.	2- cc.
August 29..............................	7 A. M.-2 P. M.	23 cc.	7.5 cc
September 5............................	7 A. M.-7 P. M.	35.5 cc.	14.5 cc.
September 12...........................	7 A. M.-2 P. M.	13.5 cc.	6 cc.

Piche evaporimeters. The Piche evaporimeters at stations (1) and (2) gave the following total results:

Date	Hours	Station 1	Station 2
August 13.........................	6 A. M.-7 P. M.	.34 cu. in.	.14 cu. in.
	7 P. M.-6 A. M.	.045 cu. in.	.04 cu. in.
August 21.........................	7 A. M.-7 P. M.	.30 cu. in.	.135 cu. in.
August 28.........................	4 P. M.-7 P. M.	.08 cu. in.	.025 cu. in.
	7 P. M.-7 A. M.	.015 cu. in.	.015 cu. in.
August 29.........................	7 A. M.-7 P. M.	.485 cu. in.	.22 cu. in.
September 5.......................	7 A. M.-7 P. M.	.45 cu. in.	.22 cu. in.
September 12......................	7 A. M.-7 P. M.	.675 cu. in.	.31 cu. in.

The Relative Humidity of the air varied at the several stations as indicated in the following table:

	August 21				August 29				September 5				September 12			
	Station				Station				Station				Station			
Hour	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
7	.79	.82	.80	.80	.86	.88	.84	.88	.88	.90	.88	.88	----	----	----	----
8	.75	.78	----	.75	.83	.83	.80	.82	.86	.88	.90	.82	.68	.70	.63	.59
9	----	----	----	----	.74	.78	.72	.75	.82	.84	.75	.78	.54	.56	.55	.63
10	.62	.66	.59	.58	.70	.72	.70	.73	.72	.79	.70	.70	.53	.57	.51	.51
11	----	----	----	----	.58	.58	.57	.59	----	----	.64	.61	.48	.53	.45	.45
12	.56	.62	.51	.57	.50	.54	.50	.47	.59	.63	.58	.58	.48	.51	.42	.44
1	.57	.60	----	----	.47	.46	.49	.52	.55	.52	.49	.52	.32	----	.36	.40
2	.57	.56	.61	.64	.52	.52	.53	.53	.45	.46	.43	.51	.33	.37	.33	.37
3	.66	.67	.61	.67	.49	.54	.52	.58	.44	.46	.38	.48	.32	.38	.35	.38
4	.62	.66	.58	.68	.54	.58	.55	.59	.45	.46	.46	.51	.35	.36	.37	.40
5	.61	.72	----	----	.52	.58	.58	.64	.47	.52	.46	.57	.39	.39	.40	.50
6	.72	.72	.68	.78	.59	.63	.66	.73	.54	.57	.64	.65	.41	.47	.43	.47
7	.70	.74	.68	.81	.72	.70	.72	.75	.73	.70	.48	.55	.43	.45	.43	.53

The psychrometric record for August 13th is incomplete, and is omitted.

The foregoing results show clearly that evaporation is much more rapid in the exposed prairie areas.

The relation which meteorological conditions bear to evaporation is well illustrated by the results which were obtained at station (1) and represented in part graphically in plates XL and XLI. Each of the figures on these plates presents three curves: The full line (A) represents the amount of evaporation from a Piche evaporimeter, measured in tenths of a cubic inch, the latter forming the ordinates of the curve; the broken line (B) represents the velocity of the wind in miles per hour, the latter forming the ordinates of the curve; and the dotted line (C) represents the temperature in Fahrenheit degrees, the latter also forming the ordinates of the curve.

In all cases the hours of the day between 7 o'clock A. M. and 7 o'clock P. M. form the abscissas of the curves, each space representing one hour.

The numbers 0, 2, 4, 6, 8, 10, 12 and 14 on the left hand side of each figure represent wind-velocity in miles per hour; the corresponding decimals represent evaporation from the Piche

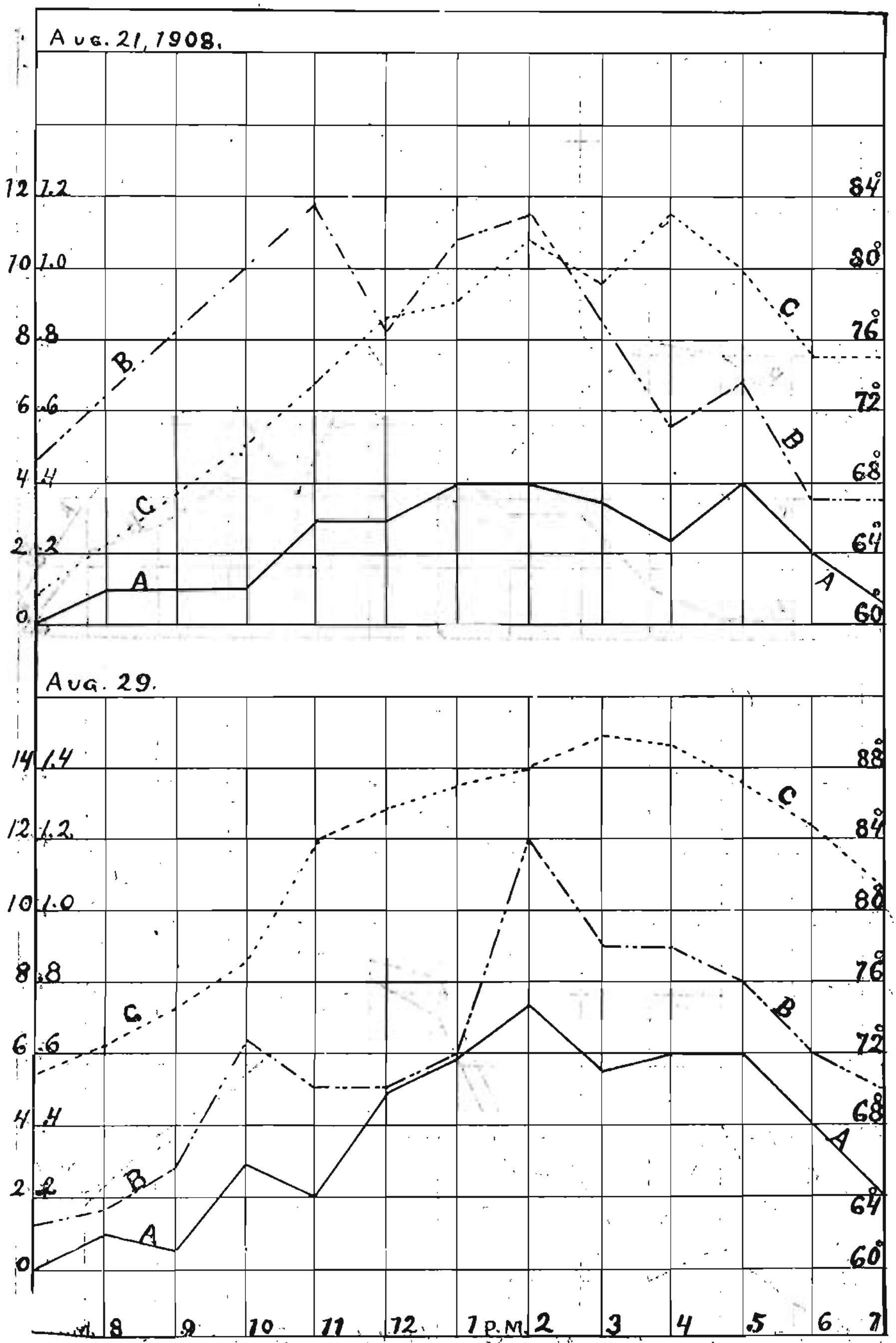

Plate XL.—Curves showing: (A) Evaporation from Piche evaporimeter in tenths of cubic inch. (B) Wind velocity in miles per hour. (C) Fahrenheit temperature. All for every hour of the day from 7 A. M. to 7 P. M. (1) For August 21, 1908. (2) For August 29, 1908. (See p. 462.)

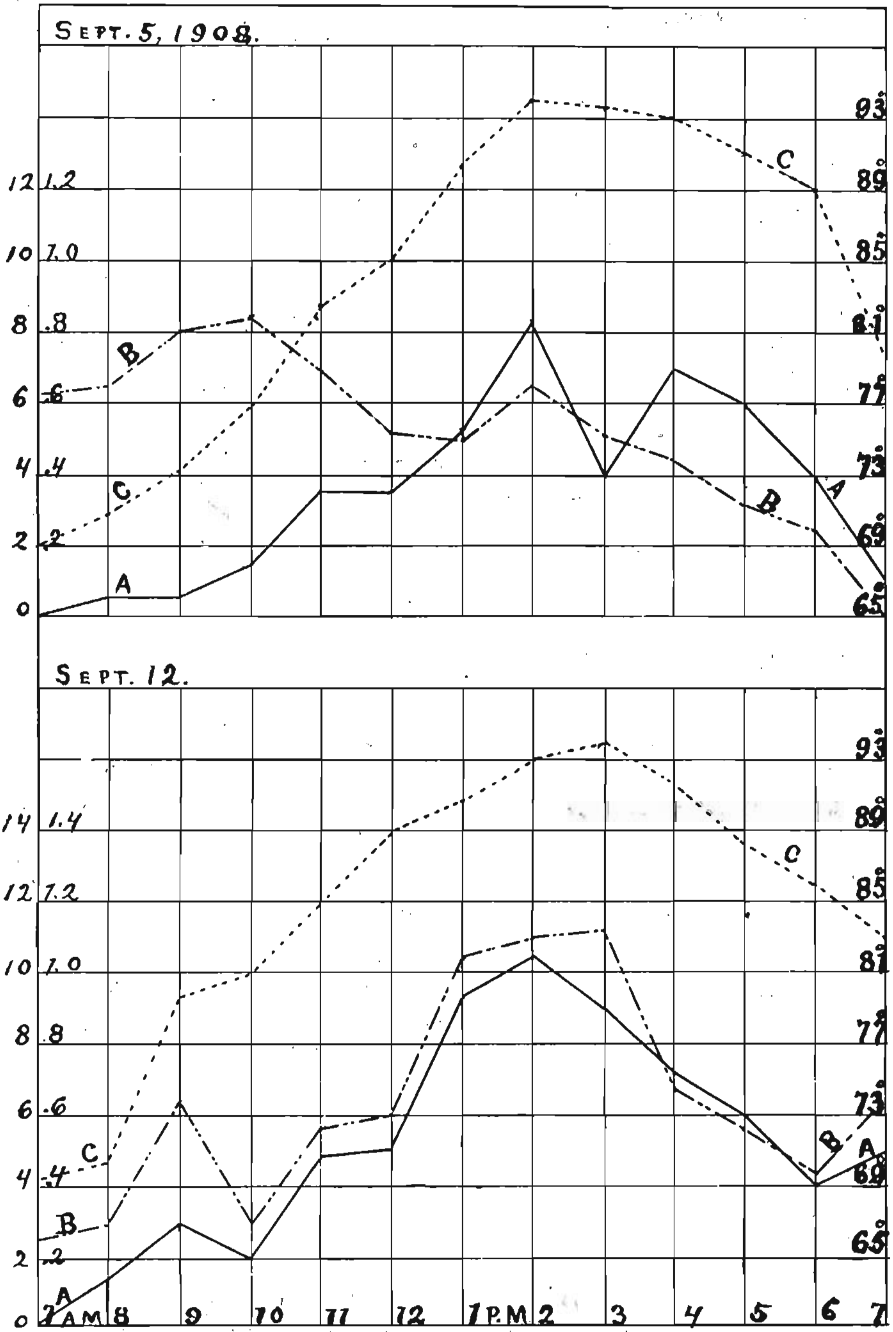

Plate XLI.—Same as plate XL. (1) For September 5, 1908. (2) For September 12, 1908. (See p. 462.)

evaporimeter measured in tenths of a cubic inch; and the degrees Fahrenheit are indicated on the right hand side of each figure.

A striking relation between evaporation and wind velocity is shown by these figures. While the temperature curve is in most cases comparatively regular the curves representing wind velocity and amount of evaporation are more or less irregular, but correspond closely to each other in their irregularities. This is especially noticeable in the afternoon when both wind and sun are most effective. The close relation between wind velocity and evaporation is more pronounced as the day advances, and it also became more striking as the dry season advanced and the relative humidity of the air diminished.

An inspection of the relative humidity table for station (1) shows the following variation:

	Minimum	Maximum	Average
August 21	.57	.79	.65
August 29	.47	.86	.62
September 5	.44	.88	.62
September 12	.32	.68	.44

Rains were frequent during the first half of August, but very little rain fell between the foregoing dates.

The curve for September 5th also shows that both wind and temperature must operate together to cause the maximum evaporation, for on this day the wind was quite brisk early in the morning, yet evaporation was slow until the temperature had increased sufficiently to induce great evaporation, the function of the wind evidently being the removal of the vapors as fast as they are formed thus making room for more. In the same connection it is interesting to compare the amount of evaporation at night and in the day time. It will be observed that at night evaporation at the several stations was more nearly the same than in the daytime, for the exposure of the several stations was then more nearly equal, the sun having disappeared and the wind having died down.

The foregoing facts suggest an explanation of the presence of dry prairies on southwesterly slopes, for these slopes are not only exposed to the prevailing southwesterly winds of summer but also to the "two-o'clock sun" which produces the maximum temperature and the minimum humidity of the air.

The clearness of the sky did not vary sufficiently to bring out any striking results. The record for the several observation days is briefly summarized as follows:

August 13. Hazy.
August 21. Hazy A. M.; cloudy P. M.
August 29. Cloudy A. M.; hazy P. M.
September 5. Clear but quite hazy.
September 12. Clear but somewhat hazy.

The direction of the wind for the same days varied as follows:

August 13. Northwest.
August 21. Mostly southwest.
August 29. Southeast A. M.; south P. M.
September 5. Southeast, then south, then southwest; at 3 o'clock P. M., west; at 5 o'clock, southwest; at 6 o'clock, southeast; and at 7 o'clock, northwest.
September 12. Southeast, then southwest, then southeast.

