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Annual Report, 1916
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Accompanying Papers

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Administrative Report

TWENTY-FIFTH ANNUAL REPORT OF THE STATE GEOLOGIST

IOWA GEOLOGICAL SURVEY,
DES MOINES, DECEMBER 31, 1916

To Governor George W. Clarke and Members of the Geological Board:

GENTLEMEN: The plans of the Iowa Geological Survey which were approved by the Board for the field season of 1916 have been carried forward successfully, and reports of the investigations are now being prepared for publication.

The State Geologist directed the work of the Survey, with the hearty co-operation of the Assistant State Geologist and the other members of the geological corps to whom special problems were assigned.

In the Administrative Report for 1915, reference was made to some detailed studies of the glacial deposits of the state which were being made by the Director and which gave promise of having considerable significance in connection with the interpretation of the complex history of the Pleistocene period. Among these studies was the problem of the origin of gumbotil which had been found on each of the three oldest drifts of the state. It can now be stated that both field and laboratory evidence indicate clearly that the gumbotils on Nebraskan, Kansan, and Illinoian drifts are the result chiefly of the chemical weathering of glacial till.

The Nebraskan gumbotil has been found in widely separated localities in Iowa. Among the many counties in which it has been studied are Decatur, Clarke, Warren, Madison, Union, Ringgold, Taylor, Adams, Adair, Cass, Montgomery, Page, Shelby, Crawford, Carroll, Tama, Humboldt, and Johnson counties. The topographic positions of the separate outcrops indicate that the Nebraskan gumbotil was formed on an extensive plain with slight relief. The maximum thickness of the Nebraskan gumbotil thus far studied is about 13 feet.

The Kansan gumbotil has the same relations to the underlying Kansan till as the Nebraskan gumbotil has to the underlying Nebraskan till. The Kansan gumbotil has a maximum thickness of more than 20 feet and is limited to tabular divides and other remnants of a gumbotil plain, which, before it was affected by erosion, was as extensive, apparently, as the original Kansan drift plain. This gumbotil occupies a definite topographic position, and where it is exposed in railroad cuts it is seen to lie horizontally in the cut and not to conform to the surface slopes which have been developed by erosion. The Kansan gumbotil has been seen at scores of places in southern Iowa and at many places in other parts of the state; in fact, the Kansan gumbotil has been studied in every county of three tiers of counties in southern Iowa as well as in many of the counties which are farther north. Moreover, within the Iowan drift area the Kansan gumbotil has been found beneath Iowan till at numerous places. It will be of interest to state that the Kansan gumbotil is now known at a sufficient number of places in Iowa to permit the restoration of the Kansan gumbotil plain as it was in Iowa before erosion began.

The relations of the Illinoian gumbotil to the underlying Illinoian drift are similar to the relations of Nebraskan and Kansan gumbotils to their respective drifts.

A comprehensive paper entitled "The Origin of Gumbotil" is now being prepared for publication by the State Geologist and Dr. J. N. Pearce of the department of Chemistry of the State University of Iowa. Another paper, which will be published in Volume XXVII of the Reports of the Survey, calls attention to the fact that there are several large granite bowlders in the Kansan drift in southern Iowa. The view which prevailed some years ago among some geologists to the effect that large granite bowlders are limited to the Iowan drift is incorrect.

Again, a paper is being prepared with regard to the gravels and related materials in the region about Afton Junction and Thayer in Union county. These gravels are so well known to students of Pleistocene geology, and their Aftonian age has been so generally accepted, that one may well hesitate to state that a restudy of these famous exposures and other exposures in the same region has revealed evidence which seems to justify further discussion of the origin and relationship of these gravels, and to warrant question being raised with regard to former interpretations.

Ever since the year 1895, when Dr. T. C. Chamberlin made reference in Geikie's Great Ice Age to the interesting characteristics of these gravels, and interpreted them to be kamelike deposits closely associated with the drift upon which the gravels lie and overlain by a later drift sheet, many glacial geologists of America and of Europe have visited the locality. Some have come merely to see the type sections of the two oldest drifts, now known as the Nebraskan drift and the Kansan drift, separated by the gravels which years ago were named the Aftonian interglacial gravels; others have come to study carefully the characteristics of the drifts and gravels and their inter-relationships. The most important contributions dealing with these gravels and related deposits have been made by Chamberlin, Bain, and Calvin.

The purpose of the paper which is being prepared is to show that the gravels of Union county, which for so many years have been called the Aftonian interglacial gravels, do not constitute a distinctive stratigraphic horizon separating the Nebraskan drift from the Kansan drift, which is the generally accepted interpretation, but that these gravels are lenses and irregularly shaped masses of gravels within a single drift, the Kansan, or, if in two drifts, the Nebraskan and the Kansan, it is not possible by means of the gravels to differentiate the two drifts.

It will be shown, also, in this paper that, although the gravels in the vicinity of Afton Junction and Thayer cannot be used to establish the presence of two drifts, there is other evidence in the region which makes it clear that the two oldest drift sheets are present, and that they are separated in age by a very long interglacial epoch. At several places near the village of Afton and also west of Osceola about twenty miles east of Afton there are fine outcrops of Nebraskan gumbotil, below which is Nebraskan drift, and above which is Kansan drift. Moreover, in Dodge township, Union county, there is a splendid section of peat lying on Nebraskan drift and overlain by Kansan drift. This peat bed was described years ago by Savage. The gumbotil and the peat are now the significant evidence of Aftonian time.

If the interpretations here outlined are correct, the Aftonian gravels of Union county have lost much of their former significance, and the type sections, particularly the Grand river section, can no longer be referred to as sections in which it is possible to study the two oldest drift sheets separated by Aftonian gravels.

The Assistant State Geologist, Dr. James H. Lees, did special work in several of the counties of the state, particularly in Adams, Crawford, and Greene counties. In addition, he rendered valuable service in editing Volume XXVI of the Reports of the Survey, and in again taking charge of the exhibit of some of the mineral products of Iowa at the State Fair. He has, moreover, by correspondence and by personal visit, furnished information to persons interested in the development of one or more phases of the geology of our state.

Besides the Director and the Assistant State Geologist, the corps employed in the regular work of the Survey during 1916 has been much the same as in previous years. Prof. John L. Tilton and Prof. Bohumil Shimek did work in areal geology; Dr. S. W. Beyer and assistants continued their investigations on the clay resources of the state; Prof. W. H. Norton continued to collect data regarding underground waters; Prof. A. O. Thomas and Dr. F. M. Van Tuyl continued their studies on the Devonian and Mississippian systems of rocks, respectively. Mr. W. H. Schoewe made a detailed study of extinct Lake Calvin, and Mr. A. J. Williams carried forward some studies on evidences of glaciation in the Driftless area of Iowa; Prof. A. W. Hixson did some work on the content and quality of the volatile, combustible matter of Iowa coals.

The Survey in 1916 continued to co-operate with the United States Geological Survey in the work of stream gaging and discharge measurements of the important streams of the state, in the collecting of mineral statistics, and in the preparation of topographic maps.

Dr. John L. Tilton has submitted his manuscript on the geology of Clarke and Cass counties, and has revised and re-written parts of the manuscript of the late Dr. James Gow on the geology of Adair county. In addition, Doctor Tilton has been studying in detail the Missouri stage of the Pennsylvanian of Iowa. Among the most important results thus far achieved in this study is the mapping of a fault in southwestern Iowa, to which he has given the name Thurman-Wilson fault. A complete description of the fault is given in his report of the geology of Cass county in Volume XXVII of the Reports of the Survey. The location of this fault has, as pointed out by Doctor Tilton, important economic bearings. It is now clear for the first time why Nodaway coal found in the southern part of southwestern Iowa is not found also in the northern part of southwestern Iowa, except in a small area close to Thurman, Fremont county. It was thought formerly that the fault at Thurman changed into an anticline near Stennett, and if so there ought to be Nodaway coal north of the anticline. It is now evident that it would be unwise to prospect for the Nodaway coal seam north of the fault line. Doctor Tilton shows, also, the effect of the fault on the present distribution of the coal in the Des Moines stage of the Pennsylvanian series.

Dr. W. H. Norton has completed his investigations on the brecciated limestones of the Wapsipinicon stage of the Devonian of Iowa; his report will be published in Volume XXVII of the Reports of the Survey. Doctor Norton has studied for several years these most interesting rocks, and hence his discussion of their characteristics and probable origin will be read with profit by all students of the problem of brecciation in rocks.

Prof. A. O. Thomas has continued his studies of the paleontology of the state. His investigations have had to do chiefly with the life of the Silurian and the Devonian. In connection with the Silurian he has been studying the abundant coral remains found in the Niagaran rocks near Monticello, in Jones county. At no other place in the world, with the exception of the Island of Gotland in the Baltic Sea, are corals so well developed as at that one small area of Iowa. Associated with the corals, Professor Thomas has discovered recently some specimens of the rare crinoid, Herpetocrinus. This is the first known occurrence of this genus from the Silurian of the state. In connection with his studies of the Iowa Devonian, Professor Thomas is preparing a paper on the echinoderms. The paper will bring together the scattered literature on the crinoids and other echinoderms heretofore described, and will describe nearly twice as many new species as had been described previously. Moreover, the sea-urchin remains to be described in the paper are the most abundant and most striking of the sea-urchins from the Devonian of the world.

The discovery of remains of Pleistocene mammals continues to be reported from time to time from various parts of the state. During the year, mammalian fossils have been found near Denison, in the bed of Iowa river at Marshalltown, near Harvey, in a sand and gravel pit in the northwest part of Mason City, in the bed of Skunk river about eight miles west of Keota, and elsewhere. These remains consist chiefly of the teeth and limb bones of the mammoth and mastodon.

Mr. W. H. Schoewe has been doing detailed field work in order to map the shore lines and other features of Lake Calvin, an extinct glacial lake. Reference to this lake was made by J. A. Udden in his report on the "Geology of Muscatine County," published in Volume IX of the Reports of the Survey. Mr. Schoewe has found that this lake when in existence covered parts of Muscatine, Cedar, Johnson, Washington, and Louisa counties. It covered an area of about 325 square miles and in places it had a depth of probably 100 feet. The outlet of the lake was at Columbus Junction. The report of Mr. Schoewe will be awaited with great interest.

It is not surprising that interest continues with regard to whether oil and gas will be found in commercial quantities in Iowa. Those persons who wish to know the attitude of the Survey on this subject should consult the administrative reports in Volumes XXIII and XXV of the Reports of the Survey. During recent years there has been considerable drilling for oil in Iowa, thus far with no success. With regard to natural gas, it may be of interest to state again that small amounts of gas have been found in sand pockets in the drift; in fact, gas in the drift is apparently somewhat widespread. Among the many counties in Iowa in which gas has been found in drift in wells being drilled for water are the following: Boone, Decatur, Emmet, Fremont, Guthrie, Hamilton, Harrison, Johnson, Louisa, Polk, Scott, and Taylor counties.

Two bulletins of Natural History are nearing completion, one by Dr. Bert H. Bailey on the Hawks and Owls of Iowa, and the other by Dr. Dayton Stoner on the Rodents of the State. The view which is prevalent among citizens of the state is that hawks and owls and related birds of prey are detrimental to the agricultural and other interests of the state and that, therefore, all of them, without discrimination, should be destroyed. It is by no means generally understood that these birds of prey are the chief destroyers of rodents and insects, many of which are harmful to crop production. The agriculturist should know that with few exceptions hawks and owls are not his foes but his friends, and he should see to it that every effort is made to preserve rather than destroy them. With regard to the rodents, it may be stated that they are the most numerous and the most widely distributed of all the orders of mammals, and since all of them are either herbivorous or omnivorous in diet they are of considerable importance to the agriculturist. Some of them are harmful and some of them are helpful in relation to crop production. It is necessary, therefore, that the farmer and gardener be able to discriminate between those rodents which are his friends and those which are his foes.

During the year 1916 the Survey co-operated, as in former years, with the United States Geological Survey in the preparation of statistics of mineral production in Iowa. The value of the output for the year 1916 was $29,158,908, which is the highest figure of record for the state, and exceeds the value of the output for 1915 by $2,095,958. Year by year for several years the value of the mineral output of Iowa has increased. During the three years previous to 1916 the values of the outputs were as follows: in 1913, $25,612,345; in 1914, $26,301,865; and in 1915, $27,062,950; a decade ago, in 1907, the value of the output was only $17,627,925.

Coal continues to be the chief mineral produced in Iowa; clay and clay products ranks second; cement ranks third, and gypsum fourth. In 1916 these four products had a value of $27,-466,541, which is more than 94 per cent of the total value of all the mineral products. In 1916 the value at the mine of the output of coal was $13,530,383; in 1915 the value was somewhat more, $13,577,608. The total tonnage of coal mined in 1916 was 7,260,800, compared with a tonnage of 7,614,143 in 1915. The five leading coal producing counties in 1916, in order of tonnage, were Monroe, Polk, Appanoose, Lucas and Dallas counties; then followed Marion, Wapello, and Jasper counties. The average number of men employed in coal mining in Iowa in 1916 was 14,443.

The value of clay and clay products in 1916 was $7,375,716, a figure which has never been exceeded in the history of the clay industry in the state. The values of the clay products in the three chief clay producing counties were as follows: Cerro Gordo county, $1,943,530, Webster county, $1,332,411, and Polk county $971,911. Iowa's production in drainage tile alone in 1916 had a value of $3,986,163; in 1915 the value was $3,802,579.

In 1916 the three cement plants of Iowa, two of which are at Mason City, the third at Des Moines, produced cement to the value of $5,063,647, which is the record value for the state. A fourth plant, located at Gilmore City, Pocahontas county, will soon begin to operate. Additional cement plants should be erected in Iowa during the next few years in order that the demands of a cement age may be adequately met. When Iowa begins permanent road construction, immense amounts of cement will be required for this purpose alone. It is indeed fortunate that within the borders of Iowa there are almost unlimited supplies of materials which can be used in making a high grade Portland cement.

The value of sand and gravel in 1916 was $980,272, of stone and lime, $610,534, and of mineral waters, $14,404.

Iowa continues to be an important producer of gypsum. At present the entire output of the state comes from Webster county, but it is hoped that before many years the gypsum deposits at Centerville may be developed also. The report of Dr. Frank A. Wilder on the gypsum deposits of the state is not yet ready for publication. When completed it will prove to be of great value to all persons interested in the gypsum industry.

It is of interest to state that in 1916 the Missouri Iron Company began to ship ore from Iron Hill, which is about two and one-half miles northeast of Waukon, Allamakee county. The general characters of this ore, the method of treatment, and other features, are described fully in Volume XXV, pages 33 to 92, of the Reports of the Iowa Geological Survey.

I take pleasure in submitting to you the following papers, and recommend that they be published as Volume XXVII, which is the Twenty-Fifth Annual Report of the Iowa Geological Survey:

Mineral Production in Iowa in 1916, by George F. Kay.

The Geology of Ringgold County, by Melvin F. Arey.

The Geology of Taylor County, by Melvin F. Arey.

The Geology of Clarke County, by John L. Tilton.

The Geology of Cass County, by John L. Tilton.

The Geology of Adair County, by James E. Gow and John L. Tilton.

Some Large Bowlders of the Kansan Drift of Southern Iowa, by George F. Kay.

The Wapsipinicon Breccias of Iowa, by William H. Norton.

Respectfully submitted,

GEO. F. KAY.
State Geologist.

GEOLOGY OF RINGGOLD COUNTY

BY

MELVIN F. AREY

CONTENTS

GEOLOGY OF RINGGOLD COUNTY

INTRODUCTION

LOCATION AND AREA.

This county received its name in honor of a gallant young officer who lost his life at the battle of Palo Alto in the Mexican war, the memories of which were still fresh in the mind of the public at the time of the organization of the county in 1851. It is in the fourth tier of counties east of Missouri river along the Missouri border. It has Decatur county upon its eastern boundary, Taylor on the west and Union on the north. Twelve of its civil townships are exact equivalents of the corresponding congressional townships, but the four townships upon the south line are fractional. Sections 31, 32, 33, 34, 35 and 36 in each are entirely wanting and sections 25, 26, 27, 28, 29 and 30 lack a little more than one-fourth of a full area in Riley and Lots Creek townships and just about one-fourth in Middle Fork and Clinton townships. The slightly southward trend of the south boundary of the state in all the counties east of Ringgold ceases about midway of this county and thenceforward the boundary line pursues a due west course. The area of the county is therefore very nearly 542 miles.

PREVIOUS GEOLOGICAL WORK.

Ringgold was one of the fourteen counties in the southwestern part of the state whose geology received special attention by White[1] in his first volume. As but two minor outcrops of indurated rock were found, the three pages devoted to this county were mostly given to the character of the surface and the drainage. The great thickness of the drift and the deep drift-valleys through which the streams flow were particularly noted. These were regarded by White as "the deepest and largest purely drift valleys in the State", "being from one hundred fifty feet to more than two hundred feet deep, from the general level

[1]Geology of Iowa, Charles A. White, M. D., Vol. I, pp. 328-330, 1870.

of the uplands of the county." Other mention of the county is confined to brief comments on the prospect of coal within its limits in volumes II and XIX of the present series of reports of the Survey and to annual tabulated statements concerning clay products in the same series.

PHYSIOGRAPHY

Topography

Simple as is the topography of many Iowa counties, it is doubtful if any one of them presents less complexity in its topographic details than does Ringgold county. The present surface configuration is the resultant of Pleistocene agencies. Such is the thickness of the drift deposits in all parts of the county that, whatever irregularities of surface may have been developed in the later Carboniferous formations during the period of their exposure to meteoric agencies, they contributed almost nothing to the existing topography beyond affording a substantial foundation for the heavy mass of glacial debris that rests upon them. The only decisive ground for qualifying the above statement exists in the valley of Thompsons Fork of Grand river which crosses the extreme northeast corner of the county. Here the river has cut through the drift and well into the Bethany limestone. It is true, however, that all this might have been accomplished under exceptional conditions within the limits of postglacial time and so far as anything in this valley within the county is concerned there is insufficient evidence to warrant a conclusion that it did not so occur. But Bain[2] who studied the channel of this river throughout its course in Decatur county and, doubtless northward into Union county, finds apparently conclusive reasons for regarding that part of the valley of Thompsons Fork of Grand river which is south of Afton Junction as preglacial.

The following are the reasons given by him for his conclusions:

"1. The Kansan drift is found undisturbed in this valley.
2. The size of the valley and the fact that much of it is cut in rock.
3. The distribution and character of its tributary drainage lines.
4. The advanced stage of the meander and rock cutting that has produced the great bend in the river in the northwest portion of Burrell township, Decatur county."

[2] Iowa Geol. Survey, Vol. VIII, p. 264, 1897.

The rock exposures in the valley of the East Fork of the Grand in sections 20 and 30, Lots Creek township, may be indicative of the preglacial existence of a channel there, but since this stream just above these localities and between them is still bedded in the drift, though very near its lower limit, it is much more probable that the channel of this river has been excavated wholly within post-Kansan time.

The larger streams have cut the original drift plain into approximately equal parallel blocks with a north and south trend and these in turn have been subdivided at their southern ends into similar smaller blocks by tributaries which make their junction with the larger streams beyond the limits of the county and state. Tributaries which lie wholly within the county have made numerous smaller triangular or subquadrangular lobes. Minor intermittent streams have continued the dissection almost indefinitely, until only relatively small areas of the original flat Kansan plain remain intact and those are confined almost wholly to the divides of the larger streams and especially in the northern half of the county.

Davis, Wayne and Ringgold counties have relatively small water courses which rise within their border, or but a short distance beyond, while the alternate counties Van Buren, Appanoose and Decatur, are traversed respectively by Des Moines and Chariton rivers and Thompsons Fork, with the results that the great drift plain common to them all has been modified in the later named counties in a much more pronounced way than in the first named. Broad undisturbed stretches of the flat Kansan plain constitute a prominent characteristic of the south two-thirds of Davis county. In Wayne county they are less noticeable, though still a marked feature of the landscape, while in Ringgold county they are to be remarked upon rather from their absence or diminution in size than from their occurrence. These areas are not only unmarked by stream channels, but are also wholly without the wide low sags that characterize the comparatively level stretches that occur in some parts of the regions of the Iowan drift.

The larger stream beds lie two hundred feet or more below the general level of the drift plain and where several streams are in somewhat close proximity the country is exceptionally rugged. Such a locality is in the northeastern part of Union township where Sand creek parallels Thompsons Fork a mile or so away and some of its own tributaries come down to it from the southwest. An exceptionally rugged topography has developed

FIG. 1.—Erosional topography in Monroe township, Ringgold county.

among the upper forks of a small tributary of Thompson Fork in the eastern part of Monroe township. This unusual condition

FIG. 2.—Erosional topography shown in section 30, Athens township, Ringgold county. Belongs at right of figure 5.

among the minor branches near the headwaters of the streams is readily explained. Ordinarily the headwater streams are quite remote from the base levels at their junction with the master stream; thus their gradient is low and consequently their erosive effects are rather moderate near their sources. In the case of Holl Run, cited above, the descent to Thompsons Fork is made within nine or ten miles. With the consequent high gradient all the branches become raging torrents with every considerable rainstorm and the results of their ravages are manifest up to their very beginnings. Such streams make headward erosive progress rapidly and not unfrequently invade the drainage areas of other less precipitous streams, capturing their tributaries and thus still further increasing their own efficiency as agents of erosion. Figure 2 is an example of this process.

A section through the drift block between two large neighbor streams in the south part of the county would be represented

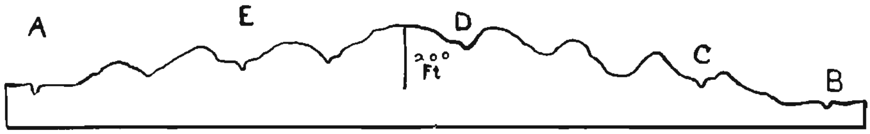


FIG. 3.—An ideal section through a drift block between two large streams in the southern part of Ringgold county.

ideally by the following diagram, figure 3, in which A and B locate the large streams, C, D and E locate the tributaries. The contour line is nowhere twice the same, of course. The altitude of the stream beds increases towards the north and consequently the height of the intervening ridge diminishes, while the number of the ridges usually increases since the blocks are subdissected by an increasing number of minor tributaries toward the headwaters of the main streams. A typical example of these blocks may be seen south of Maloy between the Platte and the West Fork of the Grand.

The flat Kansan areas (or tabular divides as they are called by Kay and others) already alluded to are found just beyond the sources of the headwater streams as in the south of Athens and the north of Riley townships, where there is an area not yet invaded by the initial streams of West Big creek, also in the sections of Athens township immediately south and west of Kellerton into which the head streams of East Big creek have failed as yet to penetrate. A similar region may also be cited about Tingley and beyond Lots Creek, south of Elston.

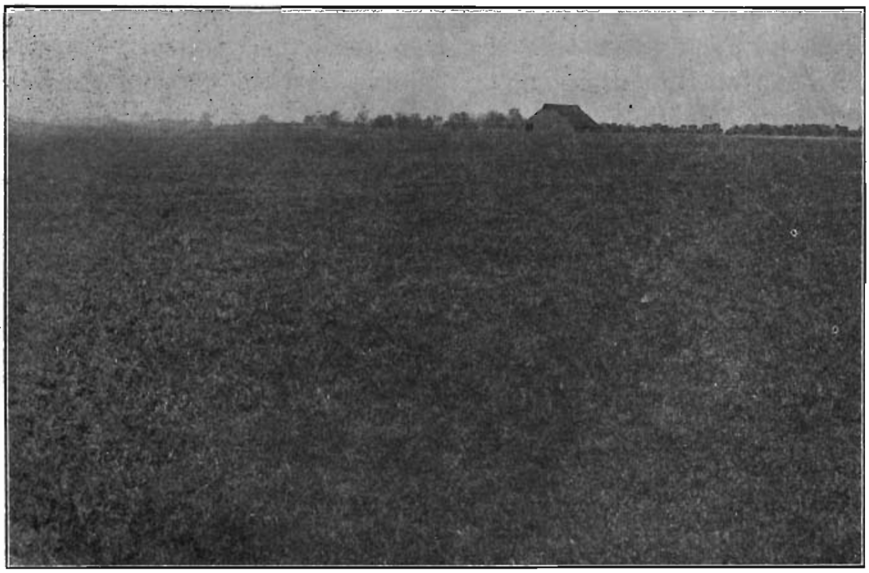


FIG. 4.—Portion of a tabular divide in section 21, Athens township, Ringgold county.

A region representative of an intermediate type of topography may be found south of Mount Ayr towards the East Fork of Grand river. It suggests an exaggerated Iowan drift topog-

FIG. 5.—Erosional topography in section 30 of Athens township, Ringgold county. This view belongs at the left of figure 2.

raphy, a billowy surface, wherein irregularity is the rule, the trend, size and form of the ridges and hills varying indefinitely. From the top of even the highest hills the view is much restricted excepting where a stream valley chances to be in the line of vision.

In the southern part of the county most of the divides and hill crests are narrow, while towards the north they tend to widen and flatten. The Chicago, Burlington and Quincy railroad southwest of Mount Ayr follows the divide between the West Fork of the Grand and the Middle Grand. On both sides of the road the surface gently slopes away to the valleys beyond in a manner quite unique for this region.

Another intermediate type approaches the flat Kansan areas in general aspects, differing in having a moderately broken or dissected surface. The drainage and soil are good and but little or no waste land occurs. This phase may be found adjoining the flat Kansan areas and also in localities whose conditions approximate those of the flat Kansan.

The only remaining topographic phase is that of the river valley. The Platte, perhaps, affords the finest illustration of a river plain to be found within the county. It is comparatively wide and lies high enough to be safely cropped in ordinary seasons, at least. Some of the rivers either have no river plains or have them only at intervals along their courses.

ALTITUDES.

The following table gives the altitudes of points within the county, or just over its border in adjacent counties, as given in Gannett's Dictionary of Altitudes, Bulletin 274 of the U. S. Geological Survey.

LOCALITY	ALTITUDE	AUTHORITY
Beaconsfield	1209	C. B. & Q. R. R.
Benton	1059	C. G. W. R. R.
Blockton, Taylor county	1081	C. G. W. R. R.
Clearfield, Taylor county	1250	C. B. & Q. R. R.
Delphos	1140	C. B. & Q. R. R.
Diagonal	1089	C. G. W. R. R.
Ellston	1214	C. B. & Q. R. R.
Goshen	1180	C. B. & Q. R. R.
Kew	1109	C. B. & Q. R. R.
Kellerton	1197	C. B. & Q. R. R.
Knowlton	1102	C. G. W. R. R.
Maloy	1120	C. G. W. R. R.
Mount Ayr	1232	C. B. & Q. R. R.
Redding	1130	C. B. & Q. R. R.
Shannon City, Union county	1144	C. G. W. R. R.
Tingley	1151	C. B. & Q. R. R.

The points of maximum altitude in the county are on the uplands along the north border of Lincoln and Tingley townships and must be about 1,260 feet above sea level. The lowest point is probably in the valley of Thompsons Fork of Grand river in the northeast corner of the county and is estimated at about 1,020 feet above sea level, making a difference between these extremes of 240 feet, which is quite in accord with the observed depth of the larger river valleys below the adjoining upland levels, where the difference ranges from 150 to 200 feet.

Drainage

The entire surface of Ringgold is covered heavily with drift debris which, superficially at least, is represented by the Kansan, by far the oldest of the drift sheets that are exposed over any considerable portion of the state. The time since the Kansan was laid down may better be reckoned in milleniums than in centuries. The drainage of the county therefore has had ample time in which to develop and, since for two hundred feet or more in vertical extent there is no indurated rock to interpose the slightest obstacle, as complete a system of drainage has been developed as can be found anywhere in the state excepting possibly in the driftless area. Bogs or true swamps are unknown. An occasional small patch that is somewhat saturated with water for a part of the year may be found, perchance, but it scarcely amounts to a disadvantage to the owner of the land. Indeed, the sole disadvantage lies in the fact that in perfecting the system of drainage, the ever active and efficient agents of erosion have cut the channels too deep by far.

The drainage of Ringgold is effected by Platte river and the Grand river system. The Platte is the largest stream that has any considerable part of its course within the county. Its headwaters are in the northern part of Union county. About ninety square miles in Lincoln, Grant and Benton townships of Ringgold are drained by it. After nearly paralleling the course of the West Fork for sixteen miles or more it swerves to the west and enters Taylor county from section 31 of Benton township. It is a quiet stream and along the lower half, at least, of its course in Ringgold county there is a fine alluvial flat of moderate width. It has a series of short, pinnately arranged branches upon the west side, but leaves the drainage upon the east to the West Fork with a single exception in Lincoln township.

Grand river is a tributary of the Missouri and in extent of its basin is comparable with the Cedar-Iowa system as two to three. In Iowa its basin comprises in whole or in part the counties of Wayne, Decatur, Ringgold, Clarke, Union and Adair. Its tributaries with one exception are from the north and have their rise in Iowa. The West Fork may well be regarded as the main stream to which all the rest are tributary as it takes its course southeastward to its master stream.

It may be pertinent to say something here about the confusion in the names of some of the rivers in southwestern Iowa and which is experienced specially in dealing with the various elements of the Grand. In this part of the state more than elsewhere the rivers have a tendency to branch dichotomously, a method that in many cases gives little distinction in size to the branches. Hence the branches are usually called forks and when they in turn divide, their divisions are called forks. Since the courses of all these streams are southward, the terms East and West Forks are very common designations for these secondary as well as for the primary branches, to the utter confusion of the stranger, if not of the resident. Then, too, as the long expression, such as Thompsons Fork of the Grand, is too cumbersome for daily use, it is abbreviated by dropping the terminal prepositional phrase or the initial descriptive part. Thus Thompsons Fork of the Grand is known in Iowa as *the Grand.* When a stream is known as the East Fork, or the West Fork, the stranger is left to wonder to what system the stream belongs.

Named in order from west to east the members of the Grand river system in Ringgold that independently cross its south border are West Fork, Middle Fork, Fletchrell branch, East Fork, Lots creek, West and East Big creeks. So far as they maintain their individuality, their courses are practically parallel. Their drainage basins with one exception are very narrow, scarcely averaging five miles. Most of them are bordered with trees below the point where their initial branches have united to form a perennial watercourse. Their tributaries are small as a rule and principally from the west side excepting in the case of the

West Fork. Bedded in the drift as they are they are muddy streams upon the slightest provocation.

Next to the Platte ranks the West Fork which we have already said should be regarded as the main line of the Grand. It rises in Union county and has in Ringgold a drainage area of about one hundred and seventy-five square miles, more than double that of any other stream except the Platte.

While most of its tributaries are small, Plum creek upon the west in Jefferson township and Squaw, Crooked and Walnut creeks upon the east are relatively large. Its basin has a maximum width of nearly twelve miles.

The headwaters of East Fork also are in Union county. Its course is quite direct. The branches that enter it within Ringgold county are few, but above the average in size. Fletchrell branch and Middle Fork become tributary beyond the state line. Middle Fork drains the territory southwest of Mount Ayr. The eastern border townships are in large part drained by the East and West Forks of Big creek and by Lots creek, all of which form a junction at a short distance beyond the state line. Grand river, or more exactly Thompsons Fork of the Grand, which in its passage from Union to Decatur county leaves merely a few acres of Ringgold county upon its eastern side, effects the drainage of about thirty-six square miles in Union and Monroe townships through its tributaries, Sand and Elk creeks.

STRATIGRAPHY

While Paleozoic formations are to be observed in but three small exposures within the county, there can be no question as to the series or stage to which the deposits immediately underlying the drift should be referred. In the first place Ringgold lies in the very midst of the area of the Missouri stage of the Pennsylvanian series. Then, too, the rocks of all the exposures in their own character as well as through the fossils which they bear testify unequivocally of the time in which they were laid down. Equally clear is the evidence that the superficial drift throughout the county belongs to the Kansan stage. The following table shows the relation of the various elements of the stratigraphy of the county.

TABLE OF FORMATIONS

Group	System	Series	Stage	Character of Rocks
Cenozoic	Quaternary	Recent		Alluvium
		Pleistocene		Loess
			Yarmouth	Gumbotil (Kansan)
			Kansan	Bowlder Clay
			Aftonian	Sand, gravel, plant remains
			Nebraskan	Bowlder clay, bluish gray
Paleozoic	Carboniferous	Pennsylvanian	Missouri Kansas City Division	Limestone

THE CARBONIFEROUS

Since the Carboniferous is almost universally deeply buried beneath the drift and since its uppermost formations belong to that portion of the system that is barren of coal, little interest economically or scientifically attaches to the oldest accessible rocks within the bounds of the county.

Pennsylvanian Series

MISSOURI STAGE.

Kansas City Division.—Neighboring counties, chiefly on the north and east, have numerous exposures of shales intermingled with which are several more or less important beds of limestone which by reason of their greater hardness have a prominence quite out of proportion to their thickness as compared with the shale beds. Sandstones occur, though they are but few. This entire aggregation of strata is a part of the *Kansas City division* and constitutes the basal portion of the Missouri stage[3]. In Keyes' general section of the Missouri in Iowa as published in Volume VII of the Proceedings of the Iowa Academy of Science, a thickness of 100 feet has been assigned to the Kansas City beds in Iowa. The report on Decatur[4] and Madison[5] counties present valuable contributions to our knowledge of the Kansas City division in the state. The exposures are quite numerous and are so distributed and related as to make the differentiation and

[3]See the report on Clarke county, this volume, page 117.
[4]Bain, Iowa Geol. Survey, Vol. VIII, 1897.
[5]Tilton and Bain, Iowa Geol. Survey, Vol. VII, 1896.

correlation of the several beds of the lowest portion of this division quite satisfactory.

The series of limestones belonging to the Kansas City division have been known by the following names.

The Westerville
The De Kalb (Fusulina)
The Winterset
The Bethany Falls (Earlham)[6]
The Hertha (Fragmental)

The Hertha is basal. Each of these substages usually consists of one heavy bed and one or more thin beds of limestone separated by shale beds of varying thickness and each separated from the other by heavy beds of shales with an occasional sandstone bed. Fossils abound in both the limestone and the shales in most localities.

Along Grand river (Thompsons Fork of the Grand, more exactly) in Union county, and near Westerville in Decatur county on Sand creek not far from its junction with Thompsons Fork, are found beds of limestone which Bain has called the Westerville limestone and which lie not far from the upper limits of the Kansas City division.

In section 1, Union township, Ringgold county, which is cut by Thompsons Fork, there is an exposure of shales and limestones along the south bank which belong undoubtedly to the Westerville limestone. A portion of the exposure was covered with drift debris washed from the steep bluffside above. A very imperfect section is given below.

3. An earthy blue limestone, fossiliferous and having the upper 3 or 4 inches very hard and separated from the softer lower portion by a very thin band of shale. The full thickness not determined.
2. A blue-gray nodular limestone, the nodular masses quite variable in size and in some cases in concentric layers; non-fossiliferous.
1. A dark blue fissile shale, 18 inches above the water's edge, the river being quite low at the time of observation.

The fossils observed in No. 3 were *Fusulina,* abundant only in places, *Rhombopora* sp. and several other Bryozoa, a *Productus*

[6]Tilton, John L., The Proper Use of the Geological Name "Bethany": Proc. Iowa Acad. Science, Vol. XX, pp. 207-211, 1913.

sp., *Rhipidomella pecosi*, *Chonetes* sp., and fragments of small crinoid stems.

A yellowish limestone, somewhat crystalline and thin bedded, occurs along the creek in section 20, Lots Creek township. Fusulina, Bryozoa and Brachiopoda fragments largely make up this stone. It is hard and has been used sparingly for foundations by the farmers in the vicinity.

In section 19, Lots Creek township, a similar rock was found. Some layers were much more crystalline, but less fossiliferous. The stone of these outcrops might be serviceable for foundations, etc., were it not that it would require extensive stripping of the overlying drift.

QUATERNARY SYSTEM

Pleistocene Series

Mantle rock practically everywhere covers the county. Its maximum depth is upwards of 280 feet, a little more than that having been penetrated in the Lewis Myers well in Athens township. It is probable that the basal part of this belongs to the Pennsylvanian series and that the driller did not carefully distinguish some of the upper shales and clays of the Missouri formation of that series. Along the immediate banks of the East Fork in Lots Creek township the thickness of the drift is reduced to a few feet. In fact in two places a broken limestone is exposed. The thickness of the glacial deposits over the upland regions averages about 200 feet, if we may judge from the few instances where the drift has been fully penetrated, as well as from the differences in altitudes of the deeper valleys and of the higher ridges. The great thickness of the drift deposits together with the fact that many thousands of years have intervened since the disappearance of the Kansan glacier, the later of the two ice sheets that left their debris over the area of the county, accounts for the unusually rugged topography of large portions of the county. These factors account also for the accompanying phenomena which are manifest everywhere and which are due immediately to the activity of the various weathering agents, included in which phenomena mention may be made of alluvial soils, sand and gravel deposits both superficial and interglacial, reddened and yellowed beds of drift, lime concretions, decadent rock fragments, soil beds, etc.

THE NEBRASKAN STAGE.

Before geologists had directed their attention to the careful and thorough investigation of the abundant drift material found almost everywhere in the northern part of the United States, the Kansan was believed to be the oldest as well as the most extensive drift sheet, at least in the middle west. A more intensive study soon made it evident that a further differentiation must be made to meet the requirements of the accumulating data. The heavy deposits in the southern part of Iowa, for instance, that had been regarded as the product of a single ice sheet gave evidence of having been laid down at two different times. This evidence came from the character of the deposits themselves as well as from the presence of more or less stratified sands and gravels, of vegetal matter and of other interglacial phenomena in the midst of the drift deposits. Today there is practically unanimous agreement among geologists as to the existence of two distinct drift sheets where but one, the Kansan, had been recognized at first. The upper of these has retained the name Kansan. The lower has been known as the Jerseyan, the Albertan, the pre-Kansan, the sub-Aftonian and the Nebraskan. The last name has been suggested by Shimek as suitable and more in accord with the names of the other drift epochs, especially as the other terms are unsatisfactory for various reasons.

The distinctive features of the Kansan have been given so often that they need not be given here. Those of the Nebraskan as given by Shimek will bear quotation. "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 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. 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 makers, being the most despised of the '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.''[7]

Other observers doubtless have found variations in the characteristics of the Nebraskan, as might be expected, but will agree in the main with the above description.

The grounds for the conviction that the Nebraskan occurs in Ringgold county are as follows: The known occurrence of the Nebraskan in Union and other neighboring counties and the almost inevitable necessity of the existence of like conditions in this county at the time the Nebraskan drift was laid down in these other counties; the evidence from the deeper wells; the occurrence of materials definitely referable to the Aftonian, below which are found in a few instances a till meeting the description by Shimek quoted above.

It is unfortunate that the available records of deep wells are so few and unsatisfactory. That they are so is easily to be accounted for, since water is looked for in the upper part of the drift and little interest is taken by the driller in its variations beyond recognizing them simply as sand, gravel, clay, etc. However, such as they are, some deep wells give warrant for regarding them as testifying to the existence of a drift sheet below the Kansan and distinct from it.

Then, too, it has long been understood that coal cannot be found in workable quantities in Ringgold county except at such depths as to preclude its profitable mining under existing conditions, so prospectors have done nothing that helps the geologist in solving his problems concerning the deeper Pleistocene deposits. Recent cuts, natural or artificial, rarely extend more than a few feet below the surface. Indeed so far as the writer's experience goes few, if any, counties of the state afford so little that is directly and positively helpful in determining the nature and relations of the materials constituting the basal part of the

[7]Iowa Geol. Surv., Vol. XX, pp. 304-307.

mantle rock and so in differentiating it from the upper portions.

There are, however, exposures of till that are found near the rock exposures in Lots Creek township which are unquestionably Nebraskan. One of these is a short distance south of Watterson. Others are found on the east and west road in section 20. It is likely that wherever in the south half of the county the mantle rock is thin, it is Nebraskan, though weathering has rendered it difficult of recognition by any distinctive features. Where Thompsons Fork of the Grand cuts the northeast corner of the county the bluffside gives in part a section as follows:

		FEET
5.	A gray loesslike clay	2- 3
4.	A dark gray till, slightly ferruginous above and almost pebbleless	15
3.	A well reddened gravel	10
2.	A blue-gray till	
1.	Till much obscured by wash from above, but doubtless a continuation of No. 2. 1 and 2 together	12-15

It would seem that 1 and 2 are Nebraskan, No. 3 is Aftonian and Nos. 4 and 5 are Kansan, though the thickness seems slight.

THE AFTONIAN INTERGLACIAL STAGE.

While in some places the Kansan rests directly upon the Nebraskan with little to indicate exactly where the line of division between the two is, if indeed material from both is not indiscriminately mingled, in many places sand and gravel beds make a distinct plane of separation, more or less continuous. Soil and forest beds and various vegetal remains not only emphasize this line of division but show that there must have been a long time interval as well. The upper part of the Nebraskan is weathered manifestly in some cases though the passage of the Kansan ice in places removed all traces of this part of the Nebraskan, or thoroughly mixed it with its own debris.

Inquiries concerning upland wells in Ringgold county revealed the fact that the great majority of them end in sand or gravel at a surprisingly uniform altitude, differences in surface elevation being taken into consideration. All over the county the depths of these wells were reported to be from 30 to 80 feet. Just above these sand or gravel beds logs and other plant remains have been reported in several instances. It is not unlikely that the old surface of the Nebraskan was eroded somewhat and this accounts in part for the varying depth of these wells.

It is concluded therefore that Ringgold county adds its testimony to the current belief among Pleistocene geologists that there was a notable interval of time between the two oldest glacial epochs.

THE KANSAN STAGE.

The melting of the Kansan ice sheet left its burden of incoherent material spread out over the county as an extended plain sloping southward. Only remnants of the original plain are to be found today. Its surface has been widely and deeply dissected and its superficial composition has been variously modified by weathering during the long period of time since it was laid down. Good illustrations of tabular divides, as these remnants are called, may be seen in Athens, Monroe and Tingley townships. In fact every township has representatives of the original Kansan surface undisturbed topographically, though in this county they are of meager extent as compared with those in the more eastern counties, among which Davis county is specially to be noted. Since the characteristics of the Kansan have been written up by so many on account of its wide extent and the interest it has always commanded and since it presents no unusual features in Ringgold county, it is not deemed necessary to discuss it further here.

GUMBOTIL.

The term gumbo has been applied popularly and by the earlier students of the Pleistocene to certain dense impervious clays, usually varying in color from gray to nearly black, very tough and sticky when saturated with water, but somewhat tractable when dry, and this term has been applied to clays under a great variety of conditions and relationships. For many years it received little serious consideration from geologists, who simply regarded it as being one of the many variations of clay and having no value in the record of changes that took place in the history of the Pleistocene. In recent years it has awakened the interest of some who have speculated as to its origin and relations without, however, pronounced satisfactory conclusions. Very recently Kay, believing that the time had come to thoroughly study the problem, has evolved a theory that very satisfactorily accounts for the character and relations of the gumbo of the Kansan tabular divides as well as of a gumbo that occurs in similar relations to the Nebraskan and the Illinoian.

A brief statement of that theory is pertinent here. After the retreat of the Kansan ice there was left as a result of its invasion an extensive drift plain with a gentle slope[8]. "This drift plain was so situated topographically that weathering agents were very effective but erosion was slight. As a result of the weathering during an exceedingly long time a grayish, tenacious, thoroughly leached joint clay, which has been named gumbo, was developed to a thickness varying from about fifteen feet to twenty feet or more. This gumbo contains only a few pebbles, which are almost wholly siliceous, and grades down into yellowish and chocolate colored Kansan drift from three to seven feet in thickness, in many places with numerous pebbles, few, if any, of which are calcareous. This drift, in turn, merges into unleached drift, oxidized yellowish for several feet; below which is the normal unleached and unoxidized dark-grayish to bluish-black Kansan drift. The gumbo is believed, therefore, to be essentially the result of the thorough chemical weathering of the Kansan drift, but subordinately, other factors, such as the wind, freezing and thawing, burrowing of animals, etc., have undoubtedly contributed to its formation."

"After the gumbo plain had been developed by weathering processes from the Kansan drift plain, diastrophic movements seem to have occurred, the plain having been elevated to such an extent that erosion became effective, and valleys began to be cut into the gumbo plain. Erosion of the gumbo plain progressed to such an extent that some valleys were cut to a depth of more than a hundred and fifty feet before grade was reached, and a mature topography was developed. Only remnants of the original gumbo plain remain, the most conspicuous of these being flat, poorly drained areas, known as tabular divides. Such divides are more prevalent east of a line drawn north and south

[8]Kay, George F., Bull. Geol. Soc. America, Vol. 27, pp. 115-117.

through south-central Iowa than west of such a line. In the southwestern part of the state, the gumbo is found only where the divides, which are no longer distinctly tabular, retain the level of the former gumbo plain."

It has been announced that detailed chemical analyses of gumbo which have been made in the chemical laboratory of the University of Iowa by Dr. J. N. Pearce strengthen the interpretations given above from the field evidence.

The theory of Kay as set forth above accounts well for a class of phenomena observed by the writer in Ringgold and other counties in southern Iowa, though his observations had been made before the statements quoted had been seen. The writer regards the theory as a distinct and valuable contribution to the settlement of one of the problems that have been attracting more and more the attention of Pleistocene geologists.

Kay also suggests that in place of the term gumbo which has always had a loose and indefinite application the term "gumbotil" be given to the superdrift clays under consideration. His definition follows. "Gumbotil[9] is a gray to dark-colored, thoroughly leached, non-laminated, deoxidized clay, very sticky and breaking with a starch-like fracture when wet, very hard and tenacious when dry, and which is, chiefly, the result of weathering of drift. The name is intended to suggest the nature of the material and its origin."

"Field work has already established the fact in Iowa that there are three gumbotils, the Nebraskan gumbotil, the Kansan gumbotil, the Illinoian gumbotil."

The presence of the Kansan gumbotil in the tabular divides is a matter of common recognition among the farmers as an impervious clay subsoil which in wet seasons checks proper downward drainage of the soil, thus creating conditions more or less unfavorable to the growing crops. It was rarely seen in roadside, or other cuts, however. Two or three gumbolike exposures were noted near the crests of the narrow ridges south of Mount Ayr, but in most instances a yellowish till with lime concretions just below the soil was seen. The latter cases are at a less elevation

[9]Kay, George F., Gumbotil, a new term in Pleistocene Geology: Science, New series, Vol. XLIV, page 637-638; 1916.

than the former and evidently are below the elevation at which the gumbotil occurs. Conditions similar to the above with even less of the gumbotil to be noted are very generally prevalent over the county.

One mile west of Watterson there is a gully eight or ten feet deep, the lower two feet of which is cut in a much reddened till containing many lime concretions. Above this is a gumbotil overlain by a siltlike clay similar to that often mentioned by Calvin in his notes on Taylor county. The whole exposure is undoubtedly Nebraskan. On the east and west road in section 20, Lots Creek township, Nebraskan gumbotil was observed.

LOESS.

This material which overlies the gumbotil and drift in many localities is to be noted in Ringgold county much more frequently than the gumbotil, largely because the cuts that disclose the near-surface mantle rock are in most cases too shallow to reach the underlying gumbotil, while they reveal a part, at least, of the loess. Since Kay's theory of the origin of the loesslike clay overlying the gumbotil is almost a necessary adjunct of his theory of the origin of the gumbotil, it is quite essential that he be quoted here. "While there is in places, loess of eolian origin on the Kansan drift of southern Iowa, much of the material which has been described as loess is thought to be not of eolian origin, but to be related more or less closely to the gumbo. The upper few feet of the Kansan gumbo, which is now limited to the tabular divides and divides closely related to tabular divides, is a fine-grained, loess-like joint clay in which, if diligent search is made, it is possible to find a few very small siliceous pebbles similar to those in normal gumbo, and it is thought that this loess-like clay is the result of changes that have been going on at or near the surface of the gumbo during the great length of time since the normal gumbo was formed. The loess-like clay which is now found as a mantle on the Kansan drift on the slopes and divides that have been brought by erosion considerably below the level of the original gumbo plain is believed to be the product, not of wind action, although wind may have been a factor, but chiefly the product of the weathering and concentration of the gumbo and to some extent the underlying Kansan drift, where erosion has not kept pace with the weathering."

This description of Kay had special reference to the loesslike clay which is prevalent in many counties which lie to the east of Ringgold county and not to the distinctive loess of eolian origin which is found so abundantly in counties which are west of Ringgold county.

In the northeast quarter of section 2, Poe township, the East Fork of Grand river has been cutting comparatively recently into its north and east bank where it turns from the east to the south and has thus exposed twenty feet or more of earth. The upper part of this exposure is loesslike and stands vertical, or nearly so. So well has it resisted erosion that in places it overhangs somewhat the underlying sand or gravel much as indurated rock may overhang the subjacent strata. The unusual thickness, six or eight feet, of this loess, its situation, and its relations to the coarser material next below, which is more or less stratified, would indicate that it is eolian in origin. On the other hand the loesslike clay seen on the top of the narrow ridges on the road from Mount Ayr to Benton and that noted in the east half of section 13, Grant township, and in numerous other localities, afford good illustrations of a material that well may have had its origin by weathering from gumbotil.

Recent Series

ALLUVIUM.

All the larger streams of the county, at least in their lower courses, are bordered with flood plains of varying extent, which by meandering they made for themselves centuries ago. In more recent times with every recurring flood they have deposited over these plains increment after increment of fine silt rich in organic matter. This deposit is alluvium. Fine illustrations of alluvial valleys may be seen along the Platte and the West Fork of the Grand, and these plains extend practically across the county, while along most of the other streams they do not extend beyond the central part of the county.

ECONOMIC PRODUCTS AND PROBLEMS

Soils

The soils of the county are classed as loess, Kansan drift and alluvium. Loess ranks among the best soils. It is porous, thus affording good root basis for plants, admitting ready drainage in wet times and allowing the rise of moisture from below by capillarity in seasons of drouth. Where it overlies gumbotil and is of itself of no great thickness, the impervious nature of the gumbotil causes the ground water to rise into the loess in wet times and thus creates conditions unfavorable to the crops. This drawback is abundantly offset in all ordinary seasons by the fact that over these divides there has never been any wastage by erosion either of the mineral constituents that contribute to plant growth, or of the organic accumulations throughout the years since plants first found congenial conditions on these broad drift plains.

Alluvium, being a wash from the surface of loess or drift soils is naturally a very productive and permanent soil. Because of its situation, however, it is subject to inundation after repeated heavy rainfalls. The same situation, however, gives it the advantage in dry seasons of being well supplied with moisture by capillarity.

Between the tabular divides on the one hand and the alluvial plains on the other is a rugged topography, wherein the mantle rock is a till, mostly Kansan. This area may be divided into two portions, one a region of mature topography about the lower courses of the main streams, wherein erosion is relatively slight, the other where the streams branch dendritically and these branches have their sources well up near the level of the tabular divides, and for no inconsiderable part of their courses are intermittent. In this region erosion is today very active, and gives to the soil little opportunity to accumulate the organic material that is its principal source of enrichment. Then too, there is not time for the mineral constituents of the soil to be set free and made available for the growing vegetation. In other words the soil is kept too thin to be at its best.

Clays

While the till contains much clay it is not of a quality to be serviceable in making tile or brick. For several years common brick were made at Diagonal, at Kellerton and at Redding. The material used was loess and the stiff mud process was employed. The style of kilns was of the down draft type mostly. The annual value of the production scarcely ever exceeded $8,000. Work was abandoned ten or more years ago, since the material was neither abundant nor did it produce brick of the best quality.