The barometric pressure at Station (1) varied as follows (measured in inches):

August 13.	28.97	to	28.88	A slight rise and then a gradual fall.
August 21.	28.79	to	28.75	A gradual fall.
August 29.	28.70	to	28.75	Somewhat irregular.
September 5.	28.72	to	28.68	Somewhat irregular.
September 12.	28.96	to	28.84	Somewhat irregular.

Relative humidity curves were not included in the figures on plates XL and XLI, for fear of causing confusion. These curves may be easily constructed by using the relative humidities recorded in the table as ordinates and the hours of the day as abscissas. For this purpose the lowest line in each figure should be marked respectively .56, .49, .43 and .31 and each vertical space should represent .06. Curves so constructed will correspond quite closely with the evaporation curves, being of course their reverse.

The conclusions reached from these observations may be briefly stated as follows: That evaporation is most rapid from surfaces exposed to the prevailing summer winds and to the afternoon sun, and that both are necessary to cause maximum evaporation; that in rough territory these surfaces are chiefly southwesterly and hence exposed as stated, and this at the time of the day when the relative humidity of the air is the lowest; that the effect of wind upon evaporation is best brought out and is greatest when the temperature is sufficiently high to produce rapid evaporation; that evaporation varies with the direction of the wind and the position of protective barriers such as ridges; and finally that upon all the areas exposed to maximum evaporation a prairie flora, largely xerophytic, is developed, while the mesophytes of the grove and forest develop in our territory only in places sheltered from the chief evaporating agencies.

Similar observations which were made during the same period at Council Bluffs and Omaha confirm these conclusions. A station was established at Council Bluffs, Iowa (on the east side of the Missouri valley) on a dry prairie ridge northeast of the Ninth avenue entrance to Fairmount Park, at an altitude of about 140 feet above the bottoms. This station was fully exposed to the south, southwest, west and northwest.

Another station was located at the same elevation near the intersection of Woolworth avenue and Sixth street in Omaha, Nebraska. This station was located on the rounded western bluffs on a slope looking northeast, and was well exposed to the north, northeast and southeast. This slope was formerly timbered but is now almost bare. This station was in charge of Mr. Lumir Buresh of the Omaha High School whose patient care and perseverance made the double observations possible, the writer taking charge of the station on the east bluff.

On the 17th of August the observations on the west side were made at another station located in a clearing on the timbered bluffs above Florence, Nebraska, all the readings for that date being made at this station. The Florence station was also about 140 feet above the river valley. All the other west side observations were made at the Woolworth avenue station.

The work was conducted in the same manner as at Missouri Valley, excepting that no evaporating pans were used.

The relative rate of evaporation on the opposite sides of the valley is shown in the following summary:

Date	Time	Piche Evaporimeter		Cup Evaporimeter	
		Council Bluffs	Omaha	Council Bluffs	Omaha
August 17	7 A. M. to 7 P. M.	.36 cu. in.	.10 cu. in.	43 cc.	24 cc.
August 30	12 M. to 7 P. M.	.41 cu. in.	.24 cu. in.		
September 6	10 A. M. to 7 P. M.	.39 cu. in.	.37 cu. in.	38 cc.	10 cc.
September 13	12 M. to 7 P. M.	.32 cu. in.	.27 cu. in.		

The direction of the wind on the same dates was as follows:

August 17. North and northeast.
August 30. South and southeast.
September 6. North, northeast and northwest.
September 13. Southeast.

The greater relative evaporation on the west side on September 13th was evidently due to the fact that the station was exposed to the southeast wind during the entire day, whereas the Council Bluffs station was sheltered.

The apparent great discrepancy between the Piche and cup evaporimeters on September 6th was evidently due to the circumstance that at the Omaha station the Piche evaporimeter was exposed to the sun while the cup evaporimeter was in the shade during most of the afternoon.

The observations already noted which were made at Ute by Mr. David H. Boot, and those made by the writer in the vicinity of the Lakeside Laboratory at Lake Okoboji in the summer of 1909, also confirm the general conclusions based on the observations made at Missouri Valley.

It is now necesary to consider the application of these results to our problem. The prairie areas are uniformly so situated that they are fully exposed to the factors which cause rapid evaporation, namely the sun and the wind. During much of the year they may present conditions quite favorable to plant growth, but there are seasons and there are portions of the year, especially in midsummer, when evaporation and consequent dessication become so extreme that only those plants which are especially adapted to dry regions can survive. The more or less frequent recurrence of such periods which are fatal to the mesophytes of the forest is sufficient to wipe out or rather prevent the development of a forest flora on those surfaces which are most exposed to evaporation. Forest trees are perennial and must exist through all the varying conditions of succeeding seasons. Any period, no matter how short, which is fatal to trees is sufficient to prevent the development of a forest even though the greater part of each season be favorable to tree-growth, and the failure of the trees of course results in the failure of the minor forest flora which in our territory is essentially mesophytic.

Moreover it should be remembered that trees are tall and lift the transpiring leaf surfaces to a considerable height. In this position the leaves are not only more exposed to the direct rays of the sun, but they are much more exposed to strong winds.

The well-known fact that wind-velocity increases with height above the ground which was demonstrated by Stevenson* and has been frequently verified since, increases the danger to taller plants and makes more difficult the development of forest trees. This increased exposure to evaporation at greater heights should also be kept in mind when comparing the results of the observations at Missouri Valley, for evaporation was there determined at or near the surface of the ground, therefore in positions most favorable to dry areas.

It should not be assumed, however, that increased evaporation necessarily means greater loss of water by the plant. Experiments which are now being conducted in the plant physiology laboratory in the State University of Iowa indicate that transpiration is stimulated and increased by somewhat greater wind velocity, but that when the velocity is increased beyond a certain maximum, which is variable for different plants, transpiration is diminished, the activity of the plant being evidently checked by the violence of the wind. The increased loss of water at the optimum velocity must not be set down as disadvantageous to the plant, for it merely indicates greater vigor and activity on the part of the plant.

However a limit must be reached, and moreover where hot, dry winds blow almost constantly, as they do in summer during the daytime in our territory, the loss of water from the unprotected younger structures and the interference with the stomatal apparatus which to some extent controls transpiration, must ultimately result in the elimination of all plants which cannot well resist these conditions.

This limits the flora of these exposed areas largely to xerophytes, and it is a fact especially worthy of note, and one which will be set out in detail in the near future, that the flora of the prairies, especially that of the usually dry midsummer period, is decidedly xerophytic. This is further emphasized by the sim-

*Journal of the Scot. Meteorological Society, New Series, vol. v, 1880, p. 348. Also cited in Schimper's Plant Geography (English edition), 1903, p. 76.

ilarity of the floras of the prairie and the xerophytic sand-dune areas, the plants of the latter being with very few exceptions identical with those of the dry prairie. That they are xerophytic is revealed in the tufted habit, as illustrated in figure 34; the development of large root-systems and the stunting of the exposed tops; the development of thick cutin, deep-seated stomata and strong protective tissues; the production of hairs and scales on the exposed surfaces; and various other adaptations which are recognized as essential to the protection of plants growing on dry surfaces. Hence the structurally protected xerophytes of the prairie persist in exposed places while the mesophytes of the forest fail, and any cause or combination of causes tending to bring about xerophytic conditions will eliminate mesophytes and give the field to the xerophytes of the prairie.

Rainfall should receive attention in connection with evaporation, but it is here given but little prominence as a factor in determining the treelessness of the prairies for the reasons first, that it is entirely sufficient for forest growth within our territory, as shown by Mr. Stern's table, and indeed it is sufficient throughout the prairie sections of the Mississippi valley, if only properly distributed, and second that it cannot be a determining cause because frequently, as illustrated by several of the figures, prairie and forest are in close proximity, upon opposite sides of the same ridge, where they evidently receive the same amount of rain.

The conclusion is therefore inevitable that the question is one of conservation rather than precipitation of moisture, and the claim usually made by meteorologists that forests have no effect on precipitation has no significance in connection with our problem, nor has it any application to the question of the influence of the forest on moisture, for the forest must be considered as a conservator of moisture rather than a rain-maker.

Moreover it must be remembered that a tree, or any other ordinary plant, is quite as much dependent for the possibility of carrying on its functions on the moisture of the air as it is on the moisture of the soil, and any conditions which serve to dissipate the moisture of the air will be fatal to many plants, especially those which are mesophytic, even though sufficient moisture falls upon the soil.

CONTRIBUTING CAUSES OF PRAIRIES.

In the extensive literature of the subject the treelessness of the prairies has been attributed to various causes. It is not purposed here to enter into a detailed discussion of the influence of the various factors which have affected the problem as that is reserved for a more extended paper on the subject now in print, but a brief review of the chief causes which have been presented in explanation of the phenomenon may be of interest.

Fire.—This has been the most widely accepted cause of the prairies, and was offered by R. W. Wells as early as 1818* and has been accepted by a large number of writers since. To those who still recall the magnitude and the fury of prairie fires this may seem a plausible explanation, for trees would be injured or killed and seedlings would be destroyed, making the perpetuation of the forest impossible.

It is much more probable, however, that such fires were possible because of the treelessness of the prairies and the consequent annual development of a compact crowded mass of vegetation which furnished abundant fuel to the flames.

While no doubt locally effective, this factor does not explain the general phenomenon. Many tracts still uncultivated have been free from the scourge of fire for thirty or forty years, yet they have not developed groves. The testimony of some of the oldest settlers in Harrison and Monona counties agrees that there has been a denser growth developed in the limited natural groves of the territory since the cessation of fires, but that there has been little or no lateral extension of the groves, nor have any new groves appeared except where set out by man. The native groves still seek the sheltered slopes and valleys as of yore.

Moreover fires do not explain the absence of trees and the presence of a prairie flora in the oak openings already described, as it would be impossible to conceive of the frequent recurrence of fires on these limited areas in the heart of the forest which

*American Journal of Science and Arts, Series I, vol. i, pp. 332 and 333.

remain prairie to the present day. Nor do they explain the absence of trees and the presence of the prairie flora on sand-dune areas which do not as a rule produce a sufficient amount of vegetation to feed such fires.

Fires cannot be regarded as more than a local modifying factor.

Excess of moisture.—Excess of moisture, especially in undrained places, is fatal to most trees, and this was regarded as an important factor in prairie-formation and was advanced as early as 1820 by Bourne,* who thought that prairies were due to excess of water and the barrens to fires. This seemed especially plausible in such regions as the Wisconsin drift area in the north-central part of Iowa where large undrained areas appeared upon the general prairie. But this explained the absence of trees from the prairie swamps and not from the higher prairie, and certainly not from the oak barrens nor from the prairie ridges of our territory.

Old lake-beds.—The same thought was carried a little farther by those who advanced the theory that the whole prairie region was once a great lake, a theory which was consistent with the lacustrine hypothesis of loess-formation. The lake theory was offered by J. D. Whitney in 1858,† and was favored by many geologists. It was especially urged by Lesquereaux‡ and by Alexander Winchell.§

This theory also fails to explain the types of prairie mentioned under the preceding head and is entirely inconsistent with the æolian hypothesis of loess-formation, a fact of special importance because much of the prairie occurs upon loess.

Old sea-bottom.—In his discussion of the prairies of Alabama W. W. McGuire** expressed the opinion that the prairies of that region were formed by the sea. Whatever may be the relation which the areas here designated as prairies bear to our northern prairies it is certain that the latter were not formed by the sea,

*American Journal of Science and Arts. Series I, vol. ii, p. 36.

†See Hall's Geological Survey of Iowa, vol. i. p. 25.

‡Geological Survey of Illinois, vol. i, 1866, pp. 238-254.

§American Journal of Science and Arts; Series II, vol. xxxviii 1864, p. 332; and Centennial History of Mason County, Ilinois, 1876, pp. 67-73.

**American Journal of Science and Arts, Series I, vol. xxvi 1834, pp. 93-98.

for glacial, fluviatile and æolian formations have been deposited in our territory since it was elevated above the sea.

Lack of moisture.—In direct opposition to the preceding views are those which were held by those who attempted to account for the prairie on the ground of insufficient moisture. Here were included the references to insufficient rainfall to which attention has already been given, and here may be included the conclusions reached in this paper.

Temperature.—Temperature alone has not been regarded as an important factor excepting in so far as it affects humidity, and also because a high temperature tends to bring out buds earlier on southern slopes and thus exposes them to late frosts. The latter, however, is of greater importance in its relation to cultivated trees. Native groves did not ordinarily develop on southerly slopes and temperature could not have therefore produced the stated effect.

Glacial action.—Various attempts have been made to connect the prairies more or less directly with glacial action, but this explanation encounters an insurmountable obstacle in the presence over large parts of our prairies of an æolian loess deposit which was evidently interglacial or postglacial, and in the presence of prairie on comparatively modern alluvial plains.

Geological formations.—Numerous efforts have been made to show some relation between the prairies and surface geological formations, but as has been noted prairies occur on all the geological formations which come to the surface in the upper Mississippi valley, and geological formations seem to affect the problem only as they determine topography or the kind of soil.

Soils.—Soils have been closely associated with the preceding factor and much importance has been attached to them. But prairies appear upon all of our soil types, and soils seem to influence the formation of prairie only when their physical composition facilitates run-off or evaporation.

Wind.—Wind alone has been considered a factor of much importance in prairie-formation but the facts presented in this paper demonstrate that it is effective only when acting with a high temperature.

Cattle and bison.—Some importance has been attached to the earlier effects produced by the tramping and grazing of great bison herds, and later to over-grazing, but these are usually regarded as merely local.

Not one of the foregoing factors can account for the prairies in their various aspects, nor can the combination of all of them explain all the phases of these treeless tracts. Exposure to evaporation and a common flora seem to be the only universal characteristics, and Harrison and Monona counties furnish a fair share of evidence to the effect that exposure to evaporation is the dominant cause of the prairie and that the prairie flora is the response to the conditions produced by this exposure.

Tree-Planting.

The conclusions concerning the cause of the treelessness of the prairies might make it appear that all attempts at tree-cultivation in the prairie sections must ultimately fail. It is extremely probable that if left to themselves the trees which have been set out on the prairies would fail excepting possibly where large groves have been set out. The usual fate of isolated trees (excepting the cotton-wood, which thrives alone) and the failure of many of the groves in the dry seasons of the middle nineties warn us that the prairie is quite as illy adapted to tree growth as ever, and that trees will succeed only when planted in larger groves and given proper care. For the conditions on the prairies are so near the border line that with proper care and attention man may throw the balance in favor of the trees and cultivate them successfully where they would fail naturally.

That forest trees will grow on the prairies of Harrison and Monona counties is amply demonstrated by the numerous groves and shelter-belts which are scattered over the landscape, and by the numerous shade-trees cultivated in the towns and along the highways.

The most common trees in the groves and shelter-belts are the box-elder, soft maple, cottonwood, green ash, walnut, catalpa, Scotch pine, Austrian pine, and red cedar. The first five and the last one are native. Willows are also sometimes planted for shelter-belts.

For shade and ornamental purposes the following species are most commonly planted in addition to those already mentioned: the American elm, red elm, black cherry, mulberry, hackberry and honey locust among native species, and the black locust, hard maple, mountain ash, white pine, balsam, Norway spruce, hemlock, arbor vitæ and other introduced species.

Most of these species require the protection of shelter-belts and for this purpose the species of the first list are suitable.

The people of the western part of the state owe a debt of gratitude to one of the old settlers of Monona county, Hon. C. E. Whiting, who not only by word but by example taught them that trees would thrive upon the prairies, and who transformed his homestead, northeast of Whiting, and its vicinity from a monotonous prairie to a region sheltered and made beautiful by splendid groves, for not only did he himself plant extensively but he inoculated his neighbors with the desire to do likewise. No grander monument stands today in our state than that which Judge Whiting erected to himself in the magnificent groves and shelter-belts which stand as evidence of his wisdom and foresight.

A brief record of these groves, furnished by his daughter, Mrs. Charles Holmes, will be of interest.

The first grove was set out in 1865. It is located near the old homestead, one of the finest country homes in Iowa, in the northeast corner of section 25, township 85 north, range 46 west, and consists largely of soft maples. The seed was planted in the spring of 1865, and the trees were cultivated like any other ordinary crop. These soft maples now vary from eight to seventeen inches in diameter, and form a dense forest from which all traces of prairie plants have disappeared though the grove was set out on the open prairie. In the shelter of this grove practically all the shade trees listed were planted and they have prospered remarkably well, adding greatly to the beauty of the home.

It is interesting to note that the original prairie flora has here been entirely replaced by a typical forest flora which has been developed notwithstanding the fact that all the trees in the grove were grown from seed.

The following grouping of plants found in the grove will suggest the manner of introduction.

PLANTS IN THE WHITING SOFT MAPLE GROVE.

FRUITS MORE OR LESS FLESHY.

Evonymus atropurpureus Jacq. Wahoo.
Fragaria virginiana Duches. Wild Strawberry.
Menispermum canadense L. Moonseed.
Morus rubra L. Mulberry.
Psedera quinquefolia (L.) Greene. Virginia Creeper.
Rhus toxicodendron L. Poison Ivy.
Ribes gracile Michx. Wild Gooseberry.
Rubus occidentalis L. Wild Raspberry.
Sambucus canadensis L. Common Elder.
Vitis vulpina L. Wild Grape.

FRUIT CARRIED BY WIND.

Acer negundo L. Box Elder.
Eupatorium purpureum L. Purple Boneset.
Eupatorium urticaefolium L. White Boneset.
Fraxinus pennsylvanica var. *lanceolata.* (Bookh.) Sarg. Green Ash.
Lactuca floridana (L.) Gærtn.
Ulmus americana L. White Elm.

FRUIT BUR-LIKE.

Arctium minus Bernh. Burdock.
Galium aparine L. Bed-straw.
Lappula virginiana (L.) Greene. Beggar's Lice.
Sanicula marilandica Michx. Black Snake-root.

SEEDS EATEN BY BIRDS. (?)

Amphicarpa monoica (L.) Ell. Hog Peanut.
Zanthoxylum americanum Mill. Prickly Ash.

MISCELLANEOUS SEEDS—SMALL, LIGHT.

Cryptotaenia canadensis L.
Plantago Rugelii Dec. Plantain.
Urtica gracilis Ait. Nettle.

ARTIFICIALLY PLANTED.

Acer saccharinum L. Soft Maple.
Juglans nigra L. Black Walnut.
Pinus strobus L. White Pine.
Pinus sylvestris L. Scotch Pine.

The fleshy and edible fruits were probably carried by birds from the native groves along the Missouri or the Little Sioux; the light or winged fruits were carried by the wind; the bur-like forms were carried by animals or man; and some of the light miscellaneous forms may have been driven along the surface of snow in winter.

It is worthy of note that with the exception of some of the trees which were set out by Judge Whiting, and the burdock which is an introduced weed, the plants are all native and belong to the forest flora. Yet the nearest natural grove is several miles away.

This complete change of flora illustrates how different are the habits and requirements of the forest and prairie floras.

The second grove was planted along the north line of the northeast quarter of the same section just west of the first grove. This consists largely of cottonwoods which were set out in 1866, seedlings from the Missouri bars being used.

Some of the cottonwoods are older, having been planted in the early sixties, and walnuts were planted later, seed which had been covered with earth all winter being used.

The third grove was planted in 1867. It is located on the north line of the same section and forms a continuous grove with the two preceding groves. It consists of walnuts which were treated as before.

The fourth grove consists chiefly of walnut which was set out in 1869. It is located along the north line of the northeast quarter of the northwest quarter of the same section.

The fifth grove was set out in 1870, and consists of soft maple. Seed collected along the Little Sioux was used. This grove is located in the northwest quarter of section 30, township 85 north, range 45 west.

The sixth grove consists chiefly of walnut and was planted in 1871. It is three-quarters of a mile long and lies along the south line of the north half of section 25. There are a few old cottonwoods in this grove.

The seventh grove is nearly a mile and a half long and extends along the north line of section 30 and the north line of the northwest quarter of section 29, township 85 north, range 45 west. The grove is about fifteen rows wide and the rows are mostly about five feet apart. This grove or shelter-belt consists of green ash, soft maple, walnut and cottonwood, and excepting where injured by stock, or where too closely crowded, the trees are thrifty.

Not only did Judge Whiting thus demonstrate the possibility of growing trees successfully on the prairies, but he gave the benefit of his experience to others, for he published numerous reports of his experiences in the government agricultural reports and in the Reports of the Iowa Horticultural Society. The latter contains a number of articles which might well be read with profit by those who are recklessly cutting away their groves and shelter-belts. The more important of these papers are the following:

Tree and Timber Culture. First Annual Report, 1867, pp. 43-45.

Cottonwoods, pp. 125-126; and Timber growing, pp. 197-200; both in the Eighth Report for 1873.

Value of the Black Walnut. The Report for 1880, pp. 379 and 380.

How far is it profitable to plant timber belts for protection? The same Report, pp. 297-299.

In the last paper Judge Whiting made a statement which should receive the attention of every farmer in the state. It is as follows: "Timber-belts for the protection of crops alone will pay."

This statement, made by a man who had greater experience than any other person in the state, is especially significant in the light of the observations made at Missouri Valley. The latter demonstrate that an obstruction which checks the hot summer winds also checks evaporation. Crops suffer from evaporation even more than do ordinary prairie plants and a shelter-belt will check this and assist in conserving the moisture so necessary to the crops. Farmers will yet come to a realization of the fact that it pays to use a strip of even the most valuable land for a shelter-belt where the field is exposed to summer winds, for the gain in the field resulting from the protection given by the shelter-belt will more than compensate in the end for the loss of possible crops on the strip given up to the grove.

As soon as time permits the writer expects to determine quantitatively, if possible, the difference which such an obstruction as the shelter-belt would offer would cause in the amount of evaporation from the adjoining field. That there is a difference the experiments thus far made demonstrate beyond question.

The record of tree-planting in Monona county would not be complete without some reference to the efforts of Judge Addison Oliver of Onawa. In 1890 Judge Oliver planted 1,500 bushels of walnuts on a tract three-quarters of a mile square in sections 16 and 17 in Franklin township, south of Onawa. The native forest of cottonwood, soft maple and elm had been removed from this tract so far as the timber was serviceable for railway uses, and the walnuts were promiscuously planted on this cut-over land. The trees were not cultivated but were permitted to grow without care. Many of the walnuts were destroyed by late frosts when quite young.

Many thousands of black locust, Russian mulberry and catalpa were also planted on the same tract, but the catalpas were all destroyed and few of the Russian mulberries survived. The black locust is regarded by Judge Oliver as the most rapid grower and the best of the hard-wood trees in this section of the state.

Judge Oliver also set out about fifty acres of walnuts, cottonwoods and some ash at his old homestead five miles southeast of Onawa. These suffered more or less from fires and neglect. He also planted four strips of walnuts totaling three and a half miles in length and each five rods wide. He also planted diamond willows in low places and regards them as very valuable for fuel.

Many other illustrations of successful tree-planting in our territory might be given, but these splendid examples sufficiently demonstrate that with proper care trees may be profitably grown on the alluvial prairies. That they may also be successfully grown on the uplands is shown by the innumerable groves which dot the hillsides and the upland prairies in both counties.

Weeds.

Many introduced plants and several native species rank as weeds. They may be only unattractive, giving to roadsides, barnyards, waste places and front yards an unsightly appearance, or they do positive injury by crowding or destroying useful crops in fields and gardens, or by restricting the area of pastures by occupying much space to the exclusion of forage plants.

Most of the foreign weeds were introduced with seeds of crop-plants, but some are undobtedly distributed by the railways which also assist in the distribution of native weeds. Several native species of plants are sufficiently adaptable to environment to become weeds even on cultivated grounds.

Cutting of weeds before their fruiting season and thorough cultivation of the soil will eliminate, or at least much restrict these pests. However, even such methods are effective only when a concerted effort is made in a large territory. Individual effort avails but little if the weeds of surrounding lands are permitted to grow unchecked.

The laws of the state already provide penalties for failure to eradicate certain weeds, but unfortunately these laws are not self-enforcing. If our citizens realized the magnitude of the loss which our state suffers annually from mere weeds a more effective public sentiment would force closer attention to the problem of weed extermination.

Most of the weeds here listed are widely distributed through Harrison and Monona counties, but in the following list only those localities are specifically mentioned in which specimens were collected. Those marked with an asterisk were introduced.

WEEDS AND INTRODUCED PLANTS.

**Abutilon Theophrasti* Medic. Velvet Leaf. Local.

**Amaranthus albus* L. Not uncommon. Turin, Onawa.

Amaranthus blitoides Wats. In dry places. Missouri Valley, Grant Center, etc.

**Amaranthus hybridus* L. Pig-weed. Common. Logan, etc.

**Amaranthus retroflexus* L. Locally very common. Missouri Valley, Grant Center, etc.

Ambrosia artemisiaefolia L. Ragweed. Very common in waste places along roadsides, etc.

Ambrosia trifida L. Greater Ragweed. Locally common on lower grounds.

**Anthemis cotula* L. Dog-fennel. Pisgah, waste places, not common.

Bidens frondosa L. Beggar-ticks. Ute.

**Brassica arvensis* (L.) Ktze. Charlock. Very common in fields, etc.

**Brassica nigra* (L.) Koch. Black Mustard. Less common than the preceding. Missouri Valley, etc.

**Bromus racemosus* L. Missouri Valley, Onawa. Local.

**Bromus secalinus* L. Cheat. Fields, local. Missouri Valley, etc.

**Camelina sativa* (L.) Crantz. False Flax. Common along railways. California Junction.

**Cannabis sativa* L. Hemp. Locally common. Missouri Valley, Logan.

**Capsella bursa-pastoris* (L.) Medic. Shepherd's Purse. Waste places. Missouri Valley, Ute, Grant Center, etc.

Cassia chamaecrista L. Partridge-pea. Locally very common on loess and in sandy places. Missouri Valley, etc.

Cenchrus carolinianus Walt. Sand-bur. On loess and sand. Missouri Valley, etc.

**Chenopodium album* L. Lambsquarters. Common in gardens and waste places. Logan, Missouri Valley, Turin, Onawa, Grant Center.

**Chenopodium urbicum* L. Goose-foot. Less common. Missouri Valley, Turin, Onawa.

Convolvulus sepium L. Wild Morning-glory. Very common along roadsides, in fields, etc. Missouri Valley, Grant Center, etc.

**Cynoglossum officinale* L. Beggar's Lice. Not common. Calhoun.

**Dactylis glomerata* L. Orchard Grass. Local. Missouri Valley, Grant Center, etc.

**Datura tatula* L. Thorn Apple. Locally common, especially in hog-pastures.

**Daucus carota* L. Carrot. Not common. Mapleton.

**Digitaria sanguinalis* (L.) Scop. Crab-grass. Common in waste places. Missouri Valley, etc.

Dyssodia papposa (Vent.) Hitch. Fetid Marigold. Very common in dry places. Missouri Valley, Grant Center, etc.

**Echinochloa crus-galli* (L.) Beauv. Barnyard-grass. Waste places. Logan, Missouri Valley.

**Eragrostis megastachya* (Koel.) Link. Snake-grass. Local. Logan, Ute, etc.

Eragrostis pilosa (L.) Beauv. Locally common. Logan, etc.

Erigeron canadensis L. Horse-weed. Very common in waste places. Logan, Blair bridge, Ute, Grant Center, etc.

Erigeron ramosus (Walt.) BSP. Daisy Flea-bane. Very common in meadows, etc. Missouri Valley, Blair bridge, Turin, Onawa, Grant Center, etc.

Euphorbia heterophylla L. Spurge. Not common. Missouri Valley.

Euphorbia maculata L. Locally common. Turin, Onawa, Missouri Valley.

Euphorbia marginata Pursh. Snow-on-the-mountain. Common in dry pastures. Missouri Valley, Turin, Grant Center.