Sand, Gravel and Bowlders

While sand and gravel are not uncommon in many of the exposures made along the roadsides, they are in few cases in such abundance as to make them of value for any purpose. They occur in places between Sand creek and Thompsons Fork in quantity sufficient for local road improvement. They also occur in a few slopes where the meander of some stream has eroded, the best examples of which are to be seen on the south bank of Thompsons Fork in the northeast corner of the county, where ten feet of gravel is exposed, and along the north and east bank of the East Fork in section 35, Liberty township. These gravels are abundant and would make good material for improving roads in the neighborhood, but they are overlain with so much other material as to render their use unprofitable even if they could be made accessible by teams. North of Kellerton occurs a sand which is suitable for use in making concrete walks and has been used to some extent for that purpose in Kellerton.

Bowlders are small and rare enough to be subject for remark when seen. They are mostly granites, granitoids or some type of quartz. Cobbles and pebbles of quartzite are fairly abundant. South of Mount Ayr a small limestone bowlder was seen. It had been weathered white on the outside, but was grayish brown on a fresh fractured surface and was intersected by small crystalline veins. The largest bowlder observed is nearly seven feet long.

Water Supply

WELLS

The supply of water is mostly from dug, bored or drilled wells wholly in the drift or alluvium. A few wells have been extended into the strata of the Pennsylvanian, but as a rule such wells are disappointing as to quantity and quality of the water. In some instances they have afforded a copious supply of fairly good water. Mr. Robert Hall has a well in the east half of the southeast quarter of section 24, Athens township, which is over 270 feet deep, yields 13 gallons per minute and has shown no lack of water for eighteen years. A six inch vein of coal was found at a depth of 208 feet. This well ends in a thick bed of coarse gravel above which was "a white sand as fine as gunpowder."

Mr. Lewis Myers has a well in the southwest quarter of the southwest quarter of section 28, Athens township, which is about 500 feet deep, and yields upon test three to four gallons per minute. Eight or nine feet of limestone was encountered at a depth of 282 feet.

Meinzer[10] found by analysis that the water of these two wells "show a large content of mineral matter, especially of sodium sulphate." In the southwest one-half of section 35, Monroe township, on Mr. Lon Beede's place is a well 435 feet deep. Limestone was met at 240 feet. Further details were not secured except that a good supply of water was obtained. Mount Ayr attempted to secure a public supply of water, but a serious cave in at a depth variously reported from 200 to 400 feet discouraged both the driller and the city and the work was abandoned. A well in the northeast quarter of the northwest quarter of section 19, Tingley township, passes through repeated beds of shale, sand and limestone and three very thin seams of coal and ends in sand at a depth of 624 feet. It has a daily product of thirty to forty barrels of water.

Most of the drift wells on or near the tabular divides range in depth from thirty to eighty feet and almost invariably end in sand or gravel. Water is practically assured in wells on the uplands unless they are situated on the naturally drained slopes,

[10]Underground Water Resources of Iowa. Iowa Geol. Survey, Vol. XXI, pp. 982-986.

but it is often limited in quantity, especially in dry seasons. The well at the Porter House in Diagonal affords a good illustration. It is a bored well seventy feet deep and at the time of a prolonged drouth it supplied the premises somewhat scantily, being pumped dry every day. The water is hard. Kellerton is situated upon a tabular divide. Wells in and about Kellerton average thirty to thirty-five feet in depth and end in a reddish gravel. Wood is not uncommonly found just before the gravel is reached. The public well on the street at Kellerton is about thirty-eight feet deep and affords good water in abundance even in dry times. A gentleman in town informed the writer that the water in his well, which is thirty-five feet deep, rises within ten feet of the surface. A few flowing wells are reported in the county but no exact data were secured. A most striking circumstance is the remarkable uniformity in well conditions throughout the county. The instances given illustrate the range of variation very well.

Meinzer[11] suggests that where seepage is slow a system of cluster wells, which has proven advantageous in Davis and some other counties, be adopted. Several wells are sunk within a short distance of one another and connected by iron pipes with a centrally placed well which is a little deeper than the others and which alone has a pump. This well serves as a common reservoir and thus yields a relatively copious supply.

Oil.

Not infrequently certain local conditions awaken the suggestion with the people that a natural supply of oil lies somewhere beneath the surface. The writer's attention has been called to a peculiar scum that appeared upon the water of an artificial pond in the east half of the southeast quarter of section 25, Athens township. Some thirty years have elapsed since the excavation of the pond, but not until March, 1910, had the scum made its appearance. The substance seen by the writer was somewhat gelatinous with a slight oily taste and a little irridescent reflection. Quite naturally some of the residents in the vicinity had become interested. However, it may be said, that whatever

[11] Underground Water Resources of Iowa: Iowa Geol. Surv., Vol. XXI, p. 985.

the origin of the scum, and it may be accounted for in several ways, it is practically certain that no reservoir of oil of commercial value underlies the locality in question. Thus far no oil bearing horizons have been found in the state. Since the subject has been quite fully treated by Calvin in volume XI of the reports of the Iowa Geological Survey, pages 22 to 27, and by Kay in volume XXIII, pages XXV to XLVII, and in volume XXV, pages XI to XIII, of the same series of reports it is not necessary to discuss it further here.

Forestry

Among the real evils resultant upon the settlement of this country is the indiscriminate removal of the natural growth of trees. The recognition of this fact is becoming quite general, however, and in many states where there are extensive tracts more or less tree clad today, but not suitable for ordinary tillage the conservation of the forest remnants and the planting and development of trees on areas unsuitable for productive tillage is regarded as of such importance by the owners that they are employing trained foresters to direct the restoration of these tracts in such a way as to make them remunerative again as fuel and timber producing areas. Nor does it require any such length

FIG. 6.—Reverted timber land in section 26, Poe township, Ringgold county. On the right hand is the first year clearing; in the center, two years after clearing; on the left hand, seven years after clearing.

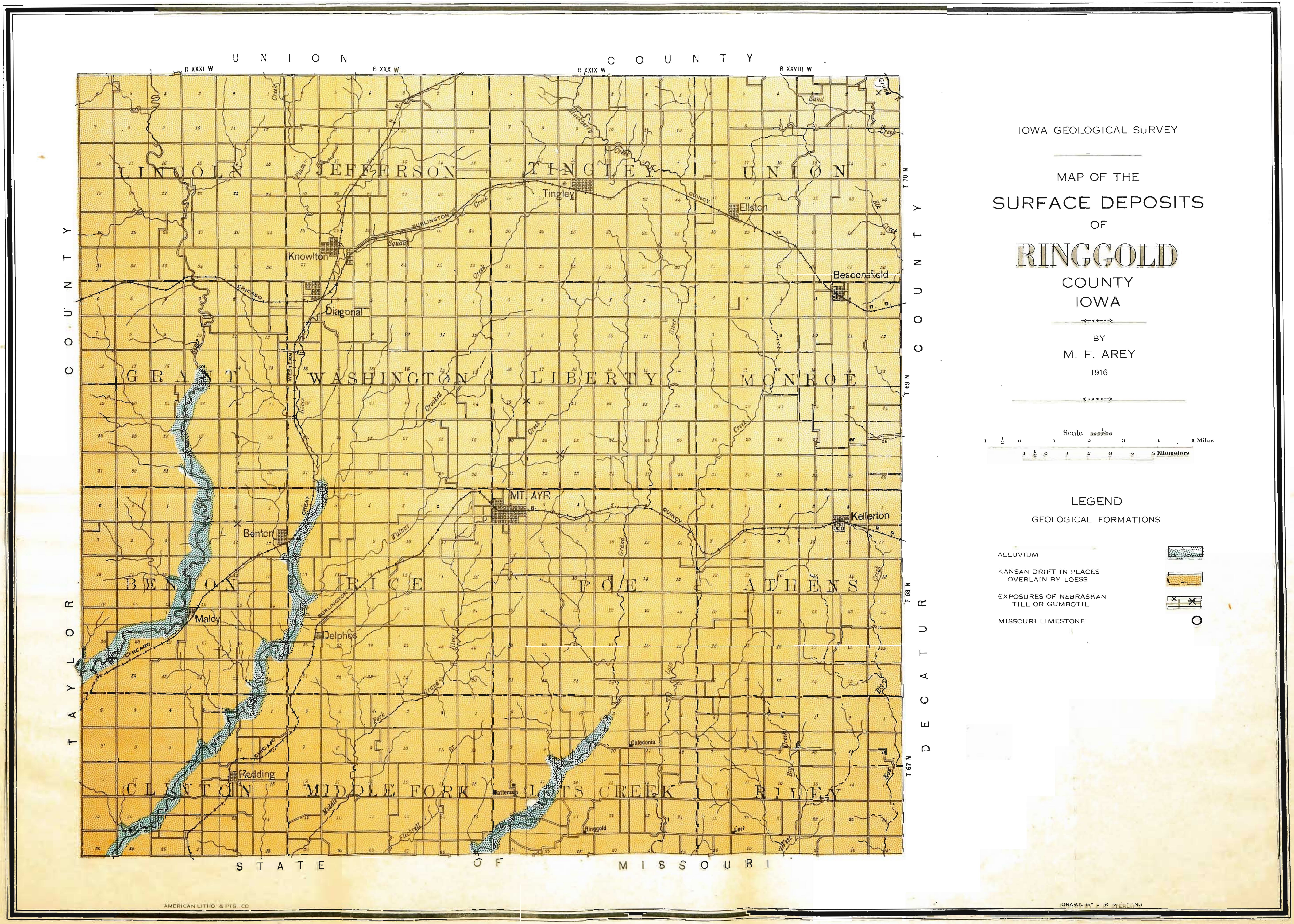
of time to bring this about as has been popularly thought necessary. Not only do owners find this commercially profitable, but they share with the general public substantial advantages growing out of the retention of a large part of the rainfall which is later given off slowly, thus preventing floods, rapid erosion and the covering of creek bottoms with gravel, sand and other forms of sterile deposits as well as making the run-off part of the rainfall available for the use of stock, mill owners, etc., for a much longer period of time. It has not been well understood as yet by owners of sections and quarter sections that even the waste nooks and corners on their farms can be profitably improved by applying to them the principles of forestry, which principles are neither so numerous nor so abstruse but that they may be made readily available by any one.

Not infrequently the papers, proud of Iowa's agricultural prosperity, declare that there is not an acre of waste land in the state. Nevertheless there are many acres that would be more remunerative growing trees, if a little care were given to the selection of the species of trees and to keeping them in good condition. Ringgold county has numerous areas of this kind, some of which, to be sure, are small, but are nevertheless worth as much attention as the other parts of the farm. That they are not now highly valued even for pasturage is evidenced by the fact that they are allowed to grow up slowly to volunteer trees and bushes, many of which are of the least desirable species and all are so browsed and broken up by the cattle as to destroy all likelihood of their ever becoming of material worth to the farmer.

At the borders of the tabular divides there are narrow, deep ravines of recent origin due to headward erosion in times of heavy storms that produce temporary torrential streams in these ravines. In this way many a fair field has been disfigured and rendered more difficult of ready access to all its parts by the constant and ofttimes rapid encroachment upon it of these ravines. Were the sides and upper ends of these ravines planted with judiciously selected shrubs and trees, erosion could be decidedly checked, if not wholly prevented.

ACKNOWLEDGMENTS

The writer is under special obligations to Professor Kay, the head of the State Geological Survey, for his personal presentation of his theory of the origin of gumbotil as well as for various other favors. During the field work every one to whom the writer looked for assistance in any way was most courteous and obliging. To all such his hearty thanks are gratefully extended.



IOWA GEOLOGICAL SURVEY
MAP OF THE
SURFACE DEPOSITS
OF
RINGGOLD
COUNTY
IOWA
BY
M. F. AREY
1916
Scale 1/125,000
5 Miles
5 Kilometers
LEGEND
GEOLOGICAL FORMATIONS
ALLUVIUM
KANSAN DRIFT IN PLACES OVERLAIN BY LOESS
EXPOSURES OF NEBRASKAN TILL OR GUMBOTIL
MISSOURI LIMESTONE
UNION COUNTY
TAYLOR COUNTY
DECATUR COUNTY
STATE OF MISSOURI
R XXXI W
R XXX W
R XXIX W
R XXVIII W
T 70 N
T 69 N
T 68 N
T 67 N
LINCOLN
JEFFERSON
TINGLEY
UNION
GRANT
WASHINGTON
LIBERTY
MONROE
BENTON
RICE
POE
ATHENS
CLINTON
MIDDLE FORK
LOTS CREEK
RILEY
Tingley
Ellston
Knowlton
Diagonal
Beaconsfield
MT. AYR
Benton
Kellerton
Maloy
Delphos
Caledonia
Redding
Ringgold
AMERICAN LITHO & PTG. CO.

GEOLOGY OF TAYLOR COUNTY

BY

MELVIN F. AREY

CONTENTS

GEOLOGY OF TAYLOR COUNTY[1]

INTRODUCTION

SITUATION AND AREA

Taylor county is the third east of Missouri river in the south line of Iowa counties. It is bounded upon the east by Ringgold, upon the north by Adams and upon the west by Page county, while Worth and Nodaway counties in Missouri are upon its southern border. All of its sixteen civil townships are exactly conterminous with the corresponding congressional townships, but owing to corrections in the survey that fell within the limits of this county and to the fact that the state boundary upon the south does not coincide exactly with the section lines of a full township, seven of the townships have fractional sec- an area of 540 5/8 square miles only, or 537 according to the Iowa Official Register for 1919-1920.

PREVIOUS GEOLOGICAL WORK

Doubtless the earliest specific reference to Taylor county by any geologist is made by White[2]. He devotes a little more than three pages to the consideration of its drainage, geology and material resources. Brief reference also is here and there made to this county in the general discussion of the various topics of interest to the geologist, the most practical and interesting of which come up in allusion to the prospects of the occurrence of coal in the Upper Coal Measures, which immediately underlie the heavy drift deposits of the county. His statement that in this series only in the valley of the Nodaway may good coal be found and that only in a thin vein has not been confirmed wholly by later investigators.

In the present series of the Geological Survey of Iowa, Taylor county Coal and Coal Mining receive due attention in volumes II and XIX. Its clays are discussed in volume XIV, and the

[1]In the preparation of this report use was made of field notes of the late Doctor Calvin who spent several weeks in the study of the geology of Taylor county.
[2]Geology of Iowa, Vol. I, pp. 344-348.

Quarries and Quarry Products in Volume XVII in each case by Beyer and Williams, while Meinzer and Norton have treated the Underground Water Resources of the county in Volume XXI.

PHYSIOGRAPHY

Topography

The topography of Taylor county has been developed wholly in the drift excepting along the valley of the East Nodaway which for about seven miles cuts the northwest corner of the county. The great Kansan drift plain formed the original sur-

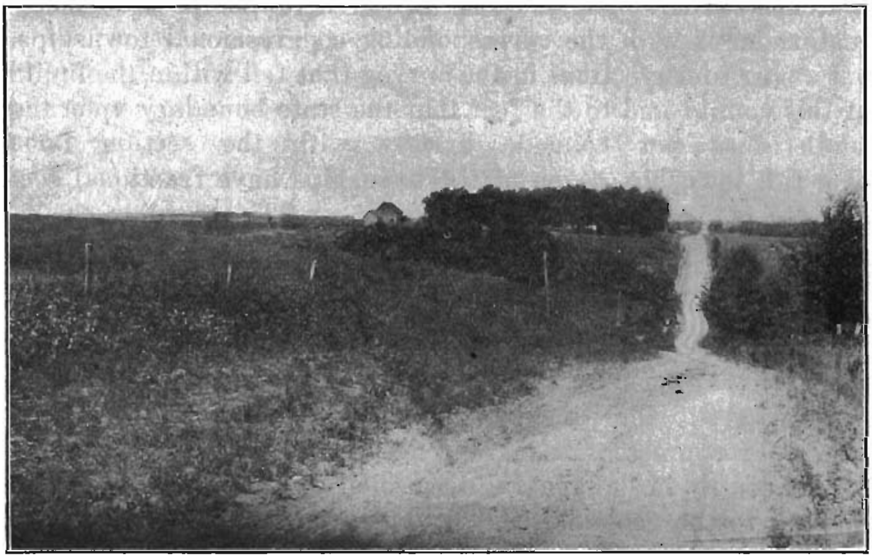


FIG. 7.—Rolling Kansan topography not uncommon in northern Taylor county. Photo by Calvin.

face which sloped gently a little to the west of south. In estimating approximately the slope of the general surface the altitude of Lenox, which is 1,293 feet according to one statement of Gannett, may be taken as very near the maximum for the county, since it is near its northern border and is situated on the uneroded Kansan plain. The altitude of Athelstan, which is 1,069 feet, may be considered as being not far from the minimum, it being near the southern border, south of Lenox in the valley of the Platte. The difference in altitude between the two places is 224 feet. The relief at Athelstan is about 150 feet, leaving seventy-four feet to represent the slope in a distance of about twenty-two miles, or something over three feet to the mile. Today this plain at its southern border has been deeply dissected by a half dozen streams having the same general trend as the slope of the surface, dividing the drift into long, narrow, parallel blocks which have themselves been trenched and carved by the tributaries of the main streams and less deeply by secondary tributaries and only here and there are they crowned with small remnants of the original plain which through the long centuries that have passed since the retreat of the Kansan ice sheet have escaped all commonly recognized effects of erosion.

Naturally the south part of the county, where the streams have the greatest volume of water, has been most deeply eroded and it is in this part of the county that flat unchanged areas of the original plain are rarely to be found, though the interstream drift blocks are capped by numerous tracts that are but slightly

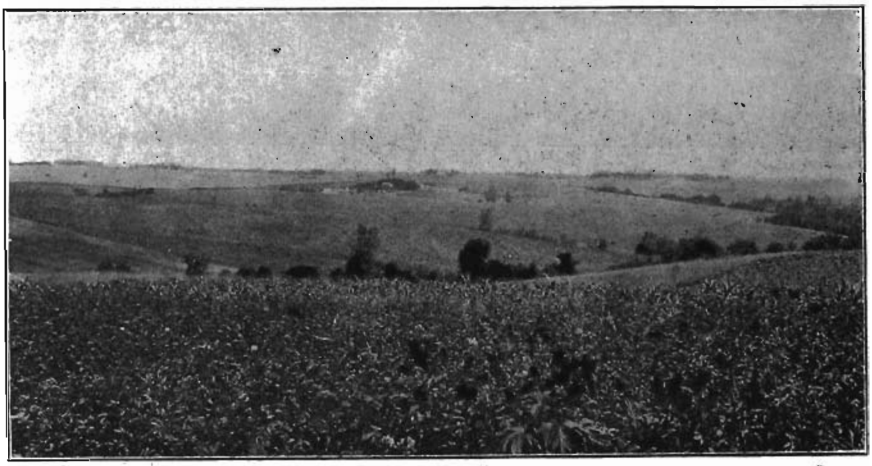


FIG. 8.—Kansan topography of northern Taylor county, showing the fairly even skyline. Photo by Calvin.

sculptured, or mildly dissected as yet. Further to the north these areas are larger in number and extent and where the headwaters of the smaller streams are found in the neighboring drift blocks, having lost their boundaries, coalesce, giving rise to a much less rugged topography, though where the larger streams enter the county already carrying a considerable volume of water in the rainy periods, the topography of their valleys is well advanced, their flood plains being broad, and their valley sides being steep and well dissected. Where the tabular divides are unchanged by erosion, they are bordered by tracts that have been moderately sculptured, the succession of swells and depressions suggesting an Iowan drift landscape. The latter, however, presents a surface for the most part as it was left by the retreating ice, the erosional

FIG. 9.—Rolling Kansan topography in Taylor county showing the great width of the valleys. This view is suggestive of Iowan topography. Photo by Calvin.

changes being relatively slight, while the former is wholly the result of erosion. From this mild type of erosion are to be found all gradations to the somewhat mature forms of the south border.

The relief of different localities ranges from a few feet to 100 or 150 feet. In extreme cases it reaches 200 feet.

Platte township has more level area than any other, perhaps, since it is traversed by no large streams, the drainage being accomplished by headwater branches of East One Hundred and Two river. Its surface, even where it is most dissected, is capable of cultivation readily since the slopes are comparatively easy. Grant, Grove, Holt, Washington, Marshall and Gay townships have many considerable areas of a moderate erosional type, though all of them have deeply eroded stream valleys crossing them. The other townships crossed by the lower courses of one or two of the larger streams have a higher per cent of rough land, though no inconsiderable part of their intervening territory with moderately sculptured surface affords much fine farm land.

The west tier of townships, Polk, Mason, Dallas and Nodaway, present the roughest topography, being traversed by the West Hundred and Two river which carries an unusual volume of water. Besides this strong erosional agent, Nodaway township is crossed by the vigorous East Branch of the Nodaway river and several tributary creeks some of which have cut completely through the drift and well into the shales and limestones of the Missouri, thus producing the maximum degree of ruggedness for the county. It is in these townships that the broadest flood plains and bottom lands occur, making compensation in part, at least, for that portion of their extent that has been marred by deep ravines and other forms of advanced erosion.

ALTITUDES.

The altitudes of the following places in the county are taken mostly from the later edition of Gannett's Dictionary of Altitudes:

LOCALITY	ALTITUDE		AUTHORITY
Athelstan	1069,	C. G. W. R. R.	Gannett
Bedford	1098,	C. B. & Q. R. R.	Gannett
Blockton	1081,	C. G. W. R. R.	Gannett
Clearfield	1250,	C. B. & Q. R. R.	Gannett
Conway	1140,	C. B. & Q. R. R.	Gannett
Conway Crossing	1158,	C. B. & Q. R. R.	Gannett
Gravity	1149,	C. B. & Q. R. R.	Gannett
Ladoga	1244,	C. B. & Q. R. R.	Gannett
Lenox	1293,	C. B. & Q. R. R.	Gannett
	1250,	Weather Bureau	Gannett
New Market	1153,	C. B. & Q. R. R.	Gannett
Sharpsburg	1270,	C. B. & Q. R. R.	Gannett
State Line	1054,	C. B. &. Q. R. R.	C. B. & Q. R. R.

Drainage

The drainage of the county is very nearly perfect. It is accomplished by branches of three small river systems. These rivers are tributaries of the Missouri, namely the Platte, One Hundred and Two and Nodaway. Platte river rises in Adair county, enters Taylor from Ringgold in section 15, Gay township, and leaves it near Athelstan, on the Missouri border, after a gently meandering course in a southwest direction through a beautiful flood plain. Just beyond the borders of the county the river turns abruptly to the west and in a course of six or seven miles receives as tributaries the West Branch and Honey creek, beyond which it flows south to its junction with the Missouri. Honey creek rises along the border of the tabular divide near Clearfield, and West Branch rises two or three miles farther south in Ringgold county not far from its western border. These two streams pursue a nearly parallel course at an average distance apart of about four and a half miles, at first in a southwest direction. The last third of their course through the county is southward. They have no perennial tributaries. Narrow flood plains more or less tree covered border them for nearly their whole length. The block of drift between them has a relief in the south of one hundred and fifty feet or more. This diminishes toward the north, disappearing entirely as the source of the head-water streams is reached. In Jackson township little, if any, of the original flat Kansan surface remains unchanged, but as one proceeds to the north, the relief lessens and rugged topography gives way to moderately sculptured interstream areas to be followed later by the tabular divides that have never suffered the ravages of erosion in any appreciable degree.

In the main there is little more to be said of the One Hundred and Two river system than has been said of the Platte system. East One Hundred and Two and Middle One Hundred and Two both rise within the limits of the county. The East One Hundred and Two is considerably larger than the other, having a course of about twenty-seven miles in the county and a drainage area of about one hundred and twenty-four square miles. Its course is southwest. Middle One Hundred and Two has little or no flood plain. Brushy creek is its largest branch. Having first united their waters, these two branches effect a junction five or six miles south of the Missouri border with the West Branch, which is really the main stream. The West One Hundred and Two rises in Adair county and its whole course in Taylor county is nearly due south. It has a fine flood plain throughout the county, and also has the largest tributary of any of the streams of the county. The wretched system of nomenclature for the streams in some of the southwest counties of Iowa is well illustrated here, for according to the maps the West Hundred and Two river itself has a tributary on the east called the West Branch of One Hundred and Two river and it has another tributary on the east called the Middle Branch of One Hundred and Two river despite the fact that Middle One Hundred and Two river flows a little farther to the south in the same county. Though in the south half of its course the drainage basin of West One Hundred and Two river is not more than thirty square miles in extent, it is broader in the north half so that it has a total area of about two hundred and twenty square miles.

The East Branch of the Nodaway river, which in common with the Platte and West One Hundred and Two rivers rises in Adair county or very near its south border, passes in rather a meandering line through the west sections of Nodaway township and then in section 6 of Dallas township swerving to the west, enters Page county. It with its several small tributaries drains only about nine square miles of Taylor county. In its brief course it has cut through the glacial deposits and made several exposures of the Missouri shales and limestones.

It has been said that the drainage of Taylor is very nearly perfect. The exceptional cases are to be found in various portions of the county though more frequently in the northern than in the southern part, and consist of small areas of a swaley, boggy character for the most part on hillsides or in depressions between ridges in moderately sculptured regions. These places are due no doubt to rainfall entering the ground and soon reaching gumbotil, the impervious nature of which checks its downward progress, causing it to pass to the lowest part of the nearly flat area where a swampy patch will often be found, though sometimes it does not show itself at the surface, but in wet seasons manifests itself in damaged crops of corn or grain whose root system has thus been drowned out. Sometimes the water reaches the eroded margin of the gumbotil on the bluffside where it slowly escapes by seepage, not in a single spot as a spring, but all along the hillside. Roadside cuts occasionally present the same phenomena.