Euphorbia Preslii Schrad. Spurge. Common in dry places. Logan, Missouri Valley, Blair bridge, Ute.

Helianthus annuus L. Sun-flower. Common. Missouri Valley, Blair bridge, Onawa, Turin, Grant Center.

**Hibiscus trionum* L. Flower-of-an-hour. Local. Missouri Valley, Modale.

Hordeum jubatum L. Squirrel-tail Grass. Very common locally. Missouri Valley, Murray hill, Turin, Ute, Grant Center.

**Ipomoea purpurea* (L.) Roth. Morning-glory. Very common in fields, especially on the alluvial bottoms. Missouri Valley, etc.

Iva xanthiifolia (Fresen.) Nutt. Marsh-elder. Onawa, Grant Center, etc.

**Lactuca scariola* L. Prickly Lettuce. Common in waste places. Missouri Valley, Turin, Onawa, etc.

Lepidium apetalum Willd. Pepper-grass. Common in dry places. Missouri Valley, Turin, Grant Center, etc.

**Lepidium virginicum* L. Pepper-grass. In waste places. Grant Center, etc.

**Lotus corniculata* L. Rare. Mapleton.

**Lychnis dioica* L. Red Campion. Not common. Missouri Valley.

Lygodesmia juncea (Pursh) D. Don. Very common on loess hills. Missouri Valley, Logan, Turin, Grant Center.

**Malva rotundifolia* L. Round-leaved Mallow. Waste places. Turin, Onawa, Grant Center.

Martynia louisiana Mill. Unicorn-plant. Reported by Pammel. Rare.

**Medicago sativa* L. Alfalfa. Common in waste places. Missouri Valley, etc.

**Melilotus alba* Desv. White Sweet-clover. Locally very common. Missouri Valley, Logan, Turin, Onawa, Grant Center, etc.

**Melilotus officinale* L. Yellow Sweet-clover. Less common. Missouri Valley, Grant Center.

**Nepeta cataria* L. Catnip. Local. Turin, Grant Center, etc.

OEnothera biennis L. Evening Primrose. Common. Missouri Valley, Logan, Grant Center.

Oxalis stricta L. Yellow Wood-sorrel. Common in fields, etc. Missouri Valley, Turin, Onawa, Ute, Grant Center, etc.

Oxybaphus nyctagineus (Michx.) Sweet. Four-o'clock. Local. Missouri Valley, etc.

Oxytropis Lamberti Pursh. Loco-weed. Locally common on dry loess hills. Missouri Valley, Turin, Grant Center.

Panicum capillare L. Old-witch Grass. In fields, etc. Missouri Valley, Grant Center, etc.

Panicum Scribnerianum Nash. Prairie Panic-grass. Common in dry pastures. Missouri Valley, Logan, Turin, etc.

**Phleum pratense* L. Timothy. Frequent. Onawa, Grant Center, etc.

Physalis subglabrata Mack. & Bush. Ground Cherry. Local. Logan.

**Plantago lanceolata* L. Plantain. In fields, etc. Missouri Valley, Mapleton.

Plantago Rugelii Dec. Plantain. Locally common. Missouri Valley, Ute, etc.

Poa pratensis L. Blue Grass. Everywhere common.

**Polygonum aviculare* L. Local. Missouri Valley, Grant Center, etc.

**Polygonum erectum* L. Local. Missouri Valley, Grant Center.

**Polygonum convolvulus* L. Bind-weed. Quite common. Logan, Grant Center, Ute, etc.

**Polygonum orientale* L. Prince's Feather. Local. Missouri Valley, Grant Center.

Polygonum pennsylvanicum L. Smart-weed. Common. Missouri Valley, Logan, Modale, Turin, Ute, Grant Center, etc.

**Rumex acetosella* L. Sour-dock. Chiefly along railroads. Missouri Valley, Turin.

**Rumex crispus* L. Curly-dock. Locally common. Missouri Valley, Grant Center, etc.

Rumex verticillatus L. Dock. Local. Missouri Valley.

**Salsola kali* var. *tenuifolia* G. F. W. Meyer. Russian-thistle. Dry places. Missouri Valley, Logan, Onawa, Grant Center.

**Setaria viridis* (L.) Beauv. Green Fox-tail. Common in fields, etc. Missouri Valley, Logan, etc.

**Sisymbrium officinale* L. Hedge Mustard. Waste places and roadsides. Grant Center, etc.

Solanum carolinense L. Horse Nettle. Local. Mapleton, Logan.

**Solanum nigrum* L. Black Nightshade. In fields and gardens. Missouri Valley, Grant Center, etc.

**Solanum rostratum* Dunal. Buffalo-bur. Introduced from the southwest. Woodbine. Reported by Pammel.

Solidago rigida L. Stiff Golden-rod. Very common in dry pastures. Missouri Valley, Logan, Turin, Ute, Grant Center, etc.

Sonchus asper (L.) Hill. Sow Thistle. Waste places. Logan, Grant Center, etc.

Strophostyles helvola (L.) Britt. Wild Bean. Sandy places. Blair bridge.

Strophostyles pauciflora (Benth.) S. Wats. Wild Bean. On loess and sand. Missouri Valley, etc.

**Taraxacum officinale* Weber. Dandelion. Very common. Missouri Valley, Ute, Grant Center, etc.

**Thlaspi arvense* L. Penny-cress. Chiefly along railways. Little Sioux, California Junction.

**Trifolium hybridum* L. Alsike Clover. Becoming very common. Missouri Valley, etc.

**Trifolium pratense* L. Red Clover. Common. Missouri Valley, etc.

Trifolium repens L. White Clover. Common. Missouri Valley, Ute, Grant Center, etc.

**Verbascum thapsus* L. Mullein. Local. Ute, etc.

Verbena bracteosa Michx. Local. Pisgah, Grant Center, etc.

Verbena hastata L. Blue Vervain. Frequent. Missouri Valley, Logan, etc.

Verbena stricta Vent. Hoary Vervain. Very common, especially in prairie pastures, etc. Throughout our territory.

Verbena urticaefolia L. White Vervain. Local. Missouri Valley, Turin, Ute, etc.

Vernonia fasciculata Michx. Ironweed. In low pastures. Missouri Valley, etc.

Vernonia noveboracensis (L.) Willd. Locally common in dry pastures. Missouri Valley, Turin.

Xanthium commune Britt. Cockle-bur. Common in waste places and fields.

Yucca glauca Nutt. Soap-weed. Locally common in dry loess pastures. Turin, Grant Center, etc.

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While it is thus difficult to make specific acknowledgments the services rendered by some of the citizens of these counties are so valuable that they should receive special mention.

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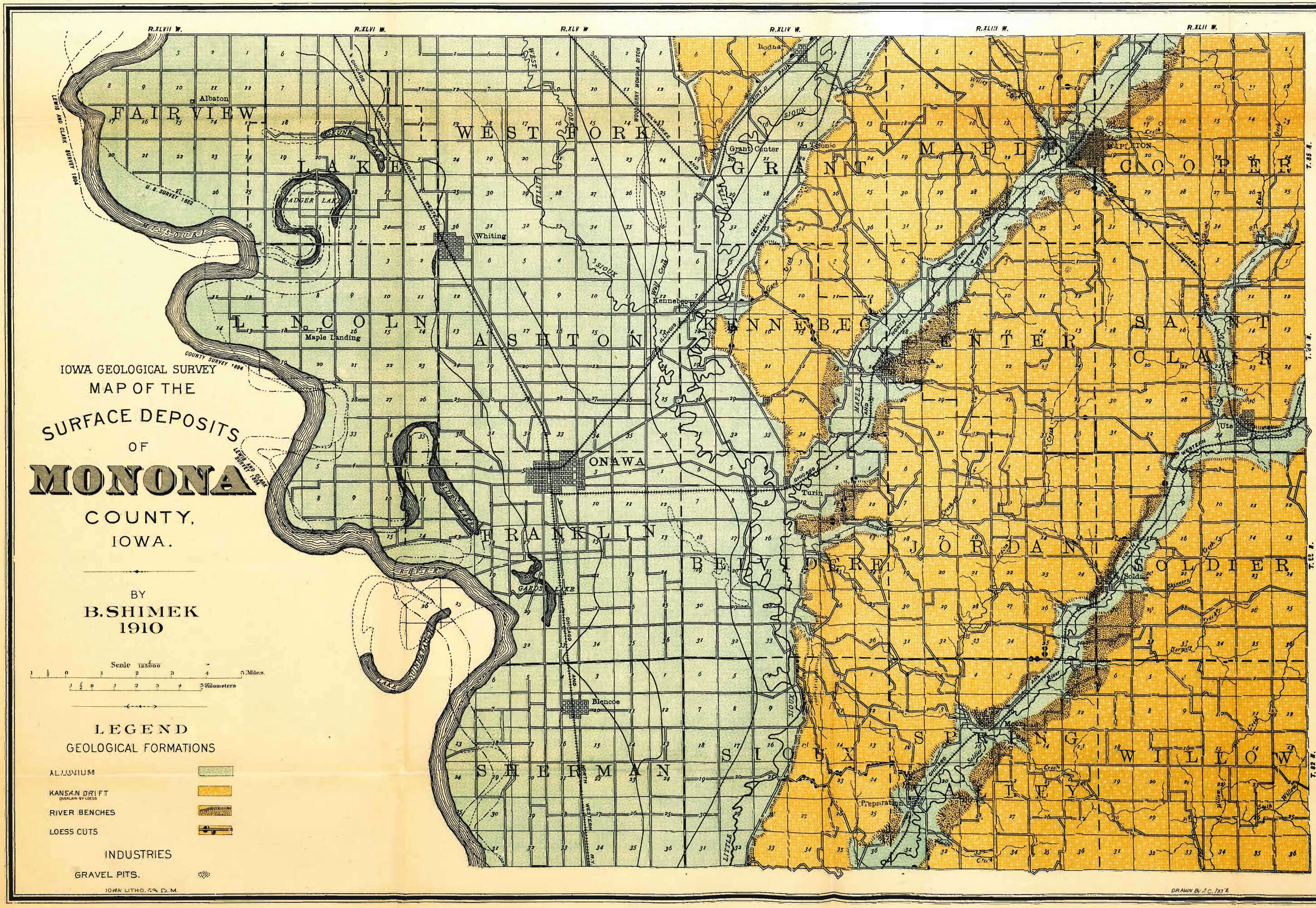
IOWA GEOLOGICAL SURVEY
MAP OF THE
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BADGER LAKE
GARDS LAKE
LEWIS AND CLARK SURVEY 1804
U.S. SURVEY 1852
COUNTY SURVEY 1894
DRAWN BY F.C.

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GEOLOGY OF DAVIS COUNTY

BY

MELVIN F. AREY

GEOLOGY OF DAVIS COUNTY

BY MELVIN F. AREY

CONTENTS

GEOLOGY OF DAVIS COUNTY

INTRODUCTION

LOCATION AND AREA.

Situated on the Missouri state line, the third county from the Mississippi river, Davis county has for neighboring counties in the state Van Buren on the east, Wapello on the north and Appanoose on the west. It comprises twelve complete and four fractional congressional townships, the latter being in the south tier. Owing to the southerly trend of the state line, the west boundary is about two-thirds of a mile longer than the east. Five only of its civil townships are conterminous with congressional townships. The area is approximately 500 square miles. Bloomfield, the county seat, is in the geographical center and is on two of the three railroads traversing the county.

PREVIOUS GEOLOGICAL WORK.

The Des Moines river passes through the northeast corner of this county for scarcely more than two miles of its course, but the outcrop of coal along its banks in many localities drew the attention of the early geologists to all the region through which the river runs and so this portion of Davis county received its share of attention.

Owen* in noting the occurrence of coal in this neighborhood describes an outcrop of coal in three seams in the midst of a mass of bituminous shale, towards the mouth of Soap creek in

*Owen: Geological Survey of Wisconsin, Iowa and Minnesota, p. 113, 1852.

section 3, township 70 north, range 12 west. He describes the coal as "slaty in character and having the appearance of charcoal on the cleavage surfaces."

The interest in this locality was enhanced by the discovery of springs along Salt creek, a small branch of Soap creek, whose waters were more or less saline. Owen gives an account* of one of these springs at some length and mentions several others, naming the constituents of their waters and giving the reactions obtained in the field, but no rigid analysis was secured in the laboratory on account of his not having obtained a supply of the water. In the Introduction to his report Owen says "By boring, a stronger water might possibly be obtained; nevertheless, the shallowness of these coal measures, the frequent rupture of the strata and consequent local reversions of the dip together with the fact of the lowest division being composed chiefly of limestone instead of sandstone, are unfavorable indications of the existence of a plentiful supply of deep seated brine, or of nests of salt, whence the permeating waters might become saturated and carry the saline matter to the surface." The correctness of his conclusion has been attested by subsequent events and existing conditions.

On the next page he mentions the occurrence in this neighborhood at an elevation of some ten or twelve feet above these springs of a bed of limestone having hydraulic properties. Cone in cone, to which he gives the German name of *Tutenmergel,* and crystals of selenite are also noted in close relation to these beds. He attributes the *Tutenmergel* not to a shrinkage of the strata, but "to an imperfect crystallization produced by a process of infiltration through beds of marly, argillaceous matter."

White† enters into a discussion of the brine springs in this and neighboring counties. As these springs will be considered later in this report his conclusions respecting them will be presented there. The hydraulic limestone described by Owen is briefly treated by White.‡ He regarded it as of little value for the ordinary purposes to which stone is applied and questions its worth for the manufacture of hydraulic lime.

*Op. cit., p. 111, 1852.
†White: Geol. of Iowa, vol. 2, pp. 334-336. 1870.
‡Ibid., vol. I, p. 237.

In volumes II,* V,† and others of the present series of the Iowa Geological Survey, particularly volume XIX, due consideration is given to the coal outcrops and mine sections in the immediate vicinity of Laddsdale and along Soap creek and a few other localities in the county.

PHYSIOGRAPHY

Topography

The present surface of Davis county may be described briefly as that of the well dissected Kansan drift. Small level areas

Figure 38. Recent headward stream erosion, section 16, Drakeville township.

varying in size from a quarter section to three or nearly four sections at the most, found in every township in the county in localities farthest from the streams, represent the comparatively unmodified surface of the original drift plain. Their boundaries are irregular and gashed by ravines that every year are eating their way ravenously into the midst of the fertile fields, the best in the county, wherever the foresight of the owner has not as

*Iowa Geol. Survey, vol. II, pp. 424-429.
†Ibid., vol. V, p. 422.

yet led him to adopt some form of practical land conservation. See figure 38. Multitudes of these deep V-shaped ravines represent the upper and outermost branchlets of the dendritic waterways, the lower and inner branches of which are often occupied by more constant streams, the beds of the latter having been cut from fifty to even one hundred and twenty feet, in some instances, below the general level. The sloping sides of the streams in their upper courses are quite generally very steep and the bridges that span the creeks are placed from ten to more than twenty feet above their beds. A sharp contrast in this and all other particulars with the Iowan drift topography appears here and would promptly interest the student of the widely variant characteristics of these two great drift sheets. Toward the lower courses the valleys begin to broaden and ever widening valley plains appear along all the larger streams. Those of Fox river are the largest, becoming towards the eastern border of the county as much as a mile and a quarter wide. In this part of their course, too, the slopes are more gentle and, towards their upper part, somewhat broken into step-like portions suggesting terraces, though that term is scarcely correct since there is usually a gentle declivity of several feet before the next rise begins.

The south two-thirds of the county has by far the greater percentage of flat upland plains. The area between Fox river and Carter creek has the largest and most numerous representatives of this type of Kansan drift topography. The roads, except where they traverse the valleys of the larger water courses, are straight, following section lines or lines parallel with them. But in the north row of townships, in order to avoid the frequent crossing of the deep and steep-sided valleys the roads have been laid out as far as possible along the crests of the ridges and so are full of short turns and make wide detours, sacrificing distance to gain ease and facility of movement; for in these townships the rugged type of Kansan drift topography is most pronounced. See plate XLII.

Preglacial influences have contributed little directly to the existing topography. The short stretch of the Des Moines river valley in Salt Creek township undoubtedly antedates glacial

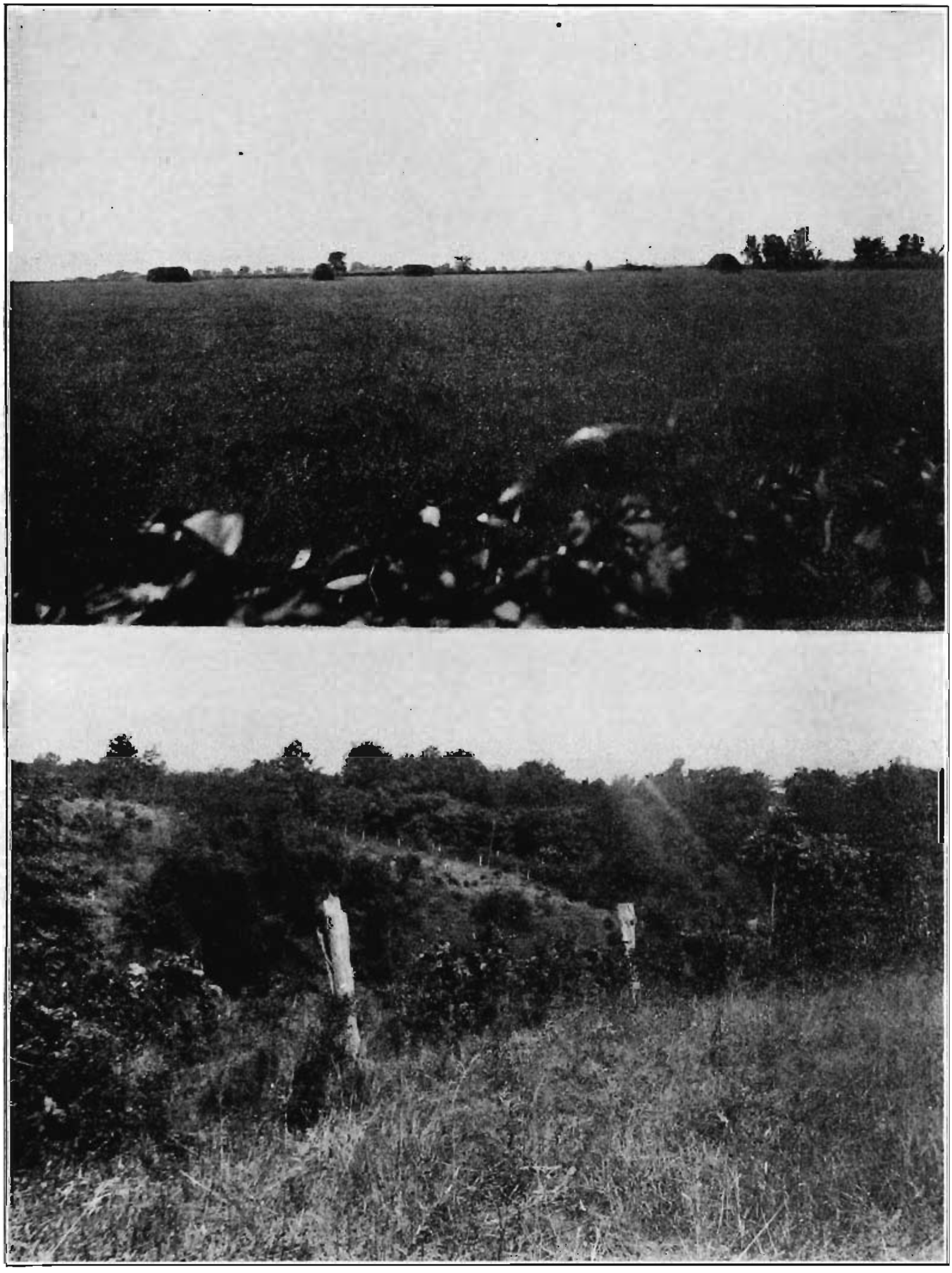


Plate XLII. Upper view—Flat-Kansan topography, section 28, Cleveland township, west of Bloomfield. Lower view—A bit of rugged Kansan topography, section 18, Drakeville township.

times. Outcrops of sandstone in the slopes along Soap creek and its tributaries in Lick Creek and Salt Creek townships indicate that a preglacial valley determined the later course of that stream, and deposits of the Des Moines stage help to make the elevations that today constitute the uplands of the northern portion of the county, the drift here being relatively thin. Nowhere else in the county have the streams cut through the Kansan till, which is much thicker southward than in the vicinity of Soap creek.

The lowest altitude in the county is in the valley of the Des Moines river which must be something less than 630 feet—the elevation a little farther up the river at Eldon. The greatest altitude is probably near Paris, the elevation of which is not far from 950 feet. From that vicinity the general slope of the face of the county is east over the drainage area of Soap creek and southeast over the rest of the county.

TABLE OF ALTITUDES

Locality	Elevation	Authority
Belknap	847	C., R. I. & P. Ry.
Belknap	877	Weather Bureau
Bloomfield	832	C., B. & Q. R. R.
Bloomfield	845	Wabash R. R.
Drakeville	891	C., R. I. & P. Ry.
Floris	706	C., R. I. & P. Ry.
*Milton	803	C., B. & Q. R. R.
†Moulton	987	C., B. & Q. R. R.
Paris	944	C., R. I. & P. Ry.
Pulaski	833	C., B. & Q. R. R.
Steuben	871	C., B. & Q. R. R.
†Unionville	936	C., R. I. & P. Ry.
West Grove	942	C., B. & Q. R. R.

Drainage

The streams of the county, with the exception of the Des Moines river which, as has been stated, has a course of but little more than two miles within the county, are small and are the upper courses of small tributaries of the Des Moines and Mississippi rivers. Proceeding from the north and east to the south and west they are: Soap and Chequest, or Jake, creeks, affluents

*In Van Buren county.
†In Appanoose county.

of the Des Moines, and Fox river, North and South Wyacondah, Carter and Fabius creeks, affluents, directly or indirectly, of the Mississippi, but reaching it beyond the borders of the state. Soap creek rises in the northeast quarter of Appanoose county in two branches which unite soon after entering Davis county. The resultant stream flows east, swerving a little to the north for the last few miles of its course and forming its junction with the Des Moines within the bounds of Wapello county. Its principal tributaries, Bear, Brush and Little Soap creeks, are from

Figure 39. Fox river valley, section 13, Drakeville township.

the north, rising in Wapello county. Salt creek comes in from the south in the northwestern part of Salt Creek township. Though small, it is probably the best known of all on account of certain salt springs near it of which further mention will be made later in this report. The basin of Soap creek is unusually rugged, the western half being particularly well dissected. In the eastern half considerable stretches of alluvial plains are not uncommon. Chequest creek, the next south and east of Soap creek, has a drainage area in the county of about seventy-five square miles.

Its two branches unite just before crossing the county line. Several small creeks, rising in Appanoose county, by their union in Fox River township, form Fox river which shares with Soap creek the honors as to size. It drains the central portion of the county. Its course is a little south of east. Owing to its narrow basin, its tributaries are small and unimportant, though its basin widens notably in the last few miles of its course within the county. See figure 39. The North Wyacondah and South Wyacondah, which form a junction in Missouri, Carter and Fabius creeks, drain the south third of the county. Their courses are southeast and nearly parallel. They are headwater streams with an average length within the county of about fifteen miles each and have little about them that is distinctive except that from the east, in the order in which they have been named above, their drainage basins gradually take on a more rugged character owing to the increasing degree of dendrition which these respective creeks have acquired. Excepting Soap creek all the waterways of the county are consequent streams, having postglacial channels.

STRATIGRAPHY

The entire county lies within the Carboniferous area and, with a minor exception, within the domain of the Des Moines stage of that system. The brief portion of the immediate valley of the Des Moines river that lies in Davis county, less than three miles in length belongs almost wholly to the Saint Louis stage of the Mississippian. From data at and about Laddsdale, the occurrence of Saint Louis limestone in the Des Moines river valley in Davis county would scarcely be expected. Laddsdale is only three or four miles from the Des Moines and in a prospect hole there, located in the valley of Soap creek and so not very much above the river level sandstone was encountered at a depth of eighty-one feet. The Saint Louis lies somewhere below this. The marked unconformity of the Des Moines and the Saint Louis stages alone may account for the outcrop of the Saint Louis not only at the river level, but well up in the bluffs as noted by Lees in the quarry above Sollenbarger branch, and also above the level of sandstones of the Des Moines beds on Vesser creek a short distance to the west. The Carboniferous shales found by Lees along the immediate bank of the Des Moines in section 12 and the sandstone of the same stage reported to have been quarried from the bed of the Des Moines give further evidence of the irregular surface of the Saint Louis in this neighborhood.

Apparently even more simple as to its time relations is the great mass of incoherent material that deeply mantles the Carboniferous rocks and which is commonly known as the drift. Whatever revelations may come in the future because of more numerous and better facilities for becoming acquainted with the older deposits of the county as well as with the deeper lying portions of the drift itself, there is accessible today a surprising paucity of trustworthy data respecting these deposits, everywhere excepting in the Soap creek valley. The relatively thin drift of this region failed sufficiently to bury an ancient valley here, so that the postglacial stream that drains this region had its course determined in advance and it has been vigorous enough to remove much of the glacial debris and thus to disclose again the beds of the Des Moines stage that had been cut through in preglacial times. The same cause has left the coal beds within easy reach, and mines and prospect holes have contributed somewhat to a definite knowledge of the strata of this locality.

The following is a schedule of the known and possible formations of the county:

SYNOPTICAL TABLE

Group	System	Series	Stage	Formation
Cenozoic	Quaternary	Recent		Alluvium
		Pleistocene	Kansan	Loess
				Bowlder till
			Aftonian	Gravel, silt, peat
			Nebraskan (?)	Dark bowlder clay
Paleozoic	Carboniferous	Pennsylvanian	Des Moines	Cherokee. Sandstone, shale, limestone, coal
		Mississippian	Saint Louis	Pella. Limestone

CARBONIFEROUS SYSTEM

Mississippian Series

SAINT LOUIS STAGE.

PELLA LIMESTONE.

Near the mouth of a small intermittent stream known as Sollenbarger branch, along the eastern margin of section 13, Salt Creek township, the Saint Louis limestone outcrops in the bed of the gully. It is here a gray, granular, fine textured, subcrystalline rock in ledges about nine inches thick. This is exposed up the branch through a vertical distance of about fifteen feet and is overlain by an eighteen-inch layer of brownish marl which responds readily to the acid test and shows also some sandy and clayey streaks. No fossils were observed in these beds. Above the marl is a fine grained, gray limestone of almost lithographic fineness and with a smooth conchoidal fracture. Where seen above the marl only one six-inch layer occurs, but it probably reaches a thickness of three or four feet farther up stream. It is here succeeded by a rougher, gray, sub-crystalline rock one or two feet in thickness which shows some small clear grains apparently quartz. Overlying this bed is a more even grained, darker drab, very fine textured limestone with rough feel. This has about the same thickness as the underlying bed, and both of them weather to a buff.

The next overlying bed is a fine grained gray limestone with finely hackly, splintery fracture and a thickness of two to three feet. A coarser, rough, gray rock with uneven fracture is exposed up the stream bed and shows a thickness of about twelve feet. It shows no bedding planes but is much shattered with here and there calcite or sandstone in seams and bands. In places a breccia is formed and a few cases are seen of a peculiar rounded body with obscure concentric structure embedded in the rather coarse matrix, giving the appearance of a stromatoporoid. Small nodules of oolitic appearance are also seen in connection with the larger masses. One fragment showed some tubes of a small bryozoan. Farther up the stream and probably directly overlying this bed are seen about four feet of finer grained limestone with sub-conchoidal fracture and smooth, light gray weathered faces.