In the country south of Ladoga the main depressions are swampy and on the slopes of the highlands the secondary depressions are too wet to produce good crops in wet seasons. Here the soil is moist and sticky, while, at the same time, in marked contrast the soil in sections 2, 3, 10 and 11, Bennington township, is granular, dry, easily crumbled and ideal for cultivation. Springlike seeps are found in the east half, northwest quarter of section 8, Mason township, in a sticky, tough, siltlike bluish deposit. In Marshall township there are small patches of very tough, siltlike, blue, sticky clay which makes seepy, miry places on the roads and more or less barren places in the fields. In Grove township there are flat sloughs between the rounded swells. An example may be noted in the northwest quarter of the northeast quarter of section 15. About the middle of the north line of section 23, Nodaway township, there is a broad slough, also another on the hillside in the northeast quarter of section 27, Nodaway township. Many other instances might be given. In each the association with gumbotil is such as to readily account for the conditions. See figure 17 for an illustration of this phenomenon.

STRATIGRAPHY

While the Missouri immediately underlies the Pleistocene deposits everywhere in the county its exposures are very few. Aside from those already mentioned as being found along the East Nodaway and its small tributaries in the extreme northwest corner, a few others may be seen in and about Bedford along East One Hundred and Two river. Mantle rock belonging to the Pleistocene and the Recent is everywhere to be observed. It is quite varied in its manifestations and involves some of the most interesting present day problems that are engaging the attention of geologists, such as the origin of gumbo and some phases of loess.

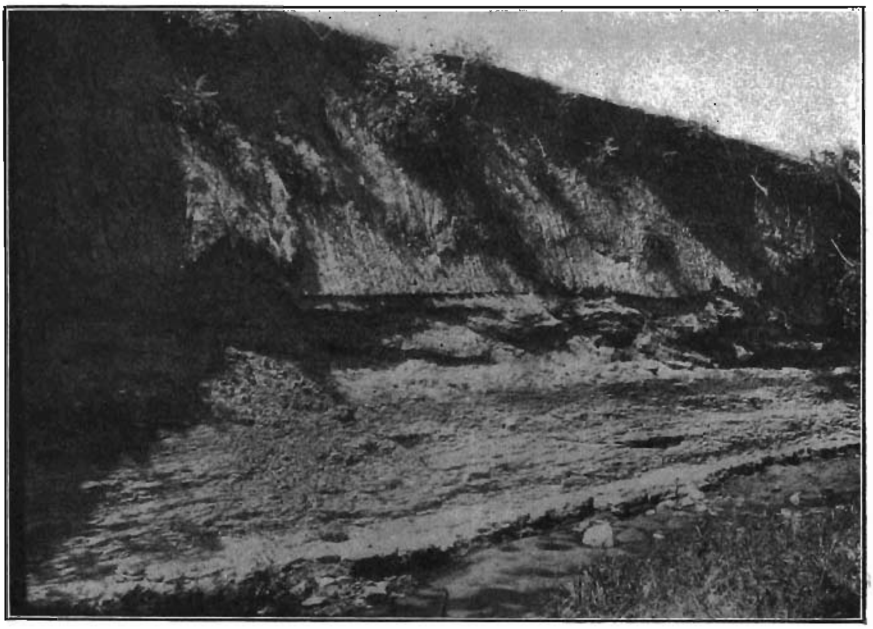


FIG. 10.—Missouri limestone overlain by loess; in the southwest quarter of the southwest quarter of section 7 of Dallas township, Taylor county. Photo by Calvin.

A table of the geological formations of Taylor county follows:

SYNOPTICAL TABLE.

GROUP	SYSTEM	SERIES	STAGE	CHARACTER OF ROCKS
Cenozoic	Quaternary	Recent		Soils Alluvium
		Pleistocene	Yarmouth	Gumbotil (Kansan)
			Kansan	Bowlder clay, blue, jointed; pockets of sand and gravel
			Aftonian	Gumbotil (Nebraskan), forest beds, peat beds, soil beds, aqueous sands and gravels
			Nebraskan	Bowlder clays, dark, friable
Paleozoic	Carboniferous	Pennsylvanian	Missouri	Shales and limestones

CARBONIFEROUS SYSTEM

Pennsylvanian Series

MISSOURI STAGE.

While the Missouri shales and limestones everywhere underlie the mantle rock, they outcrop in but two localities, near Bedford and in the valley of the East Nodaway in the northwest corner of the county. Limestone is exposed near the east end of the bridge east of the railway station at Bedford and again farther north near the river, where it formerly was quarried. This rock is referred by Calvin to the Forbes (Deer Creek) limestone.

There are exposures of the Missouri for half a mile along an unmapped tributary of the East Nodaway in the southeast quarter of section 29, Nodaway township. One of these is illustrated

FIG. 11.—Exposure of cap rock with a big Kansan bowlder; in the southeast quarter of section 29, Nodaway township, Taylor county, as it appeared in 1907. There are other exposures farther down the creek. Photo by Calvin.

by figure 11. Cap rock forms the platform on which the creek flows. In some places, however, it rises three and four feet above the usual water level, exposing below it two feet, more or less, of thin bedded shales and a foot of bastard rock very rich in fossils, *Ambocelia planoconvexa* especially abounding. Other exposures of the cap rock were observed in the northeast quarter of section 20 and in the north

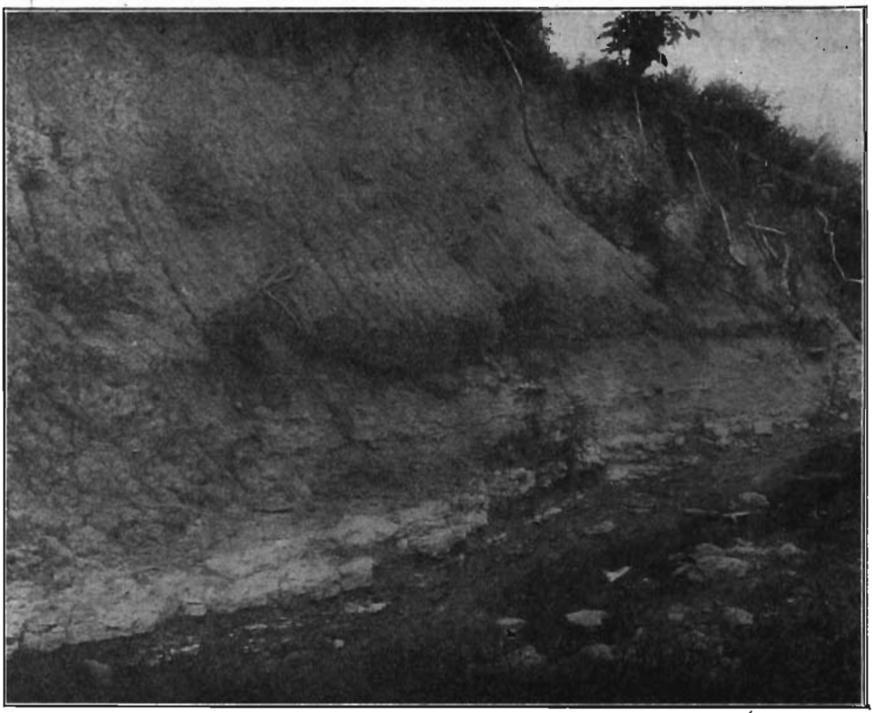


FIG. 12.—Exposure of Missouri limestone and shale overlain by gravel, "silt" and loess; southwest quarter of the southwest quarter of section 7, Dallas township, Taylor county. Photo by Calvin.

half of section 32, Nodaway township. Calvin gives the following section northeast of Hawleyville, Page county, along the west border of section 7, Dallas township. Figure 12 illustrates this outcrop.

		FEET
6.	Loess	—
5.	Blue silt	—
4.	Gravel	—
3.	Yellow weathered shale	4
2.	Harder shaly limestone, containing *Chonetes granulifera*, Fusulinas and Bryozoas	½
1.	Shaly limestone in the bed of the creek	2/3

The blue silt of Calvin mentioned above and elsewhere is undoubtedly the gumbotil of Kay[3]. Other exposures occur in this vicinity but aside from minor variations as to thickness and relative order of occurrence of the material further details are unnecessary.

According to Tilton the following beds must be represented here somewhere: Howard limestone, Severy shale (with its Nodaway coal seam), Topeka limestone, Calhoun shale, Deer Creek limestone.

THE BEDFORD WELL SECTION

Missouri Stage.—However, it should be of interest to note well the Missouri stage of the Bedford deep well section and so it is transcribed here from the section as given in the volume on the Underground Waters of Iowa[4].

SECTION OF THE BEDFORD WELL.

DESCRIPTION OF STRATA	THICKNESS FEET	DEPTH FEET
Pleistocene:		
Drift, no samples, no record	38	38
Carboniferous:		
Pennsylvanian—		
Missouri stage (722 feet thick; top 1,060 feet above sea level)		
Limestone, light gray, nonmagnesian, soft; earthy luster; permeated with minute ramifying smooth surfaced masses of calcite	6	44
Limestone, argillaceous, light gray, soft; earthy luster; and shale, plastic	6	50
Shale, drab, unctuous, noncalcareous; 8 samples	40	90
Shale, bluish drab, calcareous	5	95
Limestone, earthy, light blue-gray	5	100
Shale, drab, calcareous, 3 samples	15	115

[3]Kay, G. F., Gumbotil, a new term in Pleistocene Geology: Science, New Series, Vol. XLIV, Nov. 3, 1916.
[4]Iowa Geol. Surv., Vol. XXI, pp. 1183-1185, 1912.

Limestone, light blue-gray, soft, argillaceous; with shale	5	120
Shale, drab, calcareous	5	125
Limestone and shale: limestone soft, whitish; rapid effervescence; numerous Fusulina; encrinital, 5 samples	25	150
Limestone, light gray, soft, earthy; a little chert	5	155
Shale, greenish drab; some limestone with crinoid stems	10	165
Shale, as above; some black carbonaceous and a little blue-gray limestone	5	170
Limestone, light brown, white, gray, hard, compact; and greenish shale	5	175
Limestone, light blue-gray, argillaceous; and light yellow-gray with crinoid fragments; greenish shale	5	180
Limestone, yellow, gray, hard	5	185
Shale, dark brick-red, calcareous; 2 samples	10	195
Shale, greenish drab, calcareous, siliceous; and ocher-yellow, hard, siliceous, calcareous; 2 samples	10	205
Shale, hard, greenish drab; so highly siliceous with minute particles of quartz that it might be termed an argillaceous sandstone	5	210
Shale, greenish drab, plastic, pyritiferous; some hard, yellow fossiliferous limestone	15	225
Shale, blue-drab, soft, laminated; harder siliceous layers	25	250
Shale, drab, laminated; 6 samples	30	280
Shale, drab, with some laminæ of black coaly shale	5	285
Shale, green, fossiliferous	5	290
Shale, green, fossiliferous; some drab limestone and chert	5	295
Shale, hard, red; 2 samples	5	300
Limestone, hard, drab, with shale	10	310
Shale, drab, fossiliferous	10	320
Limestone, hard fine-grained, siliceous	5	325
Limestone, yellow-gray; and white, soft; earthy luster; 3 samples	15	340
Shale, green and black, carbonaceous	5	345
Limestone, soft, yellow, macrocrystalline	10	355
Shale, drab; 5 samples	25	380
Shale, drab; some drab limestone	5	385
Shale, drab; with sand of flinty drab limestone	5	390
Shale, reddish; with dark green-gray argillaceous limestone	5	395
Shale, red, a little brown siliceous limestone	10	405
Shale, drab, 4 samples	15	420
Limestone, light yellow-gray; crystalline in sand; 4 samples	20	440
Shale, greenish drab	10	450
Limestone, light yellow-gray; much shale	5	455
Shale, greenish; some drab limestone, flinty	10	465
Limestone, light yellow-gray	10	475
Shale, drab, 4 samples	20	495
Limestone, white; large fragments of shale	21	516
Shale, drab; some black at 516; with limestones at 525; 4 samples	19	535

Limestone, white and gray	15	550
Shale, black, fissile, combustible; and hard, gray limestone	5	555
Shale, dark drab	10	565
Shale, greenish; with white limestone in concreted powder	5	570
Sandstone, white, microscopic grains, calciferous; with shale	5	575
Limestone, white and light gray	10	585
Shale, dark drab	5	590
Limestone, hard, gray, siliceous; shale	5	595
Shale, dark drab	5	600
Limestone, yellow-gray, rather hard; much shale in large fragments	15	615
Shale, dark drab, nodules and masses of gray chert	15	630
Shale, light brown, calcareous	5	635
Shale, greenish; with gray limestone and chert	5	640
Limestone, gray; much shale	5	645
Shale, drab, black at 645; gritty at 650 and 655; with limestone at 670; sandy at 670, 675, 695, 700; coaly at 705	65	710
Sandstone, fine, gray; 3 samples	15	725
Shale, dark drab; some black; fissile	10	735
Limestone, gray, finely arenaceous	10	745
Shale, dark, and reddish brown; 2 samples	10	755
Limestone, light gray	5	760

This is a typical section of the Missouri. There are in the 722 feet of thickness sixty-five strata as determined by the interpreters, Meinzer and Norton. Two of these are sandstone, twenty-four are limestone and thirty-nine are shales. The great majority of them range from five to ten feet only in thickness. Less than half the shales are simply argillaceous. Many of them are calcareous to a greater or less extent, or are thinly laminated with limestone. Others are carbonaceous up to the degree of being combustible or coaly. A few are siliceous, one being so much so as almost to warrant its being called an argillaceous sandstone. Only a few of the limestones are relatively pure. Some are shaly, or thinly laminated with shale. Others are cherty, flinty or otherwise siliceous. Fossiliferous beds are rare among both the shales and limestones. Shallow waters prevailed, but the depth and other conditions were constantly changing, now and then by comparatively abrupt diastrophic movements of the land or sea bottom or both, but for the most part by very gentle changes of level or of the relations of the land and water. Few of these individual strata are of wide extent, if we may judge from a consideration of other sections of this stage, either partial or complete. In thinking of the conditions of the Missouri we are constantly reminded of the present day conditions of the northern margin of the Gulf of Mexico. There we find the extensive deposits forming shales, the small amount of sandstone area as at Ship Island and its vicinity and the limestones and shales of the Tortugas, etc.

Des Moines Stage.—Of the 580 feet of this stage the lower 180 feet are sandstone excepting two strata of shales five and fifteen feet thick interstratified with the two upper sandstone strata. The remaining upper 400 feet are wholly shales.

The Mississippian Series.—This series is 355 feet thick. At the very base are thirty feet of shales. Near the middle are two cherty strata. The rest of the section shows limestone exclusively.

The Devonian System.—In this section 130 feet belong to the Devonian system, of which 115 feet are limestone and fifteen feet are shale.

Silurian System.—Of the 575 feet belonging to the Silurian 120 feet are common limestone, 193 feet are dolomite, 130 feet are anhydrite marl, 30 feet are shale, 4 feet are marl and 20 feet are unknown.

THE MANTLE ROCK. THE QUATERNARY SYSTEM.

The Pleistocene contributions of Taylor county at once challenge the interested attention of the careful observer. The original materials of these contributions were doubtless very much like those of the same stages to be found in other counties where only the two oldest drift sheets have been laid down. But the changes wrought in them by the various agents of change during the immense intervals of the Pleistocene during which these agents have had free play, are unusually varied and somewhat confusing, but nevertheless of very great interest.

Pleistocene Series

NEBRASKAN STAGE

The material of this stage, the oldest of the glacial stages of Iowa, differs in its physical features so little from Kansan drift, that it is difficult to determine the age apart from certain materials which are associated with these drifts. When in southern

Iowa two drifts are found separated by gumbotil, a peat bed, or any other evidence of an interglacial epoch, the lower drift is assigned to the Nebraskan without much hesitation. Overlying the Nebraskan drift there is found, in many places in Taylor county and in other counties, a grayish, tenacious, thoroughly leached clay, which popularly is called gumbo, but which Kay has called specifically gumbotil[5], and which Calvin, in doing field work in this county in 1910, frequently noted, giving it, for the sake of distinction, the name of blue silt. The comments in his note book upon the unusual occurrence of this material under the conditions in which he found it, show that he was becoming deeply interested in the problems it suggested and had he lived there is no doubt that he would have evolved a theory for its solution.

Some of the localities where the Nebraskan is exposed quite convincingly are given here. A few rods west of the northeast corner of section 16, Jefferson township, and also one-fourth mile west of the same corner a light blue siltlike material which occurs at intervals throughout the county seems to be overlain in the bank at the roadside by true drift and it is underlain toward the east by very red ferruginous till. Calvin thought this might be an inclusion of pebbleless Nebraskan in the Kansan. It may be, however, that the lower till is the weathered Nebraskan and the silt the overlying Nebraskan gumbotil.

In the west half of section 24, Clayton township, along the road passing through the middle of the section, exposures of Nebraskan gumbotil occur beneath Kansan drift. Similar exposures may be seen on both sides of Dougherty creek in Benton township. Along the south line of section 19, Benton township, near the southwest corner, Nebraskan gumbotil underlies residual gravel. A few rods north of the school house near the southeast corner of section 9, Benton township, an exposure presents the following section:

		FEET
3.	Weathered Kansan with small pebbles, very red or brown...	2
2.	Thin band of blue silt (or gumbotil)......................	½
1.	Weathered red till with much lime..........................	2

[5]Kay, George F., Gumbotil, a New Term in Pleistocene Geology: Science, new series, Vol. XLIV, November 3, 1916.

Near the northeast corner of section 4, Benton township, a section shows weathered calcareous Kansan overlying a body of blue silt and apparently resting unconformably on it. This blue silt has many small pebbles in it. Nebraskan gumbotil occurs in a ravine north of Buchanan apparently below Kansan. One-eighth mile east of the southwest corner of section 9, Polk township, gumbotil appears below good Kansan. On a hill east of the center of the southeast quarter of section 15, Mason township, a section shows:

3. Typical calcareous Kansan.
2. Crumbly blue silt, Nebraskan gumbotil.
1. Kansan-like till (Nebraskan till).

It will be noted that the above cited instances are all in the townships of the south half of the county. This was to be expected since in the north half erosion is everywhere moderate except along Nodaway river.

AFTONIAN STAGE

The presence of Nebraskan gumbotil, at many places in Taylor county, separating the Nebraskan drift from the overlying Kansan drift, is the best evidence of the Aftonian age, which interval began with the retreat of the Nebraskan ice sheet and ended with the coming of the Kansan ice sheet. This Nebraskan gumbotil is, according to Kay, the result chiefly of the chemical weathering of Nebraskan drift during Aftonian time. Other materials, such as sand and gravel, peat, and vegetal matter, are included in the Aftonian. It is more than likely that sand and gravel in the bank of a small creek south of Adam's coal mine in the southwest quarter of the southeast quarter of section 24, Dallas township, is Aftonian, but sufficient determining data are not to be secured. Other similar cases might be cited. Frequent mention is made of meeting with wood and other forms of vegetal matter in putting down wells, but since most wells are relatively shallow, ending somewhere in the drift or just at the point of reaching rock it has not been thought worth while by the well digger to make and preserve the details of the changes in the character of the materials as they have been penetrated. The appearance of wood would impress the memory, but the depth and accompanying mineral materials would not be remembered except in a very general way. A few instances where wood was found in sinking wells are here cited: The well at the Bedford schoolhouse; the well at the Fairgrounds; two wells in the southwest quarter of section 7, Ross township; two wells in the southeast quarter of the southeast quarter of section 13, Ross township; a well near the middle of the west line of section 2, Washington township; and in a mine shaft in the southeast quarter of section 34, Dallas township. In this instance the wood was encountered above a dark blue till believed to be Nebraskan. Even in the record of the deep well at Bedford, where all the details respecting the rock formations below the Pleistocene are given with the utmost particularity, nothing is given concerning the Pleistocene save its thickness, thirty-eight feet.

KANSAN STAGE.

The direct available knowledge of Taylor county as a portion of the earth's surface is confined almost wholly to the Kansan drift formation. It is dominant in thickness, in area, extent, in variety of phases in which it appears today, and, with the Nebraskan, in forming the basis in which the topography of the county has been wrought. Out of it has come the material prosperity of the people in the main. A restricted area in Nodaway and Dallas townships produces coal which comes from the Missouri. A few wells derive their water from the Aftonian, or Nebraskan, or even from the Missouri or still older rocks. Along the larger stream courses alluvial deposits of moderate extent are found. With these exceptions, it is the Kansan, Kansan everywhere upon which the people must depend for their substantial success.

The material of which it is composed was torn from the rocks of various kinds that lay in the pathway of the immense glacier that irresistibly ploughed its way from its central Canadian source south and southeastward, until it met its defeat in changed climatic conditions and was compelled to drop along the way of its retreat, its load of gathered rock substances now in large part reduced to a pulverized condition.

In its unaltered state Kansan till, like that of the others, is made up of argillaceous, calcareous, siliceous and ferruginous matter in the main, the first named constituting by far the larger amount of its components. It is, then, a clay, dense, tough, not readily pervious, more or less plastic, of a dark bluish color, usually somewhat calcareous and with sand or gravel thoroughly intermingled, or in small pockets, streaks or bands of variable extent. Rock fragments of intermediate size are not uncommon, but bowlders are relatively not numerous. They are granitoids and greenstones mostly though quartzites, Cretaceous rock fragments and fossils are not infrequently found.

The lapse of time since the retreat of the Kansan ice sheet is variously estimated by geologists. Chamberlin and Salisbury offer as a minimum 300,000 years, as a maximum 1,020,000. The extent of this range indicates the degree of indefiniteness that attends all efforts to put estimates of Pleistocene time divisions into figures. But, when we consider the extent of the chemical changes that have been wrought in this ancient drift sheet and the erosional effects that may be observed in it wherever it has

FIG. 13.—Residual gravel exposed a few rods north of the middle of the east line of section 11, Marshall township, Taylor county. Photo by Calvin.

not been protected by later drift sheets, it is easy to conclude that the time under consideration was long, very long as we commonly estimate time.

The unweathered Kansan, of course, is found only in recent exposures such as the deeper road cuts, ravines and banks that have been eaten into by meandering streams. Overlying it usually is the weathered Kansan which has very much the same general makeup, although by oxidation, leaching and other forms of weathering, changes in color, compactness, toughness and perviousness have taken place; the degree of change varying with the distance from the surface, so that as a rule the weathered phase passes almost imperceptibly into the unweathered. In many places a thin layer of residual gravel overlies the weathered type. Figure 13 shows a good illustration of this feature. Practically all the gravel observed in the county has this position, which fact accounts for the small amount of

FIG. 14.—A road cut near the northwest corner of section 16, Jackson township, Taylor county, showing segregated lime plates and nodules near the surface of the old Kansan drift. Photo by Calvin.

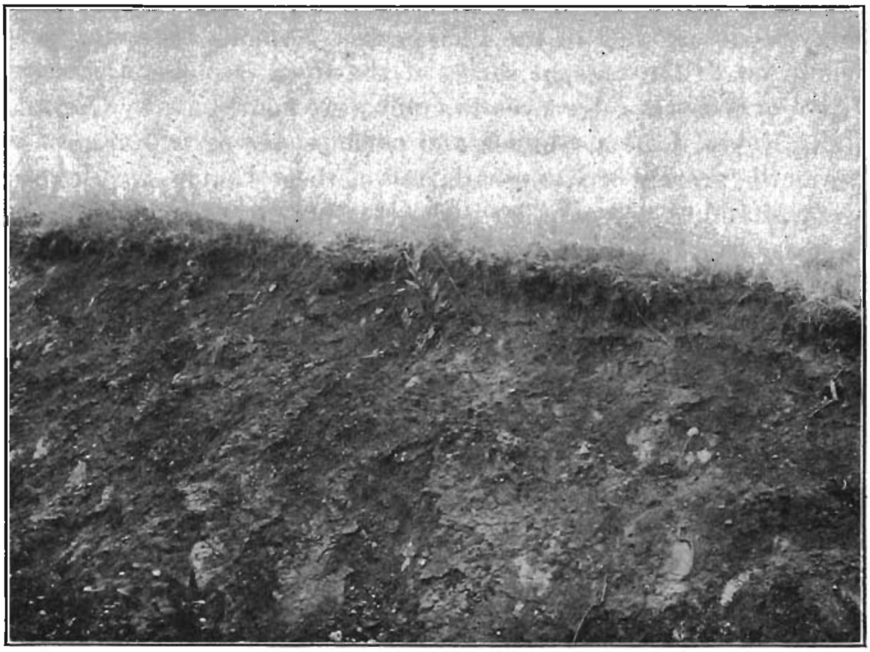


FIG. 15.—A road cut near that shown in Figure 14 and showing similar lime plates and nodules near the surface of the old Kansan drift. Photo by Calvin.

available gravel to be found here. Exposures of Kansan drift occur under various conditions. Some instances have been noted in locating the Nebraskan. A striking fact about many of the exposures in this county is that calcareous material, in concretions of some form as a rule, is found, mostly in joints "even up to the grass roots". The weathered Kansan occurs almost everywhere in the county either directly at the surface or underlying loess and gumbotil and, perhaps, a layer of residual gravel. To designate localities, then, would be obviously unnecessary. Figures 14 and 15 are views of two such localities.

Kansan Gumbotil.—In some sections of the Mississippi valley a certain obnoxious type of clay has long been recognized popularly under the term "gumbo". In Iowa this material is found in the Kansan drift areas, and here it is limited to the tabular divides. The geologist busied with the many problems that have readily offered themselves for consideration, has almost wholly ignored this material until recently, so that geological literature is signally void of more than incidental allusions to this specific product of the Pleistocene. Among the many contributions to the present series of the Iowa Geological Survey, direct or indirect references to gumbo are made only by Gordon, Bain, Keyes, Udden, Shimek and perhaps one or two others, so far as the present writer recalls and of these Udden and Shimek alone attempt to account for it genetically, though even then confessedly in a tentative way.

The term gumbo is sometimes applied to a mere surface prairie mud that, doubtless, needs no special consideration. Again it is applied to a tenacious clay found in alluvium, the origin of which may confidently be attributed to water deposition. A third type often found on the uplands of the counties in the southern part of Iowa has been regarded by several of the writers named above as a modified loess beneath which it is usually found and into which it appears to grade. So intimate seems the relationship that the term gumbo is seldom applied to it. It is regarded as a less porous and more thoroughly oxidized and leached loess that when dry resembles joint clay. Some have called it red clay for distinction's sake. In a few instances it has been called gumbo. Calvin in his unpublished notes upon Taylor county found this form of material so often thrust upon his attention that he became intensely interested in it and time and again so expressed himself as to convince the reader that it was a problem that would receive his strictest attention in writing up his report. The various names he gave to it indicated the doubts he had as to its genesis. The term he most often used, blue silt, seemed to imply that he thought it may have been in some way a water deposit. Many of these exposures in the southern townships which occur between distinct beds of till, we have referred in earlier pages of this report to the Nebraskan stage. The rest must be regarded as belonging to the Kansan.

Recently Kay, recognizing the chaotic condition of our knowledge of this whole subject and believing that the time was opportune for a more complete exposition of it than had been undertaken previously, availing himself of such data as were accessible, and after carefully examining the best known exposures of the material under consideration, has offered a theory that seems to account for the upland phases of gumbo far better than any other that has fallen under our observation[6]. It may be noted that Bain[7] and others recognized the intimate relationship of what was sometimes called an altered loess, but which was the formation now under discussion unquestionably, with the loess above it. Kay reverses the order of genesis and makes the so-called loess or loesslike clay in these conditions the product of the weathering and concentration of the gumbo. The gumbo itself he regards as the result of the weathering during an exceedingly long time of the upper part of the Kansan drift, while erosion was inactive because the plain was not subject as now to surface drainage. This weathering was therefore chiefly chemical and resulted in the grayish, tenacious, thoroughly leached joint clay commonly known as gumbo, which has a thickness varying from a few feet to twenty feet or more. It grades downward into yellowish and chocolate-brown Kansan drift from three to seven feet in thickness below which is the unleached dark Kansan drift. All the gumbo observed in the county is to be accounted for under this theory more satisfactorily than under any other, excepting some of the alluvial type noticed in the flood plain of Platte river and which for the present may best be regarded as a fluviatile deposit. To this upland gumbo for distinction's sake Kay has given the name gumbotil. Conditions being the same, gumbotil may have been developed in other interglacial stages and we have had occasion to refer to it as occurring in several of the southern townships as a phase of Nebraskan drift material.

A typical instance of the "blue silt" of Calvin is near the middle of the south line of section 15, Holt township, where it grades into loesslike clay above and into the weathered Kansan till below. This latter condition is so pronounced that Calvin's note reads: "This 'blue silt' is included in the drift and differs from loess." Again in describing a feature in the southeast quarter of section 27, Nodaway township, he speaks of "sloughy

[6]Kay, G. F., Some Features of the Kansan Drift in Southern Iowa: Bull. Geol. Soc. Amer., Vol. 27, pages 115-117; also Iowa Geol. Surv., Vol. XXV, pp. 612-615.

[7]Iowa Geol. Survey, Vol. IV, Keokuk County, p. 288 and elsewhere; also Iowa Geol. Survey, Vol. IV, Mahaska County, p. 243.

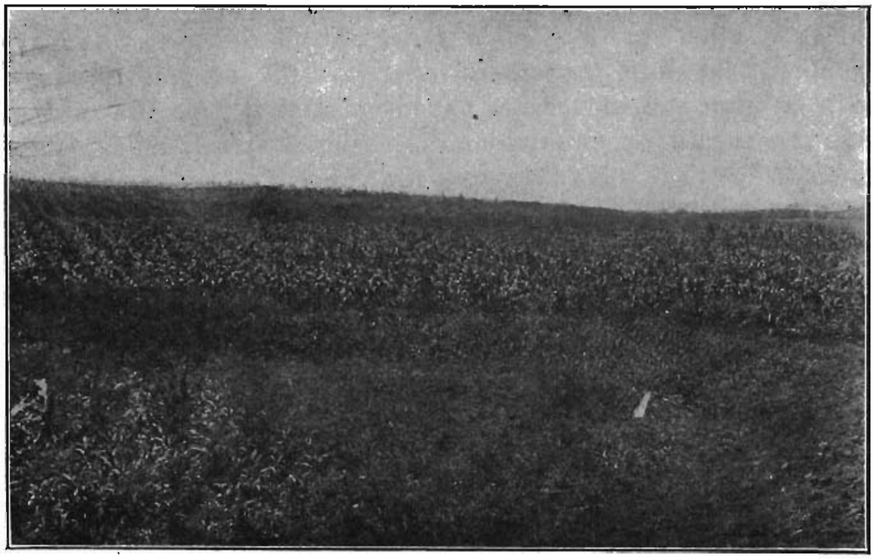


FIG. 16.—Marshy seeps on hillsides with dry land above and below. The land above the first belt of corn is too wet to plow. Southeast quarter of section 27, Nodaway township, Taylor county. Photo by Calvin.

ground well up on slopes, due apparently to deposits of 'blue silt' in the Kansan drift.'' In figure 16 one such locality is shown.

Similar exposures of the ''blue silt'' were noted in all the northern townships where erosion has cut through the upper portions of the drift only. As pointed out by Kay, ''in the southwestern part of the state the Kansan gumbo which is in situ is found only where the divides, which are no longer distinctly tabular, retain the level of the former gumbo plain.''

LOESS.

In the western part of Taylor county there is considerable typical yellowish loess of eolian origin, similar to the loess which is so prevalent in the counties nearer to Missouri river. This loess is well shown in the railroad cut at New Market, where the yellow loess in the upper part of the cut grades into gray loess below. Yellow loess is well shown in the numerous road cuts that have been made in recent years in connection with the improvement of the highways.

In the eastern part of the county there is little, if any, loess. There is, however, a loesslike clay, which is thought to be not of eolian origin but to be related more or less closely to the Kansan gumbotil. Such a relationship exists in the counties to the east of Taylor county[8]. The explanation suggested by Kay for this loesslike clay is that it is the result of changes that have been going on at and near the surface of the gumbotil during the great length of time since the normal gumbotil was formed, and that, moreover, the loesslike clay, which is now found as a mantle on the Kansan drift on the slopes and divides that have been brought by erosion considerably below the level of the gumbotil plain, may be the product not primarily of wind action but chiefly the product of the weathering and concentration of gumbotil and related materials, and it may have been brought to its present position in connection with the development of the present topography by erosive processes.

The Recent Series

ALLUVIUM.

Wherever the topography is measurably mature, the larger streams for the most part are bordered with flat and fertile flood plains, ranging from one-fourth of a mile to more than a mile in

FIG. 17.—The broad bottom lands of Platte river above Blockton, Jefferson township, Taylor county. Photo by Calvin.

[8]Kay, George F. Some Features of the Kansan Drift in Southern Iowa: Bull. Geol. Soc. of Amer., Vol. 27, pp. 115-117. See also Iowa Geol. Survey, Vol. XXV, pp. 612-615.

width. The finest and largest of these, perhaps, are along Platte river. See figure 17. Formerly all these bottom lands were wooded and in many instances remain so up to the present time though their fertile character has tempted the farmer to convert them into cultivated fields to a large extent. Only in the case of the largest streams do these flood plains extend much into the northern half of the county, but along the Nodaway and the West Branch of One Hundred and Two river they are found well up to the north border of the county. Occasionally, as in section 10, Dallas township, no bottom land appears, erosion having failed to prepare the way for the Recent deposits. Superficially alluvium is a fine loamy silt, but in the deeper deposits sand, gravel and clay are to be found. The clay is usually tough and impervious and is commonly called gumbo. If the term gumbotil is to be used specifically for the siltlike weathered till as suggested by Kay, this alluvial silt may well retain the name gumbo as a distinctive term. In some instances in times of heavy rainfall the coarse elements of the till have washed down the steep hillsides and have covered the finer alluvium of the flood plain. This is the more likely to take place in the future as the slopes have become denuded of their natural protective covering of tres and bushes and the surface becomes loosened and roughened by grazing animals clambering over the steep slopes.

SOILS

Superficial mantle rock, whether of recent or long time exposure, commonly passes under the term soil and may vary greatly in composition, degree of disintegration, perviousness, etc., and consequently in its productive quality. Taylor county is dependent almost wholly upon agriculture for its prosperity. A large percentage of its surface, wherever the topography is not too rugged to admit of cultivation, is rich and productive. Loam, loamy loess, and alluvium constitute the varieties most highly valued. Clayey, sandy and gravelly soils are so insignificant in extent as to merit no more than the merest allusion. When gumbotil is near enough to the surface to constitute the subsoil, it makes an ungenerous harborage for the roots of growing crops greatly to their detriment especially in wet seasons. Experience is demonstrating that even some gumbotil is amenable to wise treatment. It is no doubt true that sooner or later every portion of the county will prove to have its own unique method of response to the appeals of the skillful husbandman.

ECONOMIC PRODUCTS

Building Stones

In the early settlement of Bedford quarries were operated on the border of the town and quite a large amount of stone was taken out. The old school building and the old court house were built of local stone, but both of these buildings have been taken down, though a large pile of the stone is still to be seen near the creamery. It is a limestone of the usual Missouri type, yellow, clayey or earthy in part. Fossils are rare except as they are represented by comminuted fragments of *Fusulina cylindrica. Spiriferina kentuckiensis* was noted, also *S. lineata, Athyris subtilita* and *Lophophyllum profundum.* No quarrying has been done in this locality for many years. There is a natural exposure of this limestone at the southeast corner of the bridge east of the railway station.

Bowlders.—In many counties of Iowa, especially those within the bounds of the Iowan drift, large, firm bowlders of granite, granitoid and greenstone abound. These have been used freely for foundation walls and for other purposes where limestone is used ordinarily, but in Taylor county bowlders and cobbles are so rare that their occurrence becomes at once a subject of remark. Many of them show evidences of weathering. On the south line of section 34, Mason township, is an unusually large bed of gravel in which were numerous small bowlders and many cobbles, an exceptional case. An occasional bowlder was seen in section 10, Dallas township. In the northwest quarter of section 13, Polk township, on the south side of the road a bowlder two and one-half feet in diameter was noted. Residual gravel was on the other side of the road. Indeed the bowlders seem to be associated with cobbles and residual gravel and sand of a residual nature. Sand and gravel, while frequently in pockets, streaks or bands in the drift, or occurring in residual layers, are nowhere of such extent as to be of economic importance worthy of note. The largest bed of gravel seen was in section 34, Mason township.

Roads and Road Materials

Rough topography is so characteristic of the larger part of the county that hills, low or high, gently shaped or steep are the common feature of the roads. Skillful grading has already done much and will do much more to improve the roads over these hills. Gravel and crushed stone for road purposes are not obtainable to any notable extent within the bounds of the county. After grading and provisions for suitable drainage have accomplished their best for the roads, further improvements must come from the use of materials such as oil, gravel, crushed stone, and cement from without the bounds of the county.

Clay Products

Formerly brick yards were in operation in Lenox, Bedford, Blockton, Gravity and in the northwest quarter of section 30, Jackson township. In all these places excepting at Lenox the material used was an alluvial silt. The brick industry soon declined in most of these places, due in part to the fact that the demand for brick locally was never very great and also because the quality of the brick, while good, was not equal to the best and so brick was shipped in to a certain extent, thus still further restricting the market for the local product. At Lenox the manufacture of tile was added to that of brick and a flourishing business was done for several years. The plant was quite extensive in machinery and output, which in 1907 was about 600,000 brick. In 1910 nearly 400,000 tile were made. The material used was an upland siltlike clay. In the lowest two feet it is blue and sticky, quite like the blue silt that in this report has been called gumbotil. This is overlain by eight feet of a yellowish clay with ochery, ferruginous streaks running through it. The upper two feet is a dark loam. All these were used together. So far as can be learned this plant, too, has shut down, though the latest to do so.

Coal and Coal Mines

Several natural outcrops of coal in the banks of the East Nodaway and its minor tributaries in Nodaway township led to the sinking of a shaft by J. R. Foster more than fifty years ago on the East Nodaway about two miles south of Henshaw. Coal of good quality was obtained. Mining developed slowly, however, for several years. It reached a maximum of about 24,000 tons in 1901. About thirty different mines have been opened in Nodaway and Dallas townships. Some of these shut down after a brief season of activity owing to difficulty in controlling water. The demand for the product of all mines not on the railroad is local and necessarily is limited in amount. Only five mines were operated during the winter of 1917-18. One of these, operated by the Pullens, about three-quarters of a mile east of New Market, has shipping facilities over the Chicago, Burlington and Quincy Railway. Its depth is 185 feet. Its product for the year was about 10,000 tons. A section follows:

	FEET
Soil	4
Yellow joint clay	20
Blue clay	6
Yellow clay	10
Black shale	100
Gray shale	35
Cap rock	5
Slate, variable	
Seam of coal	1½-2
Fire clay	——

In the southeast quarter of section 34, Dallas township, John Bean has a mine that was worked for a short time twenty years ago. Work was resumed in this mine in December of 1917 and continued through the winter months with four men employed. This coal sold for eighteen cents per bushel. It is Mr. Bean's intention to begin work again July 1, 1918. The shaft is seventy-five feet deep.

Near this mine is the Millison mine. The shaft, which is 125 feet deep, was put down in 1917. Six to eight men were employed during the winter of 1917. Water makes the operation of this mine somewhat difficult.

John Campbell operates the mine in section 32, Nodaway township, formerly owned by Nathan Wilcox. This mine was worked for seven months in 1917 employing four men at four dollars a day. The coal sold at twenty cents a bushel. The eighty foot shaft gives a section as follows:

	FEET
Clay	10-20
Gumbo	10
Yellow soapstone	20
Blue soapstone	10-15
Cap rock	4
Slate	3- 4
Coal vein	1½-1 2/3
Fire clay	3- 4

A little north and east of the Campbell mine is the McKinley mine, very much like the Campbell mine in most details, but it could not be operated much during 1917 on account of the water.

These mines, excepting the Pullen mine, attempt to meet only the local demand. Many mines well known for twenty years or more are shut down. A very common complaint is the scarcity of help. All the coal mined in this county is from the Nodaway seam which also supplies all the coal of Adams and Page counties. This seam is in the so-called Braddyville limestones (the part known as Severy shale), a part of the Shawnee division of the Missouri stage. There is no positive evidence that the coal-bearing strata of the older formations which are productive farther east and which are known to underlie the Missouri of Taylor county, contain veins of coal that could be profitably mined. Even if the veins are there they lie at such a depth as to preclude profitable mining under present conditions.

Water and Water Supplies

Water supply conditions are in some particulars somewhat unique in Taylor county. An attempt was made at Bedford to secure an abundant supply of good water for the use of the city. With this intent a well was drilled to the depth of 2,400 feet. The only water of ample flow that was secured was salt, too salty to be fit for household or any other use. This expensive failure has checked and will check for many years any farther effort of the kind in this county. The details concerning this well may be found in Volume XXI of the Iowa Geological Survey and will not be repeated here.

The present municipal supply at Bedford is taken from several large wells situated in the valley of East One Hundred and Two river which penetrate a heavy deposit of fine sand next to the limestone. The practical difficulty in securing a sufficient amount of water for the town lies in separating the very fine sand from the water. Fortunately, over the county at large water can very generally be secured by means of bored or dug wells of no very great depth. Should a larger supply be required, the need may be met usually by a cluster of such wells so related that a single pump serves all from the central well. Sinking a single well to a greater depth may serve the same purpose. For meeting the demands of the pasture, artificial ponds are resorted to quite effectively.

Few wells are reported reaching to the rock. More rarely do they enter it and no advantage seems to result. Most wells end in gravel or sand. Some end in the unmodified till, but such wells are not likely to be constant. Dug wells are giving place to bored wells which are sunk to a greater depth thus securing greater constancy. Wells on the flood plains are constant at a depth of twelve to twenty feet. The depth of a few wells in different localities is given. They will serve as good representatives of all the wells of the county.

At the creamery at Bedford rock is reached at twenty feet. In the southeast quarter of the southeast quarter of section 13, Polk township, rock was encountered at ninety-four feet, clay only being passed through in the drift. In the southwest quarter of section 7, Ross township, there are two good wells which extend seventy feet in the drift. In section 13, same township, two wells, one of ninety and one of one hundred thirty feet, are reported. Wood was found in each of these four wells indicating that they end near the base of the Kansan drift. Near the middle of the west line of section 2, Washington township, wood was encountered at the depth of seventy-seven feet, but no water was secured. Wells near Ladoga have reached a maximum depth of one hundred ten feet. At Clearfield water is secured at fifteen to twenty feet. Around Guss wells average about forty-five feet, ending in blue clay. The public dug well at New Market ends in gravel at a depth of fifty-eight feet. Water stands fifteen feet below the surface quite constantly. Other wells here range in depth from thirty to sixty feet, depending measurably upon a difference in the superficial altitude of the individual well. About Gravity wells end in clay and range in depth from forty to forty-five feet but are not constant. Fifteen miles north wells of about the same depth, but ending in sand, are constant.

Springs.—Natural springs are not common enough to be relied upon very extensively. A few, however, of exceptional excellence occur. One is just east of the west line of section 34, Clayton township. Another is reported from the southwest quarter of section 21, Marshall township. Near the middle of section 9, Mason township, there are three and another is in the northeast quarter of section 10, same township. These springs have their origin in about the same conditions as the seepages spoken of in this report under the topic, Drainage. But in the case of the springs the conditions prevail over larger areas and the lay of the land brings the water to a single outlet rather than to many. Indeed some of the seepage places might be made to resemble at least temporary springs.

Forests and Forestry

Trees still occupy the flood plains of the streams in many places, though the fertility of the alluvium of these plains has led to their transformation from woodlands to tilled fields in perhaps a majority of cases. A fringe of trees along banks of the streams has been left not infrequently. This is particularly to be commended, since the tree roots help to prevent wash which, unrestrained, would result in meandering that ultimately would mean the removal of all the alluvium over most of the flood plains. The bluffsides that border the plains and the ravines that gash the bluffsides as well as other places where the topography is too rugged to be cultivated are more or less tree clad. But the stand of trees in all these places is of nature's own choosing and is wholly under nature's care. Usually these places are pastured and the best nature can do is greatly marred and hindered, if not practically made valueless by the trampling and browsing of cattle. Too often the trees prevent good pasturage and the stock prevent profitable tree growth. It is hard to estimate the economic waste that ensues. It is certainly unfortunate that in such counties there is not at least one farmer that, amid the multiplicity of things to which the tillers of the soil have to give attention, does not see what an opportunity is here for the display of profitable effort in introducing an application of the principles of forestry. The general impression seems to prevail that only on a large scale can this be done by lumbering corporations, for instance, or by the state, or nation. As a matter of fact, however, the benefits of a judicious use of these principles might be experienced in hundreds of places in Taylor county. A piece of rough land could be fenced, set out with a choice selection of seedling trees, or planted with nuts and seeds. With less care than an ordinary crop would require, in a few years, it would become a wonderful object lesson to all beholders. The trimmings and thinnings would soon pay for the trouble in making them and at the same time the value of what remained would be enhanced by the operation. From being a profitless acre, it would become a part of the farm to be reckoned with, having a distinct and increasing value. Besides yielding fuel and wood material always in demand about the farm for a great variety of purposes and the ever more and more valuable stand of timber, it puts a check to the wash of hillsides and to the encroachments of the ravines by headward erosion into the tilled fields, a process that is reducing the remnants of the tabular divides more rapidly than is realized ordinarily. In many instances too, the product of such erosion, if unchecked is spread over the flood plains making waste land where before had been rich alluvium only. The birds, those tireless, but too often unappreciated friends of man, would find added encouragement and make inestimable returns for such encouragement. With a small increase of time and effort this area could be increased until all the unprofitable part of the farm could be converted into a remunerative tract competing with the better portions in economic efficiency.

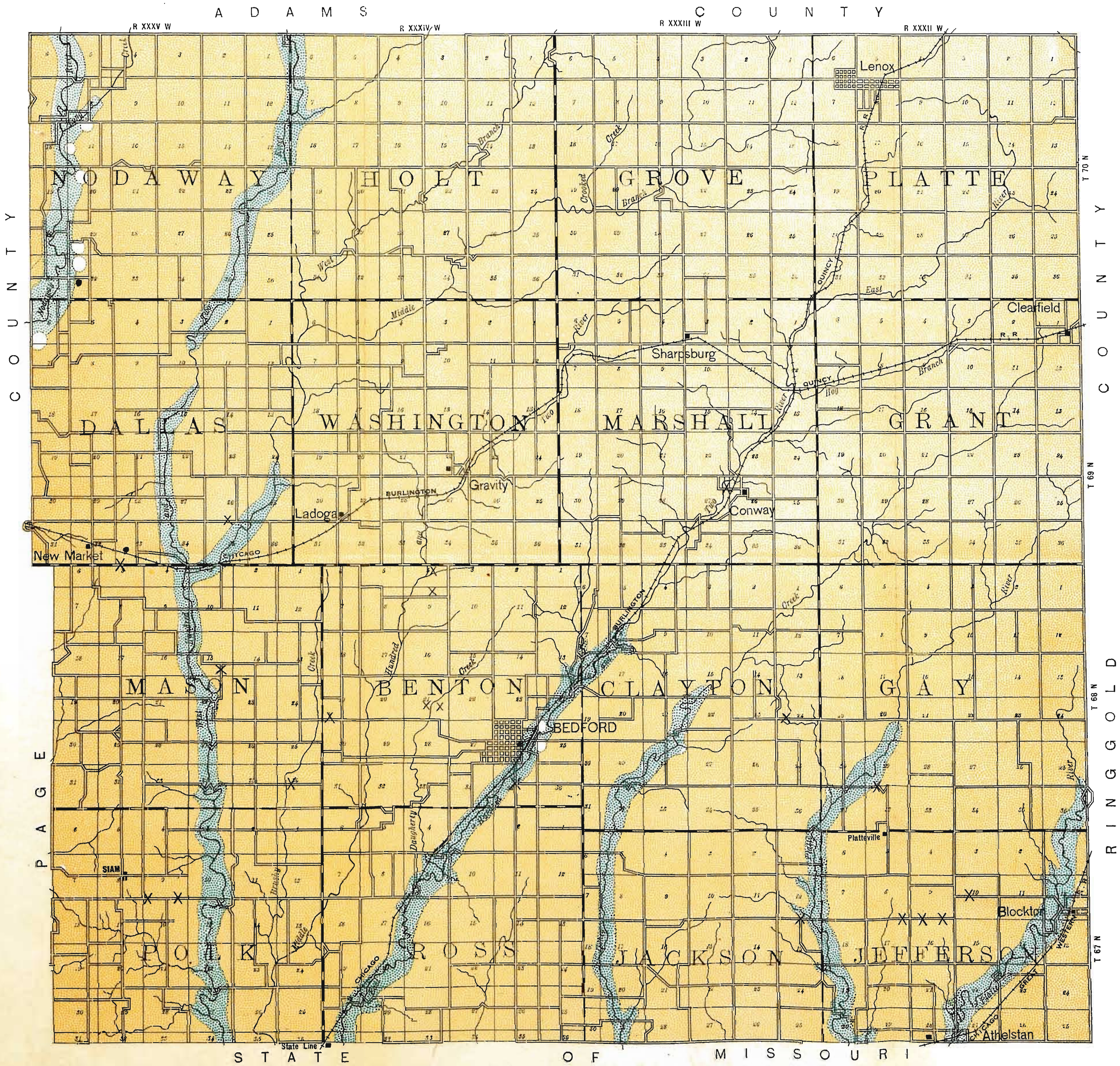
By observing the kind of trees found growing naturally in the county, no mistake could be made in selecting species adapted to the local conditions of soil and climate, though other valuable species known to flourish elsewhere under quite similar conditions might be sparingly introduced by way of experiment. The following trees were noted in thrifty condition: *Juglans nigra* L., Black walnut; at home in all parts of the county; *Carya ovata* K. Koch, Shell-bark hickory; *Quercus alba* L, White oak; *Ulmus americana* L., White elm; *Tilia americana* L., Basswood; *Acer saccharinum* L., White maple. These are among the more valuable kinds more commonly seen. Butternut and pignut hickories, a half dozen other species of oak, the honey locust, the black cherry, two species of ash and several other kinds were not uncommon. A few specimens of the hard maple were seen along the streets of some of the towns. Its value in so many ways ought to make it a popular tree for general planting.

ACKNOWLEDGMENTS

In August, 1907, the former State Geologist, Dr. Samuel Calvin, made a partial survey of Taylor county and in July, 1910, he completed the survey. His death in 1911 occurred before he had written the report. When his notes were placed in my hands with request that I prepare a report upon the county, I knew that so far as field work was concerned nothing was left for me but to go over the ground and recognize for my own sake the points of interest that he had noted. I desire now to express my very great indebtedness to him in the preparation of this report not only for the character and fulness of his notes, but also for his interpretation of their significance as it occurred to him while in the field. The details are remarkable. Nothing escaped the keen observation of this veteran investigator. Only a very small proportion of them need appear in the report, but they have been most useful in verifying and establishing general truths and principles. Nothing seemed to awaken his interest more than the frequent occurrence under very varied, but nevertheless related conditions, of what he usually called "blue silt", though sometimes he suggested that it might be gumbo, or Nebraskan till. It had plainly challenged his interest. His pur-

pose to give it the fullest consideration in the preparation of his contemplated report is everywhere manifest. I can only feebly express my obligation to my late esteemed friend for his part in this report.