Separated from the limestone by a sod-covered talus slope of four feet thickness is a fine rust-red sandstone of Des Moines age. Up a secondary draw opposite this exposure but at a level a few feet lower are exposed two feet of a soft, reddish yellow sandstone with eight inches of gray sandy limestone over it and above this a red sandstone fairly well indurated.

On a hillside overlooking the branch and perhaps twenty feet above its floor a small quarry has been opened to secure limestone for local building purposes. Its base must be ten or more feet above the contact between the limestone and the sandstone about 300 yards up the branch. The stone used is a fine grained rock with conchoidal fracture and almost lithographic texture. Six and one-half feet are exposed. Above are eighteen inches of marl, yellow, calcareous, similar to that found in Van Buren and Wapello counties. This is overlain in turn by eighteen inches of a coarse gray rock which is immediately under the soil. This exposure is doubtless near the top of the Saint Louis as small blocks of red sandstone are found on the hillside.

Less than one-fourth mile up Vesser creek (which runs east across section 13) above the mouth of the branch eight feet of yellowish, heavy bedded, well indurated sandstone outcrops in the right bank, which is formed by the bluffs of the Des Moines river valley. Above the sandstone is a fine gray limestone in two layers each four inches thick. This stone appears to be finely shattered and cemented in place. Overlying it are exposed six feet of gray sandstone. A little farther up stream a limestone is exposed at the base of the bluff with a massive sandstone above it. The limestone is twelve to fifteen inches thick. Close by is a face of two feet of a black carbonaceous shale at the level of the massive sandstone. It is probably slide material. The base of these exposures is about thirty-five feet lower than the contact of the Des Moines and the Saint Louis up the branch.

Along the west river bank in the northwest quarter of section 12, Carboniferous shales are exposed to a height of four or five feet above the water. Some of these are black and fissile, in layers one-fourth inch in thickness, while others are gray or blue, soft and clayey. Septaria and masses of a black limestone are strewn along the sloping bank but were not observed in place.

This exposure is perhaps 200 yards long. It probably occupies a small valley or other depression in the Saint Louis.

About one-fourth mile or less up stream a small opening has been made near the base of the bank to reach a bed of limestone. This has been exposed for a height of four feet. It is fine grained, almost lithographic in texture and is evidently the sub-lithographic phase of the Saint Louis. At the river level a somewhat coarser facies is seen. A total height of eight feet is found beneath the silts and sands of the flood plain. The upper foot or two is considerably weathered and stained. A small outcrop is seen immediately across the river from this locality. In the early days of Iowa history a dam was projected across the river in this locality and large blocks of stone were furnished for the purpose. The project was never carried out and the blocks still remain unused.

Going up stream on the west bank another outcrop of the sub-lithographic phase is seen extending for 100 yards or more. About two feet are exposed above the water. The rock weathers to a buff color. In all an exposure of about one-half mile occurs here along the river bank. Six or eight feet are shown at low water and the river runs over the rock. The characteristics are similar all along—a fine texture, smooth fracture, specks and crystals of pyrite showing in places. Very few fossils were seen, only a rare brachiopod.

No outcrops were noted on the west bank above this point but just within the Wapello county line limestone is exposed on the east bank and the outcrops doubtless extend over into Davis county.

The beds of the Saint Louis stage here described belong apparently to the horizon of the beds in the river at the Selma bridge over the line in Van Buren county and of the quarries opened in the bluff about half a mile below the bridge on the west side of the river. As described in the report on Van Buren county* these belong to the Compact and Granular Limestone.

Leonard in his discussion of the Saint Louis stage of Wapello county† refers the fine grained limestones and the associated marls to the Pella sub-stage. The similar strata of Davis county are here placed in the same formation.

*C. H. Gordon: Iowa Geol. Surv., Vol. IV, p. 217.
†A. G. Leonard: Iowa Geol. Surv., Vol. XII, p. 450 ff.

Pennsylvanian Series

DES MOINES STAGE.

Cherokee Formation.

The rocks of this stage are distinguished by great diversity, both in nature and order of superposition. Many of the beds vary locally either wholly, or in some of their properties, as color or texture, or in thickness. Less than 200 feet of the 750 feet maximum, as given in the recent geological section of Iowa, has been found in the northern portion of the county where reliable data are at hand. A somewhat typical section kindly furnished by Mr. Henry Poole, Superintendent of the mine at Laddsdale, operated by the Anchor Coal Company, is here given. It is upon the Copeland farm 600 feet west of section 1, given on page 516.

		Feet.	Inches.
35.	Drift	12	
34.	Black shale	2	
33.	Soft coal	2	7
32.	Fire clay	2	5
31.	Blue shale	6	
30.	Sandstone	7	
29.	Black shale	4	
28.	Coal		8
27.	Mixed rock and coal	1	2
26.	Coal	1	7
25.	Fire clay	1	
24.	Coal		6
23.	Fire clay	9	4
22.	Sandstone	6	
21.	Gray shale	7	
20.	Blue shale	2	
19.	Blue clay shale	8	
18.	Sandstone		5
17.	Black shale		11
16.	Coal	4	
15.	Black shale	10	
14.	Cap rock	1	8
13.	Black shale	1	4
12.	Coal	1	9
11.	Fire clay	4	
10.	Black shale	1	6
9.	Coal		2
8.	"Rock"		6
7.	Coal	2	6
6.	Fire clay	4	4
5.	Black shale	14	
4.	Gray shale	2	
3.	Black shale	3	
2.	Lime shale	2	
1.	Limestone (Saint Louis limestone?)		
	Total	127	4

Hinds reports a section* from the same neighborhood, with a greater surface elevation, probably, that has a total thickness exclusive of the drift, of 163¾ feet. Some of the shales and sandstones to be seen on Soap creek ten to thirty miles farther west appear to be stratigraphically above the top of this section.

In the section given in full above, if the fire clay be included, there are eighty-four feet ten inches of shales; thirteen feet five inches of sandstone; fourteen feet eleven inches of coal, one foot two inches of which is impure; and two feet two inches of "rock", presumably limestone. If this section were typical in all respects of the Cherokee formation there would be a lower percentage of coal and shale, and a higher percentage of sandstone and limestone, though shale always predominates. Higher up in a composite section of the Cherokee formation, sandstones would usually show a higher percentage than is likely to be found in the lower portion of such a section.

A hydraulic limestone occurs along Salt and Soap creeks two or three miles southwest of Laddsdale, the horizon of which it is difficult exactly to determine. That it belongs somewhere in the midst of the coal producing strata is manifest from the presence sometimes of coaly shales and coal itself in immediate connection with it as well as from a drift coal mine now operated within a few rods of outcrops of the hydraulic limestone which lies a little above the coal bed. Its place cannot be far from the cap rock which it resembles somewhat in some of its phases.

In the south half of section 13, Soap Creek township, from a cut on the hillside made in grading the highway and from the bank of the creek at the foot of the hill the following section is made up.

		FEET.
6.	A gray, gummy soil, approaching loess	2½
5.	Till, red-brown; above, mostly clay with some fine sand, below, becoming more gravelly and pebbly, with a few small bowlders	
4.	A mottled gray and brown clay	
3.	A brown clay	
2.	Sandstone, gray, weakly cemented, in irregular but thin layers: (a) on the hillside, about....6; (b) in the vertical bank of the creek	6 to 8
1.	A dense blue clay called soapstone	2

*Iowa Geol. Survey, vol. XIX, pp. 305-306.

Numbers 3 and 4 appear to be clayey shales of the Cherokee formation overlying the sandstone. The individual thickness of numbers 3, 4 and 5 could not well be determined from the manner of their occurrence along the slope of the hill, but their total thickness is fifty feet or more.

Near the center of section 12, same township, a roadside gully exposes six feet of a gray shale, very thin layered and having numerous intercalations of a ferruginous shale. The layers of both kinds of rock thicken towards the base where flattened nodules of limonite with a clay iron nucleus take the place of the ferruginous shale in part. Some of the nodules are two feet or more in their largest diameter. On the opposing hillside near the base, two feet of sandstone are exposed. As the shale has a decided dip to the south, it probably passes beneath the sandstone, as it is seen to do elsewhere in the neighborhood.

Numerous sandstone outcrops occur along the slope of the valleys of Soap creek and its tributaries, two or three of which will be noticed specifically. The same variability displayed among the other rock forms of the Des Moines stage is manifest in the sandstones of this region. They are fine and coarse grained, firm and loose textured, thin and heavy bedded, and range in color from a uniform white or gray to a yellow or red-brown, or they may be streaked and mottled.

Perhaps the most extensive of these sandstone outcrops is on the farm of Mr. John Welch in the northeast quarter of section 17, Lick Creek township, of which the following section was taken:

		FEET.	INCHES.
3.	Sandstone, thin bedded and loose	6	
2.	Sandstone, massive, white, firm and suitable for masonry	3	6
1.	Sandstone, loose grained and streaked with iron	2	6

The firm middle bed persists all along the range of outcrops here and is used to supply the local demand for walls and the like. Two hundred rods farther up the little branch there is an exposure of sixteen feet of sandstone, some beds of which thicken and thin out, several inches in a few rods, two or three times, while the overlying beds are not affected. Here also is a small syncline as well as a good example of cross-bedding

The general dip is to the south. In the southeast quarter of section 11, Soap Creek township, a sandstone outcrop has been quarried into by Mr. George Eggabroad. About four feet of the lower beds are made up of a firm, durable sandstone. Above these are two feet of thin layered stone followed by two feet of a shattered sandstone of no value. Farther west at Shepard's bridge the creek has for its left bank a vertical escarpment of a very substantial sandstone, which serves as an abutment for the west end of the bridge.

The shales of the Cherokee formation are even more diverse in their physical characteristics than the sandstones. Near the base of the formation a calcareous shale usually is found, though more scantily than the limestone, which is by no means plentiful. Near the top and somewhat below the sandstone beds described above, one or more thin beds of sandy shale are commonly found. The predominant shales are argillaceous or carbonaceous, generally scattered throughout the whole formation, and, with the coal beds, constituting the entire central mass of this formation and most of the basal portion. A limited part of the carbonaceous shales is compact and firm, the so-called "slate" of the miners. Most of the rest is weak and extremely fissile. The argillaceous shales range from thin, readily cleavable shales to a compact unctuous clay which when bluish in color is called soapstone and which when it has parted with its iron and alkaline constituents, is known as fire clay.

FOSSILS

The sandstone exposed along Soap creek and also the shales are barren of fossils. A few fossils are to be found in the hydraulic limestone and also in the associated shales along Soap and Salt creeks southeast of Laddsdale. A light, earthy, porous shale of a grayish yellow color, found about Laddsdale in some of the ravine sides, abounds in fossil fragments and a few quite perfect specimens. These include the following:

*Crinoid stems of several kinds.
Rhombopora lepidodendroides Meek.
Two Fenestellas, one very delicate.
**Spirifer cameratus* Martin.
**Orthothetes* (*Derbya*) *crassus* Meek & Hayden.
Productus semireticulatus Martin.

P. muricatus Norwood and Pratten.
P. cora D'Orbigny.
†*Soleniscus paludinaeformis* Hall.
†*Sphaerodoma primogenia* Hall.
Phillipsia major Shumard.
*Found in both localities.
†Found only in the shales and limestone on Soap and Salt creeks.
Others found only in the shales about Laddsdale.

QUATERNARY SYSTEM

Pleistocene Series

NEBRASKAN STAGE AND AFTONIAN INTERVAL.

The few deep well records that have been accessible are the sole sources of information concerning the deeper lying portions of the glacial deposits. Several wells in the neighborhood of Drakeville have been reported to have reached a soil bed and fragments of wood at a moderate depth, twenty-five to thirty feet. Such finds are spoken of as not uncommon, but none of the informants had exact data at their command. It is not unlikely that the Nebraskan constitutes no inconsiderable part of the drift in all that portion of the county where the Pleistocene deposits are thick and undisturbed as yet, but in Salt Creek, Lick Creek and Soap Creek townships, where the drift is relatively thin and much dissected by stream erosion, no evidences of the Nebraskan, or of the Aftonian, were recognized.

KANSAN STAGE.

Kansas Drift. That comparatively ancient and most extensive drift sheet, the Kansan, is everywhere prevalent in Davis county. Though variable in its minor details, it is so distinctive in its general nature as to be readily recognizable by any one at all familiar with its characteristic features. It is a true bowlder till, in which are numerous pockets and streaks of sand and gravel, usually of small etexnt. Many of the cobbles and bowlders are polished and striated on one or more sides. The bowlders rarely exceed four feet in diameter and in Davis county they are not seen at the surface very often, but are usually brought into view in the roadcuts and ravines. In the latter situation, where the originally inclosing clay has been washed away from a considerable section, the bowlders have rolled in together and appear to be plentiful. Such a ravine was seen a little northwest of Floris. The basal portion of the Kansan drift is practically unweathered and constitutes the normal, typical till. Its color is a dark gray or blue. It is very dense, but shows a tendency, when exposed, at least, to break into small angular blocks, from which fact it has been called joint clay. Above the unweathered till and grading into it almost imperceptibly at times, lies a zone of weathered Kansan having a thickness of four to eight feet. Its color is usually a yellowish or reddish brown, due to the oxidizing of its iron constituents. In Davis county a light gray color was noted in many instances. The granitoid pebbles and bowlders are frequently falling into decay. The more soluble portions of the drift have been taken up by vegetation or leached out by the ground waters. Thus by the combined activities of the various weathering agencies operating through the relatively long post-Kansan interval, such great changes have been wrought in that part of the Kansan accessible to the influences of these agents that the typical unweathered Kansan till seems to have little in common with its derivative, the weathered Kansan, except in a general way.

The principal available data for ascertaining the thickness of the drift are from reports of deep wells. These reports were from memory and so have in them an element of indefiniteness and uncertainty, yet they answer the present purpose, perhaps, fairly well. After making allowance for differences in surface levels, it is quite evident that the glacial deposit lies upon a surface of marked irregularity in level. The following figures gathered from well reports indicate the thickness of the drift in various localities.