The thanks of the writer are due to the present State Geologist, Dr. George F. Kay, for his helpful suggestions, especially in reference to his theory of the origin of the loesslike clay in Taylor county and of the immediately underlying gumbotil (the blue silt of Calvin), support for which theory is particularly abundant and convincing throughout the county. The uniform courtesy shown to the writer by all those to whom he has applied for information or other assistance is hereby cheerfully acknowledged.



IOWA GEOLOGICAL SURVEY

MAP OF THE

SURFACE DEPOSITS

OF

TAYLOR

COUNTY

IOWA

BY

M. F. AREY

1916

Scale $\frac{1}{125,000}$

5 Miles

5 Kilometers

LEGEND

GEOLOGICAL FORMATIONS

ALLUVIUM

KANSAN DRIFT IN PLACES OVERLAIN BY LOESS

EXPOSURES OF NEBRASKAN TILL OR GUMBOTIL

MISSOURI LIMESTONE

INDUSTRIES

COAL MINES

AMERICAN LITHO & PTG. CO.

DRAWN BY J. R. STERLING

GEOLOGY OF CLARKE COUNTY

BY

JOHN L. TILTON

CONTENTS

GEOLOGY OF CLARKE COUNTY

INTRODUCTION

LOCATION AND AREA

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

PREVIOUS GEOLOGICAL WORK

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

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

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

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

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

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

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

PHYSIOGRAPHY

Topography

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

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

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

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

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

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

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

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

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

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

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

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

ELEVATIONS.

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

Drainage

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

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

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

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

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

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

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

STRATIGRAPHY

GENERAL RELATIONS OF STRATA

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

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

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

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

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

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

Loess is scarcely to be recognized as a deposit.

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

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

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

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

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

SYNOPTICAL TABLE.

Group	System	Series	Stage	Substage	Character of Rocks
Cenozoic	Quaternary	Recent			Alluvium and other surface soil
		Pleistocene	Yarmouth		Gumbotil (Kansan)
			Kansan		Drift (bowlder clay)
			Aftonian		Gumbotil (Nebraskan) Peat and muck
			Nebraskan		Drift (bowlder clay)
Paleozoic	Carboniferous	Pennsylvanian	Missouri	Westerville	Limestone
				Chanute	Shale
				De Kalb (Drum)	Limestone
				Cherryvale	Shale
				Winterset	Limestone
				Galesburg	Shale
				Bethany Falls (or Earlham)	Limestone
				Ladore	Shale
				Hertha (or Fragmental)	Limestone
			Des Moines	Pleasanton	Shale (not found exposed)
				Oswego (or Appanoose)	Limestone (not exposed)
				Cherokee	Shale (not exposed)

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

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

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

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

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

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

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

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

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

CARBONIFEROUS SYSTEM

Pennsylvanian Series

DES MOINES STAGE.

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

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

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

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

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

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

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

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

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

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

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

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

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

MISSOURI STAGE

HERTHA LIMESTONE

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

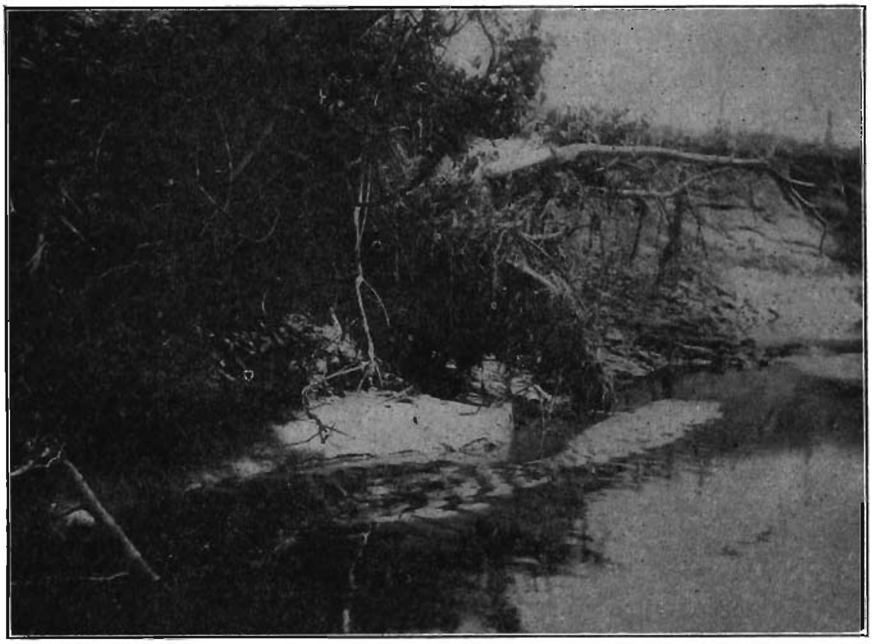


FIG. 18.—Hertha limestone: A small exposure may be seen in the bed of South Squaw creek in the northwest quarter of the northwest quarter of section 6 of Osceola township, Clarke county, about two hundred feet west from the iron bridge. At this point one foot and eight inches of the limestone is visible.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

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

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

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

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

LADORE SHALE

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

BETHANY FALLS LIMESTONE (EARLHAM)

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

THE GALESBURG SHALE

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

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

THE WINTERSET LIMESTONE

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

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

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

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

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

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

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

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

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

WESTERVILLE LIMESTONE

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

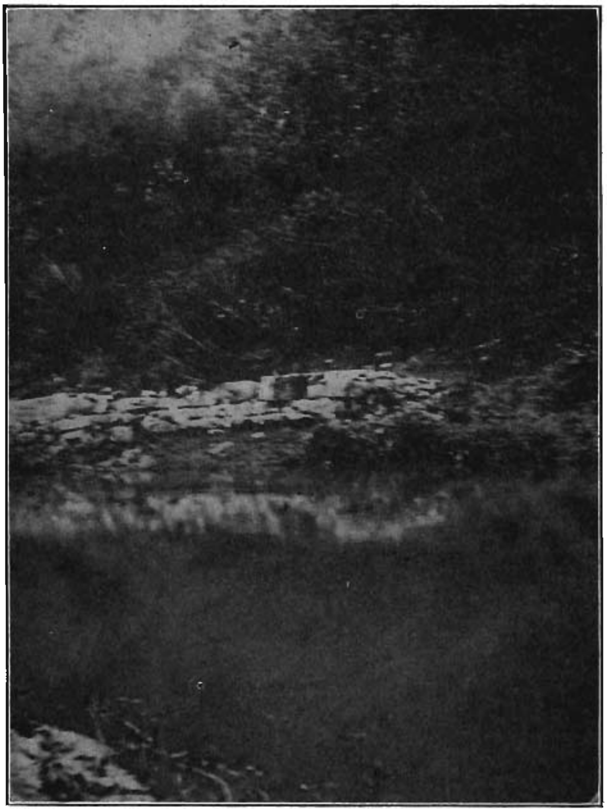


FIG. 20.—The Westerville limestone as seen at the ford at Grand river immediately west of section 31, Doyle township, Clarke county. The river flows to the left, toward the southeast.

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

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

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

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

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

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

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

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

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

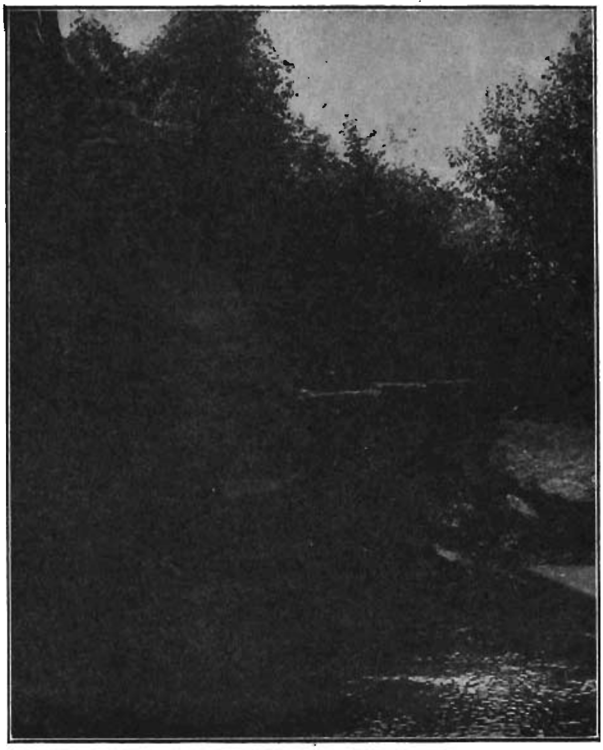


FIG. 21.—The Westerville limestone as it is exposed at the bridge over Grand river directly west of Hopeville. The topmost portion of the limestone exposed is but nine feet above the water. The most resistant stratum (No. 5 of the description) is that adjacent to the lower portion of the cement pier.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

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

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

DIP

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

Ward township.

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

Doyle township.

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

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

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

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

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

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

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

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

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

QUATERNARY SYSTEM

Pleistocene Series

GENERAL

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

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

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

THE NEBRASKAN STAGE

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

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

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

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

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

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

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

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

AFTONIAN INTERGLACIAL STAGE

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

THE KANSAN STAGE

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

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

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

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

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

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

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

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

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

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

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

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

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

THE YARMOUTH STAGE

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

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

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

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

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

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

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

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

LOESS

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

Recent Series

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

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

ECONOMIC GEOLOGY

Soils

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

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

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

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

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

Water.

WATER FOR HOUSE AND FARM

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

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

HOPEVILLE—MURRAY[57]

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

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

WOODBURN[58]

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

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

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

GENERAL RELATION OF RUN-OFF AND EVAPORATION TO PRECIPITATION

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

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

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

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

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

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

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

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

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

WATER FOR MUNICIPAL PURPOSES

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

THE WELL AT STUART, IOWA

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

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

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

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

RECORD OF CASING IN THE WELL AT STUART

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Pit and Quarry Products

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

PRODUCTION OF LIMESTONE IN CLARKE COUNTY

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

*Crushed stone for road.

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

ANALYSES OF LIMESTONE.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Clay Products

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

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

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

Coal

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

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

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

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

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

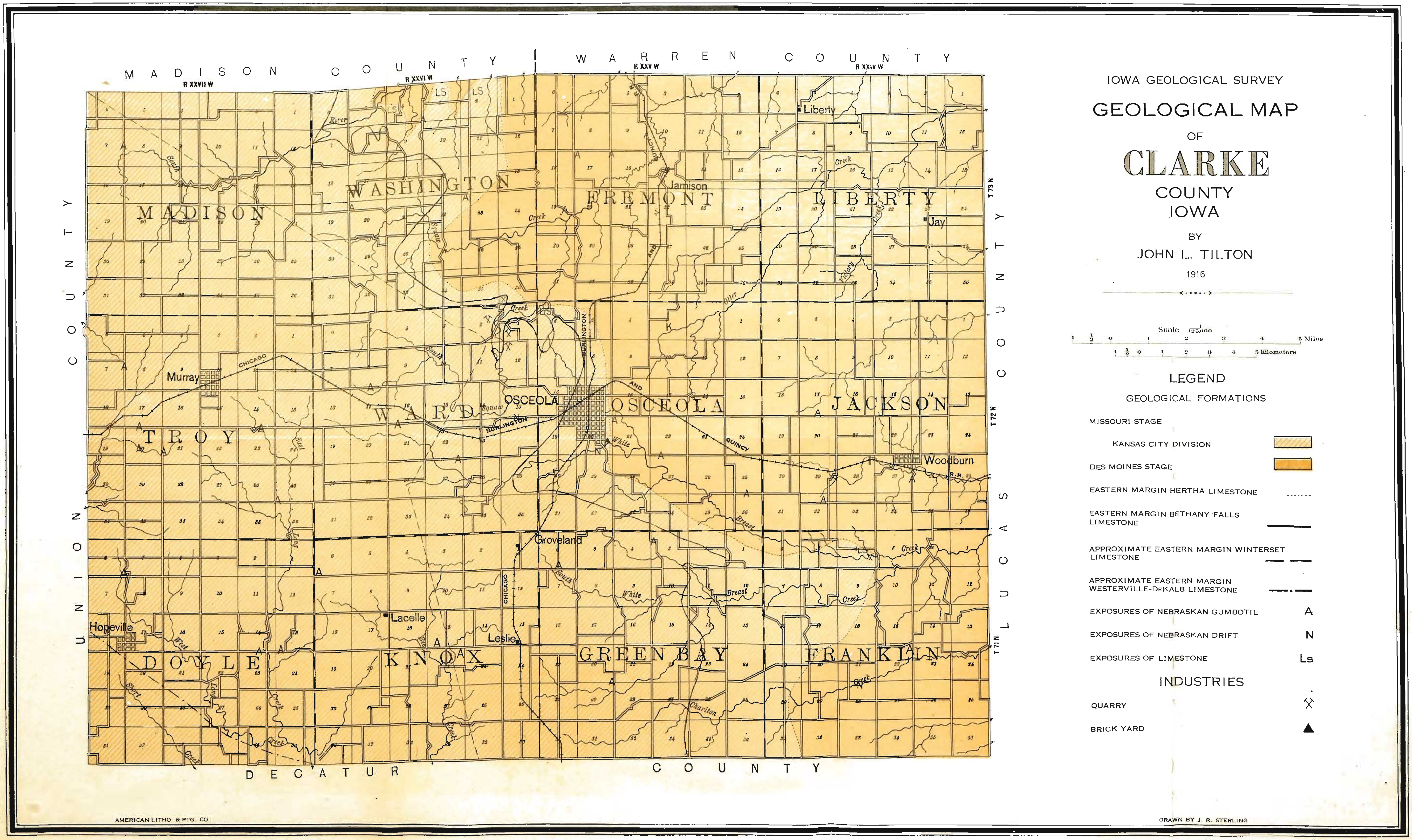
Southwest of the line described from the northwestern corner of Washington township, through Osceola to the southwestern corner of Franklin township, it does not seem probable that conditions of the market will ever warrant prospecting for coal. In this portion of the county not only do limestone beds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

Peat

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

ACKNOWLEDGMENTS

It has been the intention to give proper credit in the text and footnotes for all facts supplied by others. Beyond this the writer wishes to acknowledge his indebtedness to the numerous people throughout the county who have so courteously stopped to give data on well records and to discuss questions of local interest that bore on the work of the survey. He also wishes to acknowledge the care and skill of the Assistant State Geologist, James H. Lees, Ph. D., who has supervised the editing and assisted in the proof reading.


IOWA GEOLOGICAL SURVEY
GEOLOGICAL MAP
OF
CLARKE
COUNTY
IOWA
BY
JOHN L. TILTON
1916
Scale
5 Miles
5 Kilometers
LEGEND
GEOLOGICAL FORMATIONS
MISSOURI STAGE
KANSAS CITY DIVISION
DES MOINES STAGE
EASTERN MARGIN HERTHA LIMESTONE
EASTERN MARGIN BETHANY FALLS LIMESTONE
APPROXIMATE EASTERN MARGIN WINTERSET LIMESTONE
APPROXIMATE EASTERN MARGIN WESTERVILLE-DEKALB LIMESTONE
EXPOSURES OF NEBRASKAN GUMBOTIL A
EXPOSURES OF NEBRASKAN DRIFT N
EXPOSURES OF LIMESTONE Ls
INDUSTRIES
QUARRY
BRICK YARD
MADISON COUNTY
WARREN COUNTY
UNION COUNTY
LUCAS COUNTY
DECATUR COUNTY
R XXVII W
R XXVI W
R XXV W
R XXIV W
T 73 N
T 72 N
T 71 N
MADISON
WASHINGTON
FREMONT
LIBERTY
TROY
WARD
OSCEOLA
JACKSON
DOYLE
KNOX
GREEN BAY
FRANKLIN
Liberty
Jamison
Jay
Murray
OSCEOLA
Woodburn
Groveland
Lacelle
Leslie
Hopeville
CHICAGO
BURLINGTON
AND
QUINCY
R.R.
Squaw
White
Creek
Breast
South
Otter
Charlton
AMERICAN LITHO & PTG. CO.
DRAWN BY J. R. STERLING

GEOLOGY OF CASS COUNTY

BY

JOHN L. TILTON

CONTENTS

GEOLOGY OF CASS COUNTY

INTRODUCTION

Location and Area.—Cass county is the second east of the Missouri river and the third north of the Iowa-Missouri line. It includes Townships 74 to 77 North and Ranges XXXIV to XXXVII west of the Fifth Principal Meridian. Its 576 square miles divided into sixteen full townships of rich farm land surround its enterprising towns of Atlantic, Wiota, Anita, Marne, Lewis, Griswold, Cumberland and Massena, among which Atlantic has an enviable reputation as one of the best business centers between Des Moines and Council Bluffs.

Historical References.—A mile west of Lewis is the site of old Indiantown, located beside a former chief village of the Pottawattamie Indians. The former beautiful spring nearby where the Indians got their water from the base of a sandstone bluff is now a watering place in a pasture. Of the numerous graves on the hillsides scarcely a mound can now be seen. South of Lewis another beautiful center of Indian life is still a gem in scenery: Crystal Lake. Just south of the center of the county is the line of the old trail north of Cumberland, to the ford at Lewis, and then west, on toward Council Bluffs. On the hill-

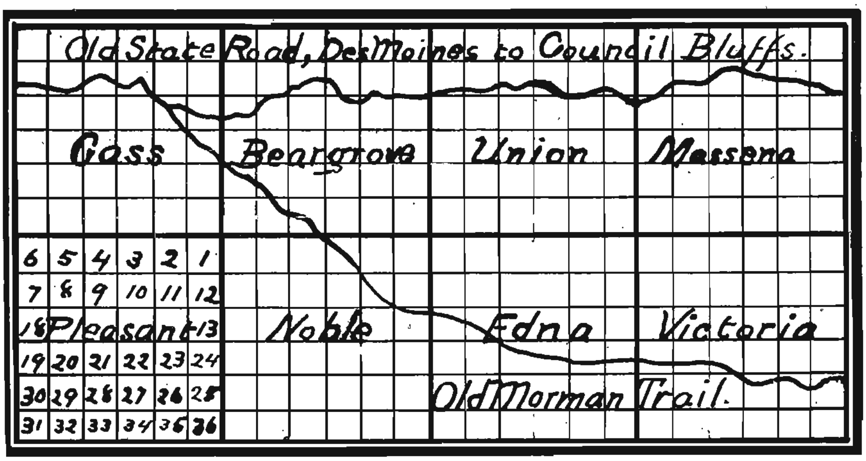


FIG. 22.—Early trails across Cass county, located by Mr. Charles H. Rhodes of Cumberland.

side at the ford the wheel ruts are still visible winding up the steep bank from the ford below the mill at Lewis Now this line of early travel is unused, for the main line of the Chicago, Rock Island and Pacific Railway crosses the northern half of the county.

Previous Geological Work.—When David Dale Owen had completed his trip up Des Moines river to study the formations along that river for a report to Congress he sent his party with the canoes and collections down the river from Des Moines while he himself took a hasty trip along the old trail from Des Moines to Council Bluffs. He mentions crossing North river, Middle river, Clanton creek, Grand river, two branches of the Nodaway, and the East, Middle and West branches of Nishnabotna river. It was only on the latter stream that any rock were found in place, for the old trail avoided the rough ground, where in a few places stratified rocks were to be seen. The brief mention that he gives of the soft brown sandstone and of three beds of limestone, "the intervening faces between the beds are hidden from view," make it evident that he crossed the East Nishnabotna at Lewis. In his further statement that "a light colored gritstone is found in a grove one mile east of the same stream" he undoubtedly refers to the "Crystal Lake" bluffs near Lewis.

The work of James Hall and of James D. Whitney described in the "Report on the Geological Survey of the State of Iowa," 1858, was chiefly upon the eastern portion of the state, work upon the western portion having been discontinued because the people were not then awake to the need and the magnitude of the undertaking. The views of those early geologists as they extended their work westward are worthy of note: "The formations throughout the southern, eastern and central parts of the state, are all of such a character as to produce soils of immense agricultural capacities; and the geological structure of the state clearly indicates that her agricultural products, her coal mines, and beds of gypsum, will constitute her greatness of resources and her future wealth."[1] In the preceding paragraph they also stated that, "All the intermediate rocks are

[1]Hall and Whitney, "Report on the Geological Survey of the State of Iowa," p. 145, 1858.

more or less calcareous, affording an abundance of lime and ordinary building stone, and some of them hydraulic cement." As they glanced westward in the state they called attention to the possible relation of strata here to strata on which some work had been done in Missouri and along the eastern slope of the Rocky Mountains. Already the peculiar distribution of the flora had attracted their attention, leading to the great problems of the loess and gumbo on which problems considerable work has since been necessary to lead to an understanding of their relations. They approached their problems from a study of conditions in Michigan where the treeless areas were sites of former lakes now filled with silt, and they suspected that the prairie regions to the south and west also were of this origin, and were drained and trenched during a later upheaval.[2] White in 1870 quotes[3] this view of Hall, and proceeds to describe the distribution of this "bluff deposit" over western Iowa, especially along a line across the northcentral part of the state. That he recognized a "gumbo" as distinct from a loess is evident in his contrast of the upland soil of southcentral Iowa with the soil of the ground moraine in the northcentral part and the so-called "bluff deposit," or loess, of the western part of the state. His judgment was influenced by the prevailing view of the time that there was but one glacial drift,[4] which was that most abundantly found in the northcentral part of the state. Evidently his thick "bluff deposit" of the western part of the state included both the loess and the upper gumbo (Kansan gumbotil).

White erroneously correlates the limestone and adjacent shale found at Lewis[5] with numbers 6 to 9 inclusive of his Winterset section,[6] and mentions the coal[7] farther south as included in 6 to 10 of his Winterset section. He thought that this seam of coal, six inches thick on the average, lay in an approximately horizontal position within the area of a large triangle south of Cass county, which horizontal plane continued northward is

[2]Idem. p. 25.
[3]C. A. White, "Report on the Geological Survey of the State of Iowa," Vol. II, p. 6, 1870.
[4]See his description of the origin of the soil in southcentral Iowa from the erosion of Carboniferous shale instead of from drift, page 9 of the same report; and his diagram of the distribution of the "bluff deposit," page 7, Vol. II.
[5]Idem. Vol. I, p. 255.
[6]Idem. Vol. I, p. 246.
[7]Idem. Vol. I, p. 257 and 375.

near the level of the beds of the streams in southern Cass county. The plan that he outlines for determining the facts with reference to the presence of coal[8] has in part been carried out, and some information is now obtainable from borings. Dr. George L. Smith has since done much toward deciphering the peculiar relation of strata in the southwestern part of the state. White's greatest contribution to the knowledge of the possible distribution of coal was his proof that the coal did not lie in a great basin bounded on the east by the Burlington limestone, and on the west by the same bed of limestone outcropping at Winterset. By a careful study of the fossils he ascertained that these limestone beds at Winterset (and farther west in the area including Cass county) were far above, and thus younger in age, than the beds at Burlington,[9] and that they dipped to the south in the southern part of the state. Hence it was possible that seams of coal such as were mined near Des Moines might exist southwest beneath those limestone beds in the western part of the state, though they would be too deep for exploitation for many years.

The sandstone near Lewis White recognized as Cretaceous in age and gave it the provisional local name, "Nishnabotna sandstone,[10] though on comparing it with sandstone found farther west in the country, he stated that he had no "doubt that the lowest portion of ours is equivalent to a part of their Dakota group."[11] The name Nishnabotna sandstone persisted till Calvin brought forward the final proof and substituted the general name, Dakota sandstone, for the local name.[12] Bain, at work in Guthrie county, also referred to the Dakota sandstone, which extends eastward into that county. It was thus fully recognized that these brown and white sandstones are a part of the extensive beds that are known to exist far to the west beneath the "great plains," even to the Rocky mountains.

In volume XIX of the Iowa Geological Survey may be found a valuable paper by George L. Smith, M. D., on "The Carboniferous Section of Southwestern Iowa," in which outcrops to the south of Cass county are described. Farther to the south in

[8]Idem. Vol. I, pp. 258-263, and 314.
[9]Idem. Vol. I, pp. 243-244.
[10]Idem. Vol. I, p. 289.
[11] Idem. Vol. I, pp. 289. See also p. 286, recognizing Jules Marcou as the first to recognize the presence of Cretaceous strata in Iowa.
[12]S. Calvin, American Geologist, Vol. II, p. 300.

Missouri there is a series of outcrops of these same beds which have been recently described by Hinds and Greene in volume 13 of the Missouri Bureau of Geology and Mines: "The Stratigraphy of the Pennsylvanian Series in Missouri," thus continuing the work of Broadhead. On pages 1117 to 1124 of volume XXI of the Iowa Geological Survey may be found the data reported by H. E. Simpson and W. H. Norton in their work upon the "Underground Water Resources of Iowa."

As work upon the present survey progressed the study of Cass county was assigned to James Ellis Gow, who had then just completed the study of Adair county. The study of Cass county was nearly completed by Mr. Gow and the work of writing up the report had just been begun when his death occurred. So little of the manuscript was completed (five pages) that a complete resurvey was necessary. This work was assigned to the present writer, who has devoted the summers of 1916 and 1917 to the problems.

In the last few years much has been done to differentiate the various drift sheets and to study the interglacial deposits throughout the state. That which is of greatest value for use in Cass county has to do with the recognition of a Nebraskan till plain that appears on the hillsides of the deepest valleys in the county, and with the causes that have operated to produce the Nebraskan gumbotil, and also the upper, or Kansan, gumbotil[13]. A paper will soon be published by G. F. Kay and J. N. Pearce in which the origin of gumbotil from the standpoint of investigations in the field and in the chemical laboratory will be discussed fully.

PHYSIOGRAPHY

Land Form

Topography.—The upland of Cass county is a part of an extensive drift plain sloping gently toward the southwest and trenched by streams that flow south and southwest and mantled by loess. Each of the large valleys has a well developed flood plain bordered by a conspicuous terrace.