In Prairie township it is 320 feet thick, in Roscoe township 286 feet, in Union township 200 feet, in Fabius township 138 feet, in Cleveland township 221 feet, in the vicinity of Floris 200 feet. Some deep wells were reported as ending in the drift, at least solid rock was not reached. In the south two-thirds of the county the drift on an average is not much less than 200 feet thick. In the north third it is much more variable and averages much less, probably, the hillside and stream cuts being used as the basis for the estimate.

The unweathered Kansan was seldom seen, but the roadcuts on the crests and slopes of the hills frequently expose from two to six feet or eight feet of the weathered zone. These cuts are to be seen in all parts of the county excepting where the flat-Kansan areas prevail. The material is a clay with which is intimately blended in ever varying proportions a fine siliceous sand with coarser particles of igneous rocks that become rarer as their size increases. Sometimes a day's ride may be made without seeing a bowlder above a foot in diameter. A few instances of the many cuts observed are given to illustrate the diversity of the nature and appearance of the unweathered till and of the character of the overlying material, when present.

On the hillside just north of the South Wyacondah in section 34, Grove township, a light gray loess-like earth is seen. It seems more clay-like than ordinary loess, but it probably does not belong to the till. The opposing hillside south of the creek gives four to six feet of red till above a layer of reddened gravel, then a dark gray clay which marks the border between the weathered and the unweathered zones. North of Stiles in the west half of section 34, the clay abounds in lime balls of various shapes and sizes. In section 21, one to two feet of dark loam overtops the clay, an unusual thickness for this county. Near the top of a hill south of Bloomfield, there were three feet of a light gray loess, then two feet of a red clay followed by six feet of lime ball clay. These varieties of earth appeared distinct as if laid down in beds, but not far away they graded insensibly into one another. In Fabius township dark loam appears oftener than in most other localities and gravel may be seen on or near the hilltops quite commonly. Mingled with this gravel are coarse pebbles and even cobblestones. Below the gravel usually is a yellow clay containing lime balls. Occasionally a red clay appeared, beneath which the jointed blue clay of the unweathered zone was sometimes seen. The crackled rather than jointed structure of the weathered zone was particularly noticeable in all the exposures in this part of the county. In the south half of section 13, Soap Creek township, a dark red till beneath two and a half feet of a gray, granular soil contains an unusual amount of gravel, pebbles and small bowlders. The lower part of the till was unusually sandy.

LOESS.

While loess is well distributed over the county, it is by no means universal. In many of the roadcuts its absence was noted. Its thickness is quite variable also, but nowhere does it appear to reach a thickness comparable with that reported in neighboring counties. No limeballs or fossils were seen in it. It is markedly different from the Iowan loess, being more clay-like in its compactness and plasticity. In color it is a decided gray. In places its clay-like nature is so emphasized as to lead to doubt that it should be classed as loess and in this phase it is popularly called gumbo. This grade of material was not often observed, however. It seems best to regard all phases of this superficial, gray, pebbleless, fine structured earth that occur in the county as the same in general nature and source, but the loess is a wind deposit while the gumbo is perhaps a water deposit.

RESIDUAL GRAVELS.

In some of the roadside banks weathered gravels were seen overlying the reddened till. In position and appearance they suggest the Buchanan gravels of the more northern drift areas, especially the deposits of the upland phase, though they never equal many of the Buchanan gravel deposits in thickness. Conditions, however, will not admit the same theory of deposition. It is not unlikely that in the earlier part of the post-Kansan interval, before vegetation had formed a protective cover, the finer materials of the till washed from the hillsides, allowing the coarser constituents to settle down together and thus to form these thin bands of gravel.

Recent Series

ALLUVIUM.

In the valleys of Fox river and Soap creek, and even in the lower reaches of some of the smaller creeks are rich alluvial deposits. The major part of the deeper lying portions of the deposits in these valleys was accumulated early in post-Kansan time and it is a heavy clayey earth, but the alluvium is much more recent in formation, indeed, every annual flooding of the valleys adds its increment of fine dark silt to the contributions of previous years. Nothing of exceptional nature was recognized in the alluvium of this county.

Soils

KANSAN DRIFT SOIL.

In every part of the county there are quite extensive areas whose only available root bed for vegetation is the weathered Kansan till, more or less superficially mingled with organic matter. In its better phases, and fortunately these are the commoner ones, few soils surpass it in strength and suitability to a wide range of plant forms. It consists of decomposed rock from which the more soluble constituents have been leached out to some extent and carried away, and rock fragments from the finest dust through all grades of coarseness, such as sand, gravel and cobbles, up to bowlders three and four feet in diameter. The great variety of rocks that have contributed to the make-up of the drift has enriched it with a complete supply of mineral food material for plants and the growth and practical decay of vegetation through the centuries has added to it great quantities of organic matter, which in process of time, by the agency of burrowing animals, from the wolf to the ant and earthworm, has been thoroughly mingled with the earthy material. By cultivation and otherwise, fresh portions of the drift are being constantly exposed to the more immediate activities of the weathering agencies, by which new supplies of plant food are set free and rendered available. Thus this till makes an enduring soil admirably adapted to maintain from year to year bountiful crops in proper variety to gladden the heart of the husbandman.

LOESS SOIL.

Over areas equally widely distributed in the county as are the Kansan drift soils may be found another soil, the loess. It is a peculiarly fine grained material of remarkable uniformity of composition and other characteristics in any given locality, but which varies within comparatively narrow limits in different localities. It consists of the finest elements of the drift, chiefly siliceous and argillaceous, picked up by the winds as they swept over areas destitute of vegetation, and dropped in plant clad districts, where the force of the winds was abated somewhat by the resistance naturally offered by the vegetation. It is a good soil, particularly well adapted to the purposes of the gardener and the cultivator of small fruits.

ALLUVIAL SOILS.

The alluvial plains, located and described under the topics, Drainage and Alluvium, usually have as a superficial deposit a soil that is very fertile. Were it not that from their location they are subject occasionally to overflow while they are in crops, they would be for many purposes the most desirable farm areas in the county. However, they offer a measure of compensation in the fact that, while the crops on other soils are suffering from the drouths that sometimes afflict them, the alluvial plains at such times seldom fail to yield good returns.

ECONOMIC PRODUCTS

Coal

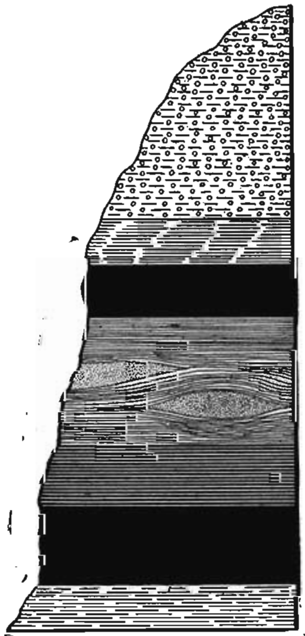
While it may be that coal beds underly a large part of the county, they have been worked in but a limited area, chiefly in the northeastern townships. At Lunsford, just north of the state line, in the south half of section 14, township 67 north, range 14 west, coal was mined a few years ago. At a depth of 265 feet a three-foot seam was found having a four to six-inch layer of shale running through it about midway. The roof was not very good, the mine was remote from rail transportation, local demand for coal was limited and so mining was abandoned and the shaft was allowed to cave in; but the fact of the occurrence of a good quality of coal in this part of the county has been established and some day its profitable mining may be undertaken with assurance. Coal is said to have been reached in other localities in the south three-fourths of the county, but the thickness of the drift and the lack of good transportation facilities have thus far discouraged all efforts to open up mines in this portion of the county. Drift mines along the banks of Soap creek and some of its tributaries have been worked more or less intermittently for years.

About thirty years ago a company was organized under the name of the Brown Cannel Coal Company, which took out some coal from a mine near Soap creek. The entry was driven a short distance and one or two rooms opened, but owing to financial troubles further development was prevented. A third seam, three and a half feet in thickness, was said to exist a few feet below, but this is not now exposed. This coal is of a dull black color, rather difficult to ignite, but burns with considerable heat. The section at the Brown Cannel mine was:

FEET.	INCHES.	
2		7. Shale, bituminous.
4		6. Coal, in places reaching a thickness of four feet.
10		5. Shale, black, fissile in part.
4	6	4. Coal.
1	6	3. Fire clay, shaly below.
3		2. Coal, not exposed but found in trenching.
2		1. Fire clay, impure.

Figure 40. Seams at Brown Cannel mine, Carbon.

Three miles northwest of Floris, in the bluffs of Soap creek, two seams of coal are exposed as shown in figure 41.



	FEET.	INCHES.
7. Drift	10	
6. Shale, bituminous	2	
5. Coal	2	6
4. Shale, bituminous, with bands and nodules of clay ironstone, graduating below into next	6	
3. Shale, firm, black, fissile......	3	
2. Coal	3	6
1. Fire clay, gray, shaly in part.	2	

Figure 41. Bluff on Soap creek, near old Brown Cannel mine, Carbon.

The most extensive mine worked in this district at present is a drift operated by the Soap Creek Coal Company. It is located a half mile west of Carbon station, to which the coal is brought over a tramway and loaded upon cars. Here is a thirty-six inch vein, including the usual two-inch clay parting. The coal, which is of good quality, overlies a fire clay and has a roof of weak shale. The output is quite variable. At the time the mine was visited, August, 1908, three to four tons a day were taken out. An eighteen-inch seam of excellent coal lies twenty feet below the above described seam. The roof is good. Eight or ten rods east of the Carbon station at a depth of 112 feet a seven-foot vein of coal was found. A thick bed of firm slate immediately overlies the coal. Wagner's mine, located in the east half of section 10, Soap Creek township, supplies local demand to some etxent. Judge Carruthers of Bloomfield found a moderate vein of coal in prospecting in section 13 of the same township. In Lick Creek township several small banks have been worked somewhat intermittently. Among these are the Dunn mine in the northwest quarter of section 8 and one near Floris. In section 7 on Soap creek the following section was taken:

		FEET.	INCHES.
7.	Drift	7	
6.	A dark limestone much like the cement rock near Laddsdale	5	
5.	Coal. Top vein	3	6
4.	An argillaceous shale, light above, becoming darker below	8	
3.	A shale quite sandy in portions and varying in color from light gray to almost black	12	
2.	Coal	3	4
1.	Creek level		

*Hinds states that the seam mined near Carbon is reported to have an areal extent of ten square miles. From observations made in this neighborhood this report is believed to be correct, though the seam has been much interrupted by the extensive erosion of the region and is also quite variable in thickness and in the character of the roof.

George Deut has operated a mine for three or four years near

*Iowa Geol. Survey, vol. XIX, p. 321.

Soap creek, southeast of Laddsdale. The vein, which is the same as the middle vein at the Laddsdale mine, is four and one-half feet thick and has a good slate roof. Eight thousand bushels were taken out here in the winter of 1908-9. The output is used to supply the local demand. James Fayne, Henry Hastings and several others operate drift mines along Salt creek, chiefly in section 8, Salt Creek township.

Near Laddsdale a coal vein outcrops which is from two to two and a half feet in thickness. It has been mined in this vicinity by drifts and shallow shafts for a long period of years. The Sickels mine, opened a number of years ago in the northwest quarter of the northeast quarter, section 8, Salt Creek township. worked a seam of excellent quality. The section is:

FEET.	INCHES.	
2		6. Sandstone, coarse, with pyrite concretions, (exposed).
	6	5. Shale, bituminous, fissile.
2	6	4. Coal.
	8	3. Coal, firm, ("smithing coal").
	3	2. Coal, impure, shaly, ("black-jack").
2		1. Fire clay, impure, gray, (exposed).

Figure 42. Coal bed in old Sickles mine, Laddsdale.

The Anchor Coal Company of Ottumwa operates a mine for shipping purposes near Laddsdale just across the Davis county line in Wapello county. Mr. Joseph Poole, the local superintendent, kindly furnishes the record of several prospect holes sunk by the company within the Davis county border, three of which are here given, and one of which has been given in describing the Cherokee formation.

Number 1, put down in 1904.

	FEET.	INCHES.
Drift	47	
Blue shale	5	
Sandstone	11	
Black shale	1	

	FEET.	INCHES.
Coal	1	10
Fire clay	10	2
Sandstone	2	
Black shale	1	
Soft coal	2	8
Fire clay	2	4
Black shale	9	
Cap rock, black, firm	4	
Black shale	2	
Black slate	3	
Coal	2	11
Black shale	2	1
Fire clay	10	
Total	117	

Number 15, on low lands east of Number 1.

Dirt	30	
Gray clay shale	2	
Black shale	2	7
Coal	1	10
Fire clay	5	7
Blue clay shale	2	
Fire clay	5	
Total	49	

Number 20, 600 feet east of Number 15.

	FEET.	INCHES.
Drift	7	
Coal	1	
Fire clay	7	
Black shale	7	10
Coal	1	2
Fire clay	10	
Blue sand shale	6	
Cap rock	2	
Black shale	1	
Coal	1	11
Fire clay	2	1
Sandstone	2	
Gray clay slate	8	
Black shale	16	
Gray clay shale	4	
Black shale	4	
Sandstone		
Total	81	

A striking feature of these sections is the extreme variability of the seams of coal as well as of the accompanying beds of shales, sandstone and limestone, rendering the identification of the coal seams puzzling, to say the least. The same feature manifests itself wherever outcrops occur along Soap creek to the west and also in such prospect holes as have been put down in all this portion of the county where coal has been found. Along Salt creek two seams outcrop with unusual persistency for two or three miles, but even here the thickness of the seams is notably variable. It is undoubtedly true that many of the deposits of coal in this locality were in unusually small lenticular basins. This makes the results of prospecting uncertain. Then too, drift-filled, preglacial channels seem to cut through the beds in places and still further to increase the uncertainty of profitable ventures.

Building Stone

This county, heavily covered with drift, affords very little stone suitable for use in building. The sandstone outcropping along Soap creek and its tributaries affords most of the available building stone in the county. In a few localities small quantities of this material have been quarried for local use. One of these quarries is in the east half of section 15, Soap Creek township. Another, the George Eggabroad quarry, is in the southeast quarter of section 11, same township. Yet another, owned by John Welch, is on the east side of section 17, Lick Creek township, along a small tributary of Soap creek. In a twelve foot exposure just above two and a half feet of soft, iron-streaked sandstone. there is a three and a half foot bed of firm, quite fine grained, white sandstone that makes a very good, serviceable building stone, but from its location there is lttle demand for it. Sandstone for building purposes has been taken from the bed of the Des Moines river below Eldon during stages of low water. A small quarry on Sollenbarger branch, section 13, Salt Creek township, furnishes a good grade of Saint Louis limestone for which, however, there is but a limited demand. Limestone has been taken out also along the river bank in the northwest quarter of section 12.

Clay

For several years A. P. Birckmier made a good common brick at a point about four miles north of Troy, using the surface loess for material, but the location is not favorable for extensive production and work has been abandoned for the present, at least. Brickmaking has been attempted in one or two other places, but from one cause or another with but indifferent success.

Lime

Mr. Joshua Miller made lime from the limestone exposed along the river in Davis county for several years during the last decade of the nineteenth century but has not burned any for a number of years owing to the slackness of the trade. Mr. Jeff Carter has burned lime in his kiln in section 11 for twenty years and still continues operations in a small way. He obtains his stone from the exposures on the river bank opposite his kiln. Both these men speak well of the quality of the lime obtained. It is white and burns evenly and cleanly.

Hydraulic Limestone

Along Soap creek, its tributary, Salt creek, and the short ravines leading down to it, in the immediate neighborhood of the brine springs a mile or two southwest of Laddsdale, a limestone outcrops that has for years attracted attention as a hydraulic limestone. This is the stone referred to by Owen and White in their reports, as noted under the topic Previous Geological Work, in the first part of this report. There seem to be two fairly distinct varieties, though intergradations also are to be found. The first variety is of a slate color, while the other is a dark blue-gray. It overlies a coaly shale which in places gives way to a true coal. It varies in thickness from two or three feet to six or seven feet. It sometimes is in thin layers; at other times it is quite thick bedded and dense in structure. Fissile shales sometimes separate beds of the two varieties. When taken from its place it is readily broken, but after thoroughly drying it becomes very hard. It has a decided conchoidal fracture with very sharp edges between the faces. Weathered surfaces have a mud gray color in sharp contrast with that of fresh surfaces. It is usually destitute of fossils, excepting along natural faces where numerous crinoid stem fragments and a few brachiopods appear.

Owen* presents analyses of the two varieties as follows:

	Dark earthy	Light gray
Water of absorption	001.5	001.
Silica	15.5	053.
Carbonate of lime	63.6	029.9
Magnesia	1.2	7.4
Alumina	8.3	6.2
Protoxide of iron	7.4	1.8
Protoxide of manganese	.4	trace
Soda	.4	.6
Potash	.3	trace
Loss and bituminous matter	1.4	.1
	100.0	100.0

He makes the following comment:

"The light gray is much inferior in quality to the dark earthy variety, indeed, it is hardly entitled to be considered hydraulic."

At the time that attempts were made to improve the Des Moines river with the view of making it navigable, Mr. Harward manufactured cement from this rock, which was used in the construction of the Bonaparte dam, but a flood carried away the building used in his work and nothing further has been done towards manufacturing a cement from this material.

White† says "The stone was analyzed by Dr. Owen, and found to contain less both of alumina and magnesia than has hitherto been found requisite for the successful production of good hydraulic lime. No full history of its use has been obtained, and the most that can be said of it at present, is that it seems to have made a very good and durable mortar." Since the analysis of a hydraulic limestone does not necessarily determine its real value as a cement maker, a further actual test of the cement product of this stone is desirable before its exact worth can be known and those interested in it could secure such a test without much trouble or expense.

Road Materials

For the most part the ordinary soft earth upon the natural surface is the only road material at hand and unless better

*Geological Survey, Wisconsin, Iowa and Minnesota, p. 112, 1852.
†Geology of Iowa, vol. 2, p. 320, 1870.

material is brought in at a practically prohibitive expense, the reliance for securing good roads must be placed in a well drained, convex surfaced road upon which the simple, but most effective King drag is systematically and persistently used. A few limited localities are fortunate in having ready access to a fairly good gravel that can be used with excellent results.

Water Supply

WELLS.

By far the greater number of the wells in the county are dug or bored. While drilled wells, reaching to or penetrating somewhat into the rock, are comparatively few, new ones are constantly replacing the shallow drift wells that, aside from the streams and the few scattered springs, were the only source of water supply for many years. The drift wells were rarely sixty feet deep and often were no more than ten or twelve feet in depth. Mr. S. L. Berry reports a custom formerly current in some localities of digging a series of wells in clusters of five or six, sometimes as high as ten or twelve, about fifteen feet apart. These wells were connected by boring from the base of one well to the base of another with a two-inch augur. After the hole was bored, two-inch tile were pushed into the tunnel made by the two-inch augur. Such wells are still in use. In many instances the cluster of wells is given an outlet at the base of a hill, making an artificial spring. Ordinarily all the wells in the cluster save the one from which the water was drawn were arched over above the high water mark and filled up. These wells end in a gray hardpan practically impervious to water, so that none of the results of the seepage are lost by settling into the subjacent drift. In the southwest quarter of section 28, Cleveland township, a well 221 feet deep ends in a very dark clay which was described as almost black. Possibly this is Aftonian material.

At Laddsdale water is secured plentifully from driven wells about fifteen feet deep. The site is upon the margin of Soap creek valley.

At Floris dug wells range in depth according to location but they rarely exceed sixty feet. A few drilled wells that end in rock are in this neighborhood. They are from 150 to 200 feet deep.

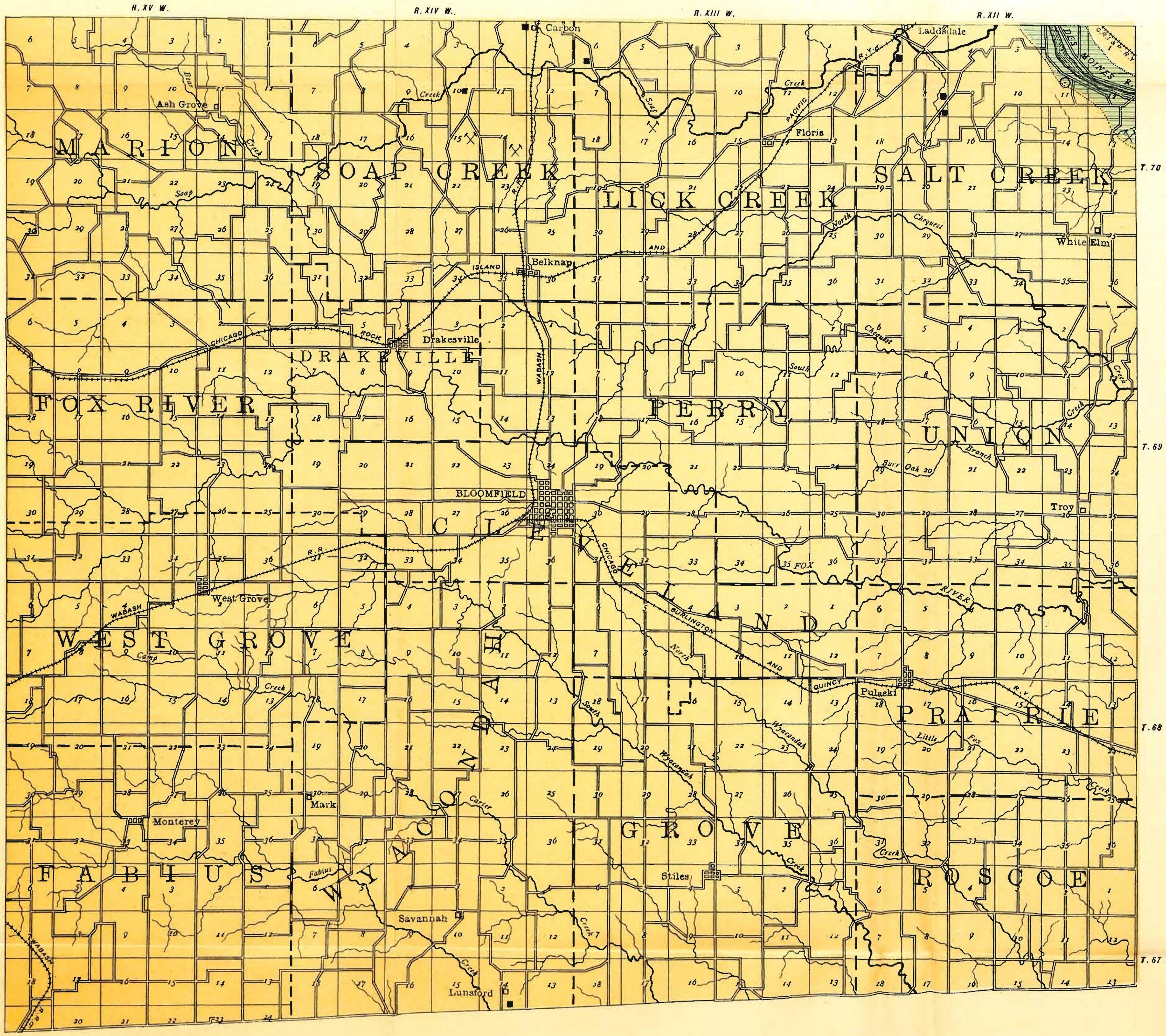
At Troy and vicinity dug wells twenty to thirty feet in depth give a good supply of water as a rule. Bored wells occasionally go down eighty or ninety feet. A few miles north several wells reach rock at a depth of 200 feet.

At the center of section 6, Prairie township, a well 328 feet deep enters the rock six or eight feet. Gravel occurs at 160 feet. Dug wells at and near Stiles are twenty-five to thirty feet deep. Bored wells are from seventy to 100 feet deep. In Fabius township wells twenty to thirty feet deep give a sufficient water supply ordinarily, but where such have failed resort is had to cluster wells. A few wells have been put down to the rock at depths varying from 140 to 180 feet. At Lunsford a seep well thirty feet deep supplies an abundance of good water. It is said to be a typical well for this neighborhood.

A well driller at Pulaski has drilled deep wells in about every township in the county, but from a notion that his information is too valuable to be given away, he declines to say more than that the drift has a range in depth from 150 to nearly 300 feet and that good water can always be secured plentifully at the rock surface or a few feet below it. The city well of Bloomfield is 1,817 feet deep. Its supply is ample for the city's needs. The average daily amount pumped is 18,000 gallons. The driller's record could not be secured.

SPRINGS.

Only a few perennial springs have survived the settlement and cultivation of the county. Naturally, from the fact that Soap creek valley has been cut through some of the sandstone beds of the Cherokee formation, most of the large springs are in that valley. A spring in section 28, Cleveland township, has attracted some attention because of an iridescent scum that gathers upon its surface and suggests the possibility of an oil reservoir beneath the surface. When it is remembered that there is a well upon the same section that is 221 feet deep and that ends in the drift, the impossibility of oil reaching this spring from the indurated rock is apparent.



IOWA GEOLOGICAL SURVEY

GEOLOGICAL MAP OF DAVIS COUNTY, IOWA.

BY

M. F. AREY.

1910

Scale $\frac{1}{125000}$

1 ½ 0 1 2 3 4 5 Miles.

1 ½ 0 1 2 3 4 5 Kilometers

LEGEND

GEOLOGICAL FORMATIONS

PENNSYLVANIAN
DES MOINES

MISSISSIPPIAN
SAINT LOUIS

INDUSTRIES

QUARRIES

LIME KILNS

CLAY WORKS

COAL MINES

IOWA LITHO. CO.

DRAWN BY F. C. TATE

SALT SPRINGS.

Along Salt creek, in the township of Salt Creek, certain saline springs early attracted notice. Under the topic Previous Geological Work we have spoken of Owen's interest in these springs. White also gave them a share of attention. Those who are interested in the history of the action of the State in reference to the so-called "saline lands" of Iowa are referred to White's account in full as given in pages 334, 335 and 336 of his second volume.* There is found a list of twelve springs reported from six counties, one of which was located in Davis county, one in Van Buren, two in Appanoose, one in Decatur, one in Wayne and six in Lucas county. Of these White has the following to say. "All these localities have been visited by one or more members of the geological corps, and careful search made for the reputed salt springs, and in most cases we have failed to find any trace of them, and in the majority of cases no spring of any kind was found upon the section as indicated in the foregoing list. Diligent inquiry was also made of the early settlers of the region with no better success, one of whom quaintly remarked that he 'supposed Iowa ought to have saline lands since Florida had them, which state was admitted into the Union at the same time with Iowa.' We are therefore driven to the conclusion that the persons who selected those lands as saline lands were in most cases mistaken as to their real character."

Davis county, practically alone of the counties named above, has really had saline springs, but the present writer has had the same experience in finding any in existence today that White's assistants had in the '60's. The fact is these springs have mostly suffered the fate of the great majority of the weak springs of Iowa. They have ceased to flow excepting in times when the ground is thoroughly saturated with water. Mr. William Lynch of Eldon gave the information that twenty years ago Doctor Martin had a Sanitarium on Vesser creek on the place now owned by Charles Nupp. This Sanitarium was located at a salt spring because of its reputed medicinal qualities, but some sixteen years ago the spring completely dried away and has never reappeared, and the building has been removed. Several

*White: Geol. of Iowa, vol. II, 1870.

small brackish springs are reported to exist still, though diligent search and inquiry failed to reveal the location of any of them.

ACKNOWLEDGMENTS

The writer appreciates the uniform courtesy shown him by those from whom he sought information or assistance of any kind in the pursuit of his work in the county. C. W. Ramseyer, Esq., of Bloomfield, was specially helpful and many others are gratefully remembered for their kindly interest and helpfulness. Professor Samuel Calvin, the State Geologist, has indentified the characteristic fossils of the exposed rocks at Laddsdale. To Assistant State Geologist Lees we are indebted for the observations and report on the Saint Louis outcrops in the Des Moines river valley as well as for other valued assistance. To both gentlemen our sincere thanks are given.

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