[13]Kay, George F., "Gumbotil, A New Term in Pleistocene Geology;" Science, New Series, Vol. XLIV, Nov. 3, 1916.

Along the east side of the county the West Nodaway and various tributaries rise close to the county line and drain the southeastern half of the county. Farther north Turkey creek heads a few miles east of the northeast corner of the county, along the crest of the great divide of Iowa that separates the area drained to the Mississippi from that drained to the Missouri. Troublesome creek and East Nishnabotna river rise farther away along the same divide in the east and northern portions of Audubon county. Indian creek, flowing south near the west county line, rises at a distance from the divide and drains the area between the East Nishnabotna and the East Fork of the West Nishna-

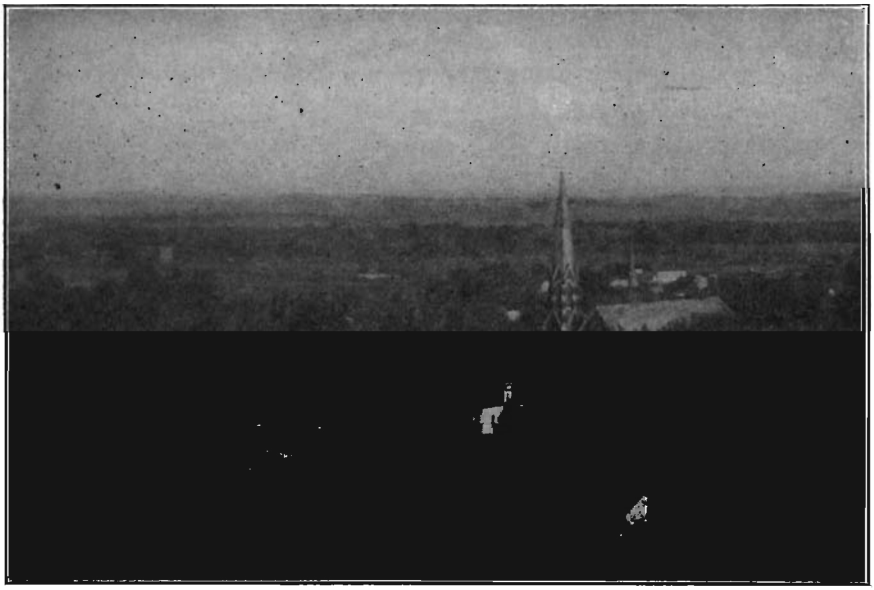


FIG. 23.—View looking northwest across the valley of Nishnabotna river from the dome of the Court House at Atlantic, Cass county.

botna. With this arrangement of streams there is a corresponding gradation in the topography. Along the eastern portion of the county the surface is rolling. If one follows down the streams of this region the valleys are seen to be progressively deeper and broader to the south and southwest. The deeper and broader portions of each valley contain not only a flood plain but also a low terrace, or second bottom. Along Turkey, Troublesome and Indian creeks, and especially along the East Nishnabotna, the chief streams of the county, the flood plain is very conspicuous and is bounded by lines tangential to the outside curves of a broad meander belt. Along East Nishnabotna river and Indian creek flooding is now diminished by drainage canals. Bordering these flood plains is a low terrace eight feet above the flood plain. South of Lewis to the county line this terrace broadens out to a conspicuous plain from one to three miles wide. North of Lewis even to the north county line it broadens out in places to a width of a mile.

The slopes from the Kansan upland plain down toward the bottom land along the rivers in the southwest third of the county

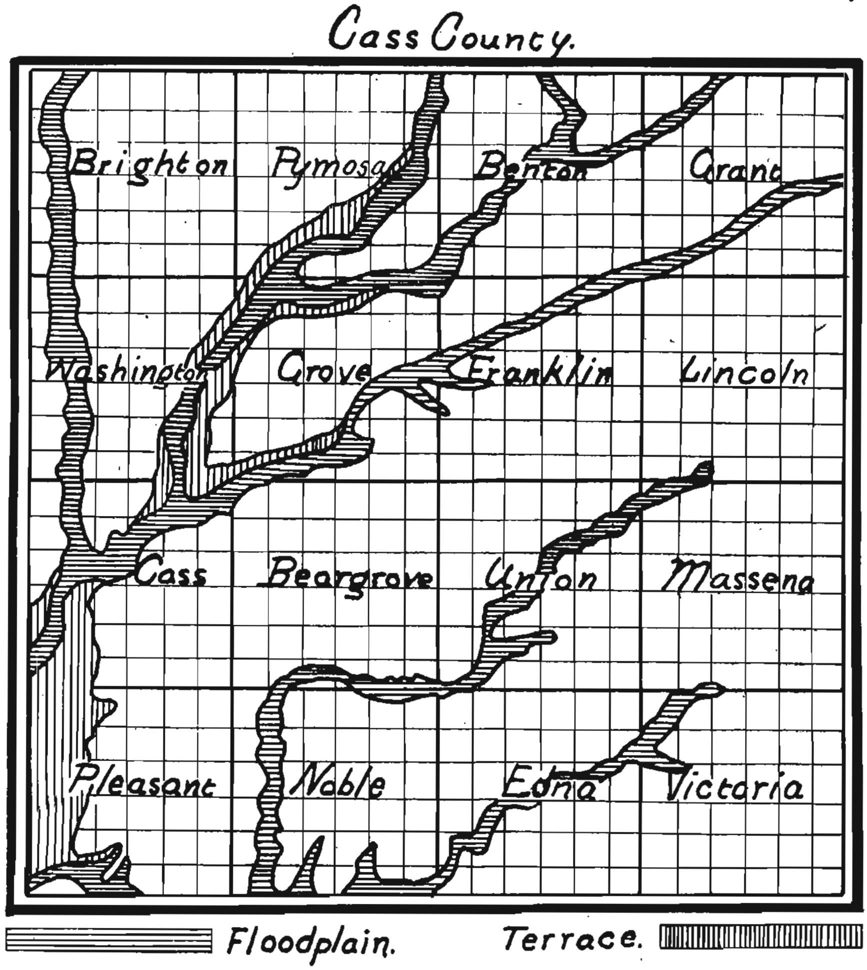


FIG. 24—Flood plains and terraces where these are conspicuous in Cass county.

are broken in a peculiar and interesting manner by a few small but picturesque nooks along cliffs of sandstone, parts of a topography of a bygone age that have been brought to light by erosion of drift that had concealed them. One stretch of such scenery lies along the west side of the river west and northwest of Griswold, just west of the county line. Another is at Spring creek, a mile west of Lewis. A third, and the most beautiful of all, is south of Lewis at Crystal Lake, and along the line of the old quarry on the east side of the road near by. A fourth is in section 33 of Beargrove township, and a fifth is in section 31 of Noble township. Several smaller outcrops of this sandstone are to be found, but these five are little gems of scenery adding beauty to the topography by contrast. In a few places the regular profiles of valleys eroded in drift are broken by ledges of limestone that, like the sandstone, have been discovered by erosion of the drift. The most conspicuous disclosure is at Lewis, where the limestone is the site of a dam for water power, and a mile further west where Spring creek falls over a low ledge near the road. Old quarry faces rise above the stream in section 36 of Noble township and 31 of Edna township.

The relief for the county as a whole is about 360 feet. Along the eastern side of Lincoln township the local relief is slight. It increases in amount west and south till it reaches a maximum in the southwest quarter of the county. It is most rugged along the south county line, which crosses the streams and divides at right angles, where valleys are deepest.

TABLE OF ELEVATIONS

	FEET
Railway station at Massena†	1,211
Level of creek bed a few yards south of Massena station‡	1,183
Crest of hill north of Massena§	1,306
Southwest corner of Massena township‡	1,206
Center of Massena township§	1,316
Crest of ridge one mile south of Massena‡	1,306
Railway station at Cumberland†	1,223
Level of Seven-mile creek 1½ miles north of Cumberland§	1,105
First hill top south of Cumberland‡	1,317
Top of shaft at Briscoe‡	1,135
River bed at Fox Quarries (Sw. qr. of sec. 31, Edna Twp.)‡	1,102
Railway station at Lewis†	1,157
Bed of river below dam at Lewis‡	1,093
Crest of hill at Lewis§	1,208
Base of sandstone, Spring creek, west of Lewis‡	1,102

Bed of Spring creek west of Lewis‡	1,080
Railway station at Griswold†	1,098
Bed of river west of Griswold‡	1,076
Railway station at Marne*	1,194
Abutment of bridge 444, 3 miles east of Marne*	1,212
Railway station at Atlantic*	1,160
Bed of river west of Atlantic‡	1,124
Bed of Turkey creek south of Atlantic (se. qr. sec. 28, Grove twp.)‡	1,136
Court House, Atlantic*	1,216
Vista Place, Atlantic‡	1,292
Abutment of R. R. bridge 440, ½ mile east of Atlantic*	1,156
Railroad station at Lorah*	1,204
Creek bed east of Lorah‡	1,184
Railroad station at Wiota*	1,205
Bed of Turkey creek at Wiota‡	1,185
Railway station at Anita*	1,258
Bed of Turkey creek at Anita‡	1,236
Railroad culvert one mile west of Anita*	1,244
Railroad culvert three miles west of Anita*	1,233
Base of Missouri limestone Eureka shaft, southeast of Anita	1,198
Relief, section 7, Brighton township‡	146
Relief, section 1, Benton township‡	125
Relief, sections 15-16, Benton township‡	113
Relief, section 35, Franklin township‡	85
Relief, three miles south of Anita‡	143

*"Spirit Levelling in Iowa", Bull. 460, U. S. G. S.
†Gannet's "Dictionary of Altitudes," Bull. 274, U. S. G. S.
§Barometric data by James Ellis Gow.
‡Barometric data by John L. Tilton.

GRADIENTS OF STREAMS

	DISTANCE MILES	TOTAL FALL FEET	FALL PER MILE, FEET
Lorah to Atlantic	6¼	60	9.6
Atlantic to Lewis	11.	31	2.8
Atlantic to Griswold	21.	48	2.3
Lewis to Griswold	10.	17	1.7
Lewis to Stennett	21.1-3	50	2.3
Griswold to Elliott	7.1-3	29	4.
Elliott to Stennett	4	4	1.
Anita to Wiota	7	51	7.3
Wiota to Lewis	12.	100	8.1-3
Cumberland to Fox Quarry	8.5	103	12.1
Massena to Fox Quarry	10.5	181	17.

The gradients of the streams given in the table are based on data from the sources named in the Table of Elevations. Dis-

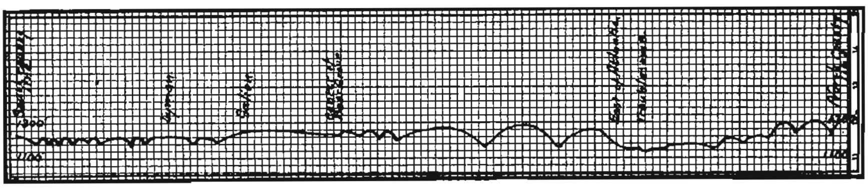


FIG. 25.—An approximate profile north and south through the centers of Pymosa. Grove, Beargrove and Noble townships, Cass county.

tances are measured along straight lines from one location to another; those along the Nishnabotna were projected on one straight line used as a base line.

The comparatively high gradient in the eastern and northeastern part of the county is partly due to the winding course of the streams, which increases considerably the actual distance the water flows, and partly due to the steeper gradient of the erosional curve in the upper course of a stream. There is but one break in the gradient, which is at the dam eight feet high at Lewis.

The origin of the topography is best considered in connection with the various deposits, especially those of the Kansan and post-Kansan stages. It should be noted that prior to the present

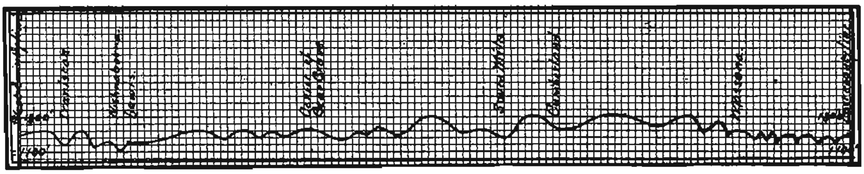


FIG. 26.—An approximate profile west by north on a straight line through Massena, Cumberland, Lewis, and Iranistan, Cass county.

landscape on which we live there have been within the limits of Cass county and on the deposits here described, three landscapes preceding the present one. These four landscapes are as follows:

1st. On the Missouri limestone and shale, that are chiefly of marine origin.

2nd. On the Dakota sandstone.

3rd. On the Nebraskan glacial drift.

4th. On the Kansan glacial drift. This, with its modification of loess, is the present landscape.

The character and relation of these deposits and the sequence of events will now be presented in order.

STRATIGRAPHY

NOMENCLATURE

The various limestones at Winterset have not as yet been directly connected through intermediate beds in Iowa with the formations of southwestern Iowa because of the thick deposits of drift that conceal all underlying deposits except in a few localities at considerable distance from each other. Fortunately, however, the formations in Madison, Decatur and Clarke counties have been connected with those at Bethany Falls, Missouri, and thus with the series of outcrops along Missouri river to Kansas City, a series first worked out by Broadhead[14] and recently reviewed by Hinds and Greene[15]. To the west end of this long series of outcrops G. L. Smith has connected outcrops in southwestern Iowa[16], and continued the series northeast to Stennett a few miles southwest of Cass county, and to Briscoe south of Cumberland.

Not only is the work along Missouri river in Missouri essential to work in southwestern Iowa, but also the work in Nebraska and in Kansas, for in those states the same formations appear that are found in southwestern Iowa. The strata in these different areas must be correlated.

Because of work from different starting points different names have been proposed for various important sets of strata, and different groupings proposed. Charles R. Keyes in 1899, seeking to coördinate these different names, proposed a series of terms that were accepted with some modifications by G. L. Smith in his report of the "Carboniferous Section of Southwestern Iowa." Recently Hinds and Greene in reviewing the work of Broadhead and correlating strata in Missouri with those in Kansas, have presented their reasons for refusing to accept some of the names adopted by Keyes and by Smith and have given a clear, systematic arrangement of terms based not only on the Missouri section but also on the Kansas and Iowa sections. With the exception of the use of Drum limestone instead of De Kalb limestone all the variations from previous nomenclature used in Iowa seem well grounded and acceptable. It is not the present intention to discuss the relative merits and priority of the different terms. This has been nicely done both by Keyes in his early papers, and by Hinds and Greene in their recent review of the terms in the light of the latest research. It is necessary, however, to compare the terms as used by Keyes and by Smith with those used by Hinds and Greene and by Condra and Bengtson.

[14]G. C. Broadhead, "Coal Measures of Missouri," Transactions of the St. Louis Academy of Science, Vol. 2, 1868 (read May 5, 1862).
[15]Henry Hinds and F. C. Greene, "The Stratigraphy of the Pennsylvanian Series in Missouri," Missouri Bureau of Geology and Mines, Vol. 13, Second Series, 1915.
[16]George L. Smith, "Carboniferous Section of Southwestern Iowa," Iowa Geological Survey, Vol. XIX.

Hinds and Greene, Strat. Penn. Series in Missouri (feet)	Keyes, Vol. 7, Proc. Iowa Acad. Sci.		Condra[17] and Bengtson No.		G. L. Smith, Vol. XIX, Iowa Geological Survey	Feet		Other Names
					M'Kissicks Grove sh.	75		Admire sh.
	Cottonwood ls.		18	Tarkio	Tarkio ls.	25		Barclay, Emporia ls.
			17	Preston	City Bluffs Beds	210		Willard sh.
100+ Wabaunsee			16	Fargo				
Tarkio ls.	Atchison sh.		15	Burlingame			Atchison sh.	
			14	Rulo				
350-475 Shawnee								
Scranton sh.			13	Ashland				
Howard ls.	Osage sh.		12	Southbend	Bradyville ls.	45		
Severy sh.[18]			11	Louisville				
			10	Union				
Topeka ls.	Topeka ls.		9	Meadow				Hartford ls.
Calhoun sh.	Calhoun sh.	Platte sh.						
Deer Creek ls.	Forbes ls.		8	Forbes	Forbes ls.	18		Stennett, Nodaway
Tecumsey sh.	Tecumsey sh.							
Lecompton ls.	Lecompton ls.		7	Cedar Creek				
			6	Cullom				
Kanwaka sh.	Lecompton sh.				Platte sh.	86		
200-300 Douglas								
Oread ls.	Plattsmouth ls.		5	Plattsmouth	Plattsmouth ls.	40		
			4	Weeping Water				
Lawrence sh.	Andrew sh.		3	Oreopolis	Andrew sh.	172		Strawn, Kickapoo, Ottawa
Iatan ls.	Iatan ls.	Lawrence sh.	2	Sturm				
Weston sh.	Weston sh.		1	Nehawka	Iatan ls.	16		
100-140 Lansing					Weston sh.	76		
Stanton ls.	Stanton ls.				Plattsburg ls.	19		Piqua, Garnett, Burlington, Cave Rock
Vilas sh.								
Plattsburgh ls.	Parkville sh.							
Lane sh.								Leroy sh. Carlyle ls.
200-225 Kansas City					Parkville sh. (including Iola)	22		
Iola ls.	Iola ls.							
Chanute sh.								
Drum ls.	Thayer sh.							Westerville ls., Cement City ls., DeKalb, Fusulina, Dennis
Cherryvale sh.								
Winterset ls.								
Galesburg sh.								
Bethany Falls ls.	Bethany ls.				Bethany ls.	165		Earlham, Mound Valley
Ladore sh.								
Hertha ls.								Fragmental ls.
950-1140						969		

The part of the section along Missouri river that especially relates to the work in Cass county is the Shawnee formation, in which it will be seen that the Osage shales of Keyes are divided by Hinds and Greene into two divisions of shale with a limestone between. It will also be noted that G. L. Smith gives the name, Bradyville limestone, to the cap rock of the Nodaway coal, which coal in the Missouri river section is in the Severy shale, overlain by the Howard limestone. Since the name Howard limestone was proposed and defined in 1898 and the name Scranton shale in 1908, both terms must be used in preference to Bradyville limestone and City Bluff beds, both of which terms were proposed in 1909, though they had been under consideration prior to that time. Forbes limestone as used by G. L. Smith seems in the general section[19], but not in the records of core drilling, to include not only the thin beds of shale between the beds of limestone but also shale both above and below the limestones. Keyes recognizes the Forbes limestone as one of the subdivisions of the Platte shale. The other subdivisions are the same as those adopted by Hinds and Greene, excepting that Kanwaka shale supersedes Lecompton shale, the name Lecompton being retained for the limestone member.

In the table that follows Shawnee, Douglas, Lansing and Kansas City are mentioned as divisions of the Missouri stage, that the subdivisions may be listed as substages, but the beds listed as in general limestone contain partings of shale, and those listed as shale may include what is limestone.

SYNOPTICAL TABLE OF FORMATIONS

GROUP	SYSTEM	SERIES	STAGE	SUBSTAGE	CHARACTER OF ROCKS
Cenozoic	Quaternary	Recent			Alluvium and other surface soil, clay and sand.
		Pleistocene	Peorian		Deposits of loess.

[17]Condra and Bengtson, "The Pennsylvania Formations of Southeastern Nebraska," Nebraska Academy of Science Publication, Vol. 9, No. 2.

The correlation here given of the subdivisions in Nebraska is by Dr. George E. Condra.

[18]Contains the Nodaway coal seam of Iowa, which is correlated as near the Quitman and Osage-Topeka coal seams.

[19]George L. Smith, "Carboniferous Section of Southwestern Iowa," Iowa Geological Survey, Vol. XIX, p. 655, 1908.

SYNOPTICAL TABLE OF FORMATIONS—(Continued)

Cenozoic	Quaternary	Pleistocene	Yarmouth			Kansan gumbotil.
			Kansan			Drift (bowlder clay).
			Aftonian			Nebraskan gumbotil.
			Nebraskan			Drift (bowlder clay).
	Tertiary	Pliocene	Ozarkian			Bog and other deposits.
Mesozoic	Cretaceous	Upper Cretaceous	Dakota			Sandstone, a little shale.
Paleozoic	Carboniferous	Pennsylvanian	Missouri	Shawnee Division	Scranton	Shale.
					Howard	Limestone.
					Severy	Shale; Nodaway coal.
					Topeka	Limestone.
					Calhoun	Shale.
					Deer Creek	Limestone.
					Tecumsey	Shale.
					Lecompton	Limestone.
					Kanwaka	Shale.
				Douglas Division	Oread	Limestone.
					Lawrence	Shale.
					Iatan	Limestone.
					Weston	Shale.
				Lansing Division	Stanton	Limestone.
					Vilas	Shale.
					Plattsburgh	Limestone.
					Lane	Shale.
				Kansas City Division	Iola	Limestone.
					Chanute	Shale.
					DeKalb	Limestone.
					Cherryvale	Shale.
					Winterset	Limestone.
					Galesburg	Shale.
					Bethany Falls	Limestone.
					Ladore	Shale.
					Hertha	Limestone.

GENERAL RELATIONS

The formations in Cass county represent five series: the Pennsylvanian, the Upper Cretaceous, the Pliocene, the Pleistocene, and the Recent.

In the Pennsylvanian series only a portion of what is known as the Shawnee formation, or division, of the Missouri, is visible at the surface in Cass county, other divisions being concealed. The limestone was laid down when distinctly marine conditions prevailed; the shale, when shore conditions were nearer at hand. These conditions alternated back and forth a number of times. At one time the conditions were those of an extensive swamp in which the Nodaway coal seam was laid down and then concealed by a subsidence in which first shale and then limestone were deposited, then shale again. Excepting in the southeast corner of the county all above the Deer Creek (Forbes, Stennett) limestone has been removed by erosion, and in the rest of the county many feet of the rocks below this limestone also have been removed in the long intervals that preceded the deposition of the Dakota sandstone.

During these great intervals of erosion many changes are recorded in other parts of the country. It was in the first of these four periods, the Permian, that in the Appalachian region the strata there laid down were gradually crushed together and upheaved into the Appalachian mountains, and the eastern half of the great interior of the continent was thrown into gentle folds and raised bodily above the ocean. Likewise in the southwest, as a continuation of the Appalachian folding, occurred a similar folding and uplift known as the Ouachita uplift. In the low ground of the southwest a wonderful Amphibian fauna left its impress. During the three remaining periods, the Triassic, Jurassic and Comanchian, or Lower Cretaceous, a remarkable reptilian fauna roamed over the land, swam in the waters, and even flew through the air. In the last of these three periods the sea advanced from the south as far as Kansas, and then, because of changes in level, retreated again far to the south.

It was during these long periods of erosion, while all of these changes were taking place, that the Pennsylvanian limestones and shales of Càss county were undergoing weathering and removal, the sediment was carried far to the southwest as valleys were eroded and a new landscape developed. Another change in level, accompanied by a downward warping of the northwestern part of the state, brought a new advance of the sea that crept farther to the east in the northern part than in the southern part of the state. This advancing Cretaceous sea spread beneath its waves the clays and sands of a submerging landscape, and then shore currents washed the sand into an extensive and thick bed that in Kansas, Nebraska and the Dakotas is the great water carrier supplying thousands of artesian wells, the Dakota Sandstone. In Cass county this sandstone is well exposed in some places, and extends beneath the glacial drift throughout a considerable portion of the county. If other Cretaceous strata, the Colorado, Montana and Laramie beds, were laid down within the confines of the county they have since been removed by erosion. Indeed, in the state as a whole remains of only the Dakota and of the Colorado deposits, the Niobrara, have been found.

During the time that what is now Cass county was beneath the border of this extensive sea there was a far different fauna and flora than had existed previous to that time. The leaves embedded in the Dakota sandstone are not like those found in Carboniferous strata, but are netted veined and somewhat modern in aspect, in contrast with the ferns and club mosses of the Carboniferous. Of animal fossils the great beds of Brachiopods of the Pennsylvanian are absent, and in their places are to be found beds of Pelecypods unlike those from the Pennsylvanian, though fossil shells have not been found in the deposits of Dakota age in Cass county, nor fossils of the remarkable reptiles of the types already mentioned that frequented the land and sea of Cretaceous time.

It was in the latter part of this the Cretaceous period that the Rocky Mountains were pushed up and the great interior sea was largely drained. During at least a part of this time, and probably all of it, what is now Cass county was again subject to erosion that continued during the periods of the Tertiary, the Eocene, Oligocene, Miocene and Pliocene, that followed, when large areas of the great West were sites of extensive lakes. During this time a new landscape was here developed. River valleys were cut deep into the Dakota sandstone, and in places entirely through the sandstone into underlying limestone and shale of the Pennsylvanian strata. This erosion in a rugged country of sandstone hills continued till in Pleistocene time an advancing ice sheet, the Nebraskan, crept over Iowa. As this melted away the drift was at first deeply weathered, then somewhat uplifted and eroded[20], and then the valleys were partly silted up in Aftonian time ere again an ice sheet, the Kansan, crept far to the south, and gradually melted away, this time leaving deposits that, while three different ice sheets, the Illinoian, the Iowan and the Wisconsin, invaded other parts of the state, were in Cass county constantly subjected to weathering under varying conditions of elevation, till now a new landscape meets our view, covered with the flora of the present, and inhabited by the recent fauna.

These four series of formations, the Pennsylvanian, Upper Cretaceous, Pleistocene and Recent, are thus separated by landscapes, each carved in the preceding deposits by the action of rivers, in coöperation with the other agencies such as are at work today in the formation of soil and of the hills and valleys of the present surface. The landscapes then formed deserve recognition along with the deposits themselves. Indeed, the relation of the various formations cannot be appreciated till the mind can picture the action in these long continued periods of erosion, and see these ancient hills and valleys in their relation to each other.

PALEOZOIC GROUP. CARBONIFEROUS SYSTEM.

Pennsylvanian Series

MISSOURI STAGE

The best section of Carboniferous strata to be found in the county is a mile west of Lewis, beginning with an exposure of limestone on Spring creek a few rods north of the bridge and extending up a small ravine to the west parallel to the road (west center of the northwest quarter of section 9, Cass township).

[20]The change in level was not very great. See discussion of Thickness of Aftonian Deposits, and Estimate of Aftonian Relief.

THE SPRING CREEK SECTION A MILE WEST OF LEWIS.

		FEET	INCHES
13.	Soil, sandy	2	
12.	Sandstone, fine-grained, thin bedded, yellowish brown, soft	3	
11.	Sandstone, much decomposed, brownish yellow..	5	
10.	Parting between beds of sandstone, like an unconformity, sloping irregularly northwest......		
9.	Sandstone, fine, yellowish, decomposed..........	3	6
8.	Nodules of hematite		2-4
7.	Sand, white, unconsolidated	1	
6.	Sandstone, imperfectly exposed	8	
5.	Shale, imperfectly exposed	3	
4.	Shale, blue in upper portion, then dark reddish brown, then yellowish and soft (yellow ochre), then brownish red	7	6
3.	Limestone, gray, full of Fusulina................	5	6
2.	Shale, gray	2	
1.	Limestone in thin layers, gray; Crinoid stems, *P. longispinus*, *P. nebrascensis*, *C. verneuilianus*, *S. subtilita*, *Sp. cameratus* and Bryozoa.......	4	10
	Creek bed	45	8

In this section the lowest part (numbers 1-5) is distinctly Carboniferous (Missouri) and the upper part (numbers 6-12) is distinctly Dakota sandstone. The dividing plane is judged to lie in number 5, beneath which the shale is like water soaked Carboniferous shale, while above it sand is the chief constituent. Number 3 of this section is the stratum used in comparing elevations of different outcrops: number 7 at Stennett, numbers 8 to 9 at Fox quarry, the outcrops a mile and a half south of Lewis, and those on Turkey creek three and a half miles northeast of the Spring creek outcrop.

A mile west of Spring creek, Indian creek exposes limestone and shale (southwest quarter of the southwest quarter of section 5). Here two inches of fossiliferous limestone lies over two feet of blue shale. These are parts of numbers 2 and 3 of the Spring creek section. Still farther west, near the southwest corner of section 7, but in the next county, a well in the upland is said to have reached limestone at a depth of two hundred feet with no evidence of sandstone above it.

Near the mill at Lewis, a mile east of the Spring creek section, the water falls about eight feet over a dam that is said to rest on limestone. Such limestone as is visible corresponds to number 1 of the Spring creek section. At the old quarries below the dam (northeast quarter of the northeast quarter of section 9, Cass township) about six feet of this same limestone and overlying gray shale appear, above which are two feet of a yellow shale, then three feet of a washed deposit containing brown sand. The top of the limestone, corresponding to number 3 of the Spring creek section, is here seventeen feet above the water in the river and perhaps three feet above the general level of the bottom land. At present all beneath the limestone is concealed and there is no well record revealing the stratum.

The section at Lewis as it was exposed in 1870 is given by White[21]:

WHITE'S SECTION AT LEWIS (1870).

		FEET
10.	Yellowish, marly clay, with occasional thin calcareous layers	2
9.	Grayish, compact limestone	2-3
8.	Marly clay	4
7.	Fragmentary limestone, with flinty nodules	1 1-3
6.	Grayish, compact limestone	2½
5.	Dark colored carbonaceous shale	½
4.	Dark colored, concretionary, and very flinty limestone	3
3.	Yellowish, and bluish marly clays	10
2.	Grayish limestone	1
1.	Yellowish, marly clay	2
	Total	27

A mile southwest of Lewis a few beds of limestone and shale appear in the hillside on the south side of the river (southwest quarter of the northwest quarter of section 15).

It is said that there used to be a ford two miles north of Lewis not far from the present bridge in that locality, and that near this ford limestone was to be seen in the bed of the river. At the present time the limestone is not visible, at least when there is a considerable volume of water flowing in the river.

Near the southwest corner of section 31, Grove township, limestone is said to have been taken from the bed of the creek, but the strata are now concealed. In the south half of the northeast quarter of section 1, Cass township, three feet of limestone exposed on the side of a ravine is a mass of *Fusulinas*, with a light yellowish brown sandstone above. Across the road to the east an upper six inches of this limestone, here thin bedded, is crossed

[21]C. A. White, "Report on the Geological Survey of the State of Iowa," Vol. I, p. 374.

by the creek. Here may be seen Crinoid stems, Polyzoa, *Chonetes verneuilianus*, and many fragments not identifiable.

Close to the south county line are the Fox quarries, in which little work has been done in recent years. The following section was obtained east of the road (northeast quarter of the northeast quarter of section 31, Edna township).

SECTION AT FOX QUARRY

		FEET	INCHES
17.	Small fragments of decomposed limestone with *Fusulina*, large Crinoid stems, Bryozoa, *P. nebrascensis*, *Chonetes verneuilianus*..........	2	
16.	Shale, gray		10
15.	Limestone, gray; *Fusulina*		2
14.	Shale, yellow below, dark above................	1	4
13.	Limestone, gray		7
12.	Shale, gray and yellow.........................		10
11.	Shale, dark	7	
10.	Shale, light and brown, with some weathered limestone		7½

FIG. 27.—Fox quarry, east of the road. (Northeast quarter of the northeast quarter of section 31, Edna township, Cass county.)

9.	Limestone, light gray; numerous Crinoid stems..	2	3
8.	Limestone, light gray, dense stratum	1	
7.	Not exposed	2	
6.	Limestone, light gray, dense stratum............	2	
5.	Limestone, light gray, in several thin layers; many *Fusulina;* dip 1° 45″ S 10° W..........	1	8
4.	Limestone, light gray; Crinoid stems, Bryozoa, *Derbya crassa*, *Stroparollus*, and many shell fragments		10
3.	Limestone in two layers; corals: shaly parting		1
2.	Limestone, weathered		4
1.	Not exposed	23	
	River bed, low water	46	6½

In the above section numbers 4 to 6 correspond to number 1 of the Spring creek section, while numbers 8 to 9 correspond to number 3 of the Spring creek section. The crinoid stems in number 9 are more noticeable than in number 3 at Spring creek.

Across the road to the west, in section 36 of Noble township, are the same beds above described except the topmost one, which is absent; but the beds are even less exposed to observation. They were described by Lonsdale in his report on Montgomery county[22], and also by G. L. Smith[23] in his paper on Southwestern Iowa.

Half a mile up the river from Fox quarries ten feet of limestone bearing *Fusulinas* are to be found above a crinoidal limestone two to three feet thick and corresponding to numbers 6 to 9 of the Fox quarry section. The ten feet next below are not exposed. In the bed of the river is a foot of thin bedded limestone.

On Rose branch just south of the county line (opposite the southwest quarter of the southeast quarter of section 32, Noble township) are traces of an old quarry. No strata in place are now visible, but fragments at hand are of the *Fusulina* limestone, like that at Fox quarries not far away.

Three miles east of the Fox quarries, but in the next county south, Adams, is a coal shaft at the Briscoe mine (opposite the southeast quarter of the southwest quarter of section 34, Edna township), on which Mr. Charles Porter gives the following data:

[22]E. H. Lonsdale, "Geology of Montgomery County," Iowa Geological Survey, Vol. IV, pp. 393-394, 1894.
[23]G. L. Smith, "Carboniferous Section of Southwestern Iowa," Iowa Geological Survey, Vol. XIX, pp. 627-628.

COAL SHAFT AT THE BRISCOE MINE.

		FEET	INCHES
7.	Bowlder clay, with stratum of sand at 25 feet....	32	
6.	Shale, blue	55	
5.	Shale, black	30	
4.	Cap rock	2	
3.	Coal, dipping slightly southwest................	1	6
2.	Fire clay	1	3
1.	Limestone in bottom of sump..................	4	
		125	9

The dip of the coal as measured by the writer is 2° 48′ to the south.

The Chapman mine near the above mine is described by C. R. Keyes[24] and Henry Hinds[25].

The section at Stennett, to which frequent reference must be made under Correlation, is described as follows by G. L. Smith[26]:

THE SECTION AT STENNETT.

		FEET	INCHES
13.	Limestone, residual	5	6
12.	Shale, calcareous		6
11.	Limestone, gray, fine-textured	1	8
10.	Shale, buff and gray, argillaceous	3	6
9.	Limestone, variable, earthy below................	5	
8.	Shale, buff	1	
7.	Limestone, blue above, cherty	6	
6.	Shale parting		2
5.	Limestone, variable	5	
4.	Shale, argillaceous	1	6
3.	Shale, black, bituminous	3	
2.	Limestone, shaly	2	
1.	Limestone	3	
	Total	37	10

Dr. Smith states that in the above section at Stennett, "numbers 1-4 belong to the Platte shales, numbers 5-9 are the Forbes limestones (Deer creek), and that above No. 9 is the lower part of the Braddyville (Howard) limestones."

Distribution.—In the western part of the county the Missouri formations with their limestone and shale lie next beneath the glacial drift and alluvium along the valley of Nishnabotna river from two and a half miles northwest of Griswold to about five miles north of Lewis, along the valley of Indian creek as far

[24] C. R. Keyes, "Coal Deposits of Iowa," Iowa Geological Survey, Vol. II, p. 441.
[25] Henry Hinds, "The Coal Deposits of Iowa," Iowa Geological Survey, Vol. XIX, p. 392.
[26] G. L. Smith, "Carboniferous Section of Southwestern Iowa," Iowa Geological Survey, Vol. XIX, p. 636.

north as the southern boundary of Washington township, and along the valley of Turkey creek to the northwest corner of Beargrove township. From well records it appears to be next beneath the drift for a part, if not all the way, north from Lewis through section 11 of Washington township, 25 of Brighton township, and 17 and 8 of Pymosa township. The area along Turkey creek is extended south by a well record to the town of Marker (section 3 of Beargrove township). In a northeasterly direction are isolated areas in section 33 of Franklin township and 26 of Benton township, and still farther to the east in sections 10 and 15 of Lincoln township. In the southern part of the county it lies immediately beneath the glacial drift along Three Mile creek as far north as section 23 of Noble township, is beneath a thin deposit of Dakota sandstone in section 18 of Edna township, and beneath drift again in section 20 of Union township. It outcrops in the south bank of section 36 of Noble town-

FIG. 28.—Dakota sandstone at Spring Creek. (West center of the northwest quarter of section 9, Cass township, Cass county.) Numbers 9 to 12 form the cliff at the bottom of which are springs formerly used by the Indians.

ship, and 31, 30, 29 and 28 of Edna township, and has been penetrated by digging along a narrow strip south of the creek in sections 34 and 35. To the northeast of these locations it is found beneath the drift in section 20 of Victoria township, in sections 30, 32 and 27 near Massena, and beneath a thin deposit of Dakota sandstone in sections 5 and 6 southwest of Massena.

Presumably the above named records mark the distribution of higher portions left after erosion in the great intervals of time between the close of the Carboniferous period and the beginning of the Cretaceous. Along the streams the Carboniferous strata are exposed only in places, as in the neighborhood of Lewis and Iranistan and southwest of Reno. Generally the glacial drift extends below the level of the streams. Northwest of Griswold, in Pottawattamie county, the Dakota sandstone is beneath the level of the river; and throughout the upland generally wells equal in depth to some which reach Carboniferous strata, penetrate Dakota sandstone, and do not reach Carboniferous at all.

It is also noticeable that all but one of the wells that are reported to reach the Carboniferous strike a resistant limestone, not shale; and that near Lewis and Iranistan, and along Turkey and Three Mile creeks, a resistant limestone is at or near the uppermost Carboniferous exposed, though southwest of Reno and at the mine at Briscoe, southeast of Reno, shale lies above limestone.

These exposures of the Carboniferous and the wells that reach it are largely in the southwest half of the county.

Correlation.—In testing the above correlation based on general texture, sequence and fossil content the following data have been secured from railroad levels and barometric measurements:

	Altitude above sea level	Difference	Distance	Dip.
	FEET	FEET	MILES	
Top of No. 3, Spring creek section....	1109	0	0	3° 45′ N. 5° E.
Top of No. 3 at Lewis, below dam....	1110	1	½	3° 45′ N. 5° E.
Top of Fusulina limestone, Turkey creek	1123	14	4	Horizontal
Top of No. 7, Stennett...............	1076	—23	17½	3° E.[27]
Top of Nos. 7 to 9, Fox quarries.....	1135	26	13½	1° 45′ S. 10° W.

[27]The location of a steep dip to the north was not visited (Vol. XIX, Iowa Geological Survey, p. 636).

In this marked difference in dip there is a general plan. At Stennett and Fox quarries the dip in the limestone is toward a fault plane, the facts concerning which will be discussed later. At Lewis, northwest from this fault plane, the dip is in the opposite direction from that at Fox quarries; and at the most distant place, at Turkey creek, the beds are almost horizontal.

The second most noticeable fact is the actual difference in level between number 7 at Stennett and numbers 8 and 9 at Fox quarries, at which places it has previously been thought the same formations outcropped.[28] Half way between these two levels are the limestones at Lewis and Spring creek; and three-quarters of the way up between them are the limestones at Turkey creek; but the differences in level between them all are so slight that they might be accounted for by slight local differences in dip.

The third most noticeable fact is that from Stennett to Stuart the strata go down the geological sequence; for the Des Moines formation is at the surface along ravines just north of Stuart, and was reached by a mine shaft six miles south of Adair. At present there are no data whatever of the presence of a fault extending northwest-southeast across this region[29]. The difference from Stuart to Stennett can be accounted for most satisfactorily by a general dip to the southwest. This, however, is not true with reference to a northeast-southwest fault at right angles to the above named northwest-southeast direction, as will be discussed at the close of the description of the stratified rocks.

In the preceding discussion the *Fusulina* beds at Spring creek, at Lewis, at Turkey creek and at Fox quarries are described as one and the same bed. The slight differences are accepted as possible in a region of varying dip, especially when it is noted that Spring creek, Lewis and Turkey creek are from seven and a half to eight and a half miles to the northwest of the line of reference (from Stennett to the Eureka shaft) and Fox quarries are five and a half miles to the southeast of that line. When, however, comparison is made between the dip and the level of

[28]G. L. Smith, "Carboniferous Section of Southwestern Iowa," Iowa Geological Survey, Vol. XIX, 1909, pages 627-628 and 636.

[29]H. Foster Bain makes no mention of a fault in Decatur county south of Clarke county. See also the report on the geology of Clarke county, by the present writer, and comments on the geology of Adair accompanying the report on Adair county, in this volume.

numbers 8 and 9 at Fox quarries and the dip and level of number 7 at Stennett, twelve and a fourth miles southwest of Fox quarries, the difference is not so easily accounted for. Comparing the sequence at Fox quarries with the sequence at Stennett, it is noted that numbers 2 to 9 at Fox quarries present seven feet and eleven inches of limestone, with not over two feet of intercalated shale, and that shale is in one bed concealed; while at Stennett there are twenty-one feet of limestone and seven and a half feet of intercalated shale, divided between four distinct beds. Furthermore, numbers 3 to 4 at Fox quarries have an abundance of fossils in the lowest part with a Fusulina bed nearly two feet thick immediately above, not to mention the Fusulina bed at the top of the quarry; while near the base of the limestone at Stennett there is no such fossil horizon, nor is there such a distinct Fusulina limestone present. It therefore appears to the writer that the beds at Stennett are not[30] identical with those at Fox quarries nor with those at Spring creek, Lewis and Turkey creek.

How, then, can these isolated beds of southwestern Cass county be located in the Missouri section?

Data published by the survey make it possible to determine the position of the base of the Missouri limestone to the northeast at the old Eureka shaft[31] just east of the county line southeast of Anita. The base of the Missouri limestone is here close to 1,198 feet above sea level.

It is assumed that the limestone outcropping at Stennett, in the opposite direction, where it has been carefully studied, has been correctly identified by G. L. Smith[32]. If the Clarinda well record from the Deer creek (Forbes) limestone down is drawn beneath the section at Stennett, the base of the Missouri limestone at Stennett is located at 471 feet above sea level. This gives a difference in level of 727 feet in thirty-four and a half miles, which is twenty-one feet per mile, which corresponds to an average dip in this direction of fifty-four and six-tenths minutes.

[30]Compare p. 627, Carboniferous Section of Southwestern Iowa, Iowa Geological Survey, Vol. XIX.

[31]Northeast quarter of the northwest quarter of section 4, Eureka township, Adair county. See C. R. Keyes, "Coal Deposits of Iowa," Iowa Geological Survey, Vol. II, p. 442, 1894.

[32]For the records at Stennett see "Carboniferous Section of Southwestern Iowa," Iowa Geological Survey, Vol. XIX, and further papers by Smith in volumes XXII and XXIII of the Proceedings of the Iowa Academy of Science. For the record of the Clarinda well see p. 618 of Vol. XIX, Iowa Geological Survey.

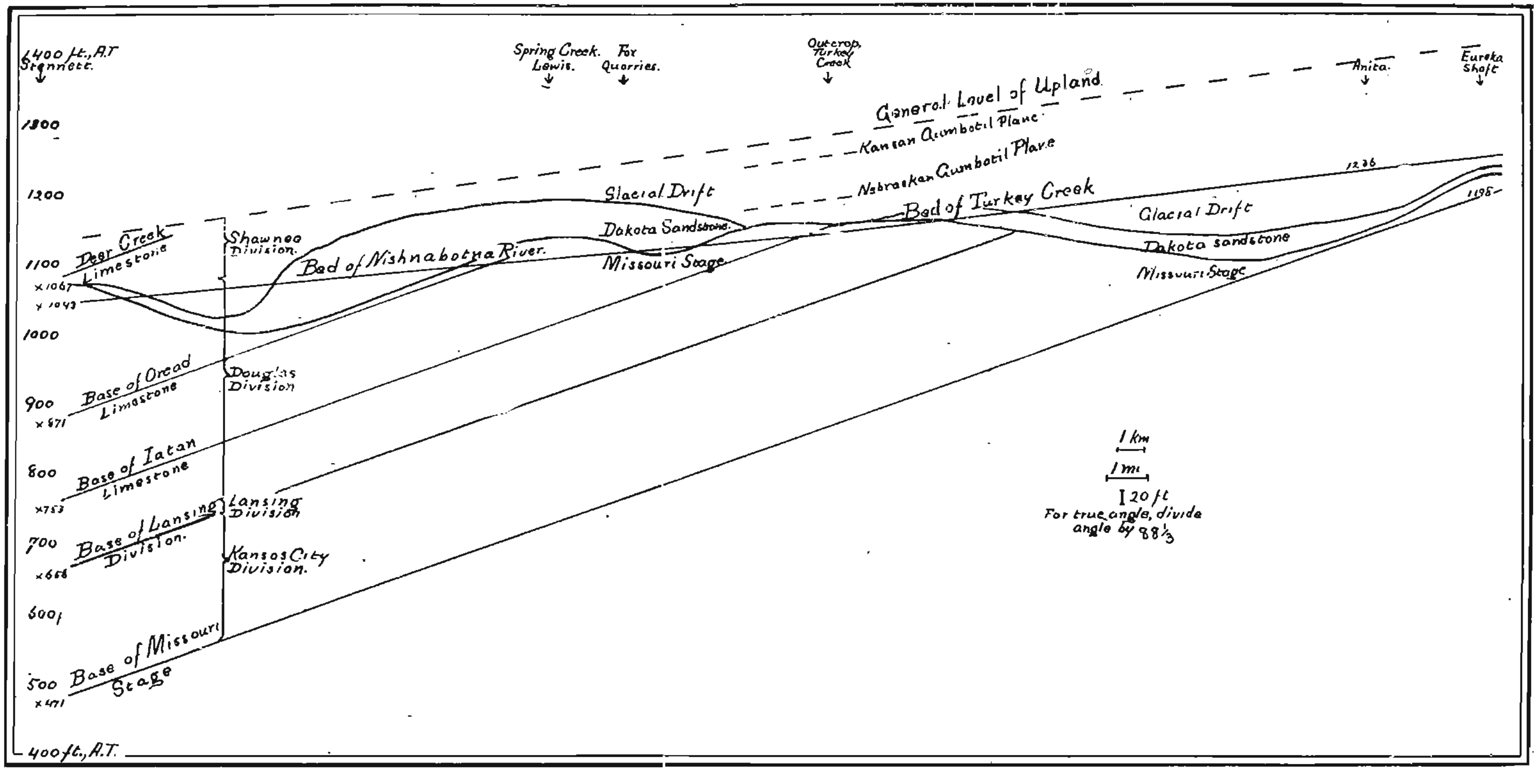


Diagram of structure from Eureka shaft southwest across Cass county to Stennett along the west side of the fault plane. The vertical intervals on the left are from the "Record of the Clarinda Diamond Drill Hole" (Iowa Geol. Survey, Vol. XIX, p. 618), except that the Oread limestone (No. 78) is, for the reason given in the text, drawn seventy feet below the position stated in the drill record.

The various beds below the Deer creek at Stennett should lie consecutively next beneath the Dakota sandstone or the drift between Stennett and Eureka shaft, with minor variations due to changes in dip and to possible thinning of the shaly members beneath the Oread limestone, as stated by Hinds and Greene[33]. An exact plotting brings a part of No. 71, a shale at a depth of 315 to 346 feet in the Clarinda section, to the surface at Fox quarry. A variation downward of about seventy feet, due to dip, to a thinning of the shale, or both combined, would bring No. 78 of the Oread (Plattsmouth) limestone to the level of the *Fusulina* bed at Fox quarry. A variation upward would bring the Iatan limestone to this level. The description of the Iatan limestone given by Hinds and Greene does not fit, that limestone being particularly deficient in *Fusulina* beds, while such beds are a marked characteristic of the Oread (Plattsmouth) limestone. In the Clarinda well record such a limestone bed is particularly mentioned (No. 78) in the base of the limestone. In Missouri such beds are mentioned as present, but they are especially characteristic of the upper portion of the formation. At Fox quarries *Fusulinas* are exceedingly abundant in a thin stratum of weathered limestone at the top of the excavation, and the succession of limestone and shale and the character of all the beds fits nicely the general description given of the Oread beds of Missouri. It therefore appears that the limestone in southwestern Cass county is the Oread limestone.

Since the Oread limestone outcrops in the southwestern part of Cass county the Iatan limestone must come to the plane of unconformity beneath the Dakota sandstone near Cumberland; and the Plattsburg limestone should come to this plane of unconformity about half way between Cumberland and the eastern border of Lincoln township. Consulting the distribution of the Missouri as indicated by well records it will be noted that the Missouri formation (probably the highest portions of it) was encountered immediately beneath the drift in a line from section 28 to section 3 south of Atlantic, (see accompanying map of the geological formations of the county) in section 17 northwest of Cumberland, and in two areas north of Massena. It will also

[33]Hinds and Greene, "The Stratigraphy of the Pennsylvanian in Missouri," p. 183, 1915. They state that the shale is 145 feet thinner in Iowa than in Missouri.

be noted that another area, for the Stanton, or Plattsburg, limestone, appears in Lincoln township and northeast of Wiota. Apparently the intervening concealed portions stretching northwest to southeast between these areas mark the locations of the Lawrence (Andrew) shales, Weston shales and Lane (Parkville) shales. The beds of the Kansas City formation are known to lie beneath the Dakota sandstone in Eureka township of Adair county, close to the southeast corner of Grant township, Cass county; hence they lie next beneath the Dakota sandstone and the drift throughout nearly all, if not all of Grant township, the northeast half of Benton township, and the northeast third of Lincoln township.

Throughout the larger portion of Cass county, as well as of adjacent regions to the west, north and east of Cass county, these formations are concealed both by thick deposits of drift, and by deposits of Dakota sandstone. The distribution of outcrops and well records, as illustrated on the map, indicates that the northeastern boundary of each formation curves toward the west, so that in the southeastern parts the general direction is northwest-southeast, while in the northwestern parts of the county the general direction is several degrees more to the west, ten degrees in the north center of the county and nineteen degrees in the southwest portion of the county.

The above discussion applies to that portion of Cass county northwest of a line drawn northeast from where the road south from Cumberland to Briscoe crosses the county line, to the northeast corner of Victoria township. Southeast of this line the Scranton shale and Howard limestone, above the Severy shales, including the Nodaway coal, of the Shawnee division are beneath the Dakota sandstone and the drift.

MESOZOIC GROUP. CRETACEOUS SYSTEM.

Upper Cretaceous Series

DAKOTA STAGE

In the Spring creek exposure already described (west center of the northwest quarter of section 9, Cass township) a part of number 5 and all above that number are referred to the Dakota sandstone. In this particular locality there is considerable sand with the shale, so that the strata are described as sandstones, which in position correspond to what in other places are distinctly shales. The heavy beds of sandstone, numbers 9 to 12, form the cliff at the bottom of which are springs. In number 10 there is in the sandstone a parting sloping irregularly northwest. Crossbedding due to current action is a common feature in the sandstone.

At Crystal Lake (southeast quarter of the southwest quarter of section 15, Cass township), a mile south of Lewis, there is a delightful shady recess beneath a cliff of sandstone which rises to a height of twenty-four feet, above which is a bowlder clay sloping back to the highest ground of the upland. Water from the base of the sandstone, and just above the underlying shale, is piped into an artificial pool near at hand. The top of the shale and the base of the sandstone at the pool are thiry-eight

FIG. 29.—Crystal Lake is a delightful spot. The bluff of Dakota, sandstone is on the south side of the pool.

feet above the bed of the river. Near the top of the sandstone there is a curved plane of separation between a finer stratified sand above and a coarser sand beneath and on one side of the finer sand, seemingly marking a plane of contemporaneous erosion. This is at about the level of the shale half a mile to the southeast.

SECTION AT CRYSTAL LAKE.

		FEET	INCHES
6.	Bowlder clay		
5.	Sandstone, irregularly bedded, part stained yellow	10	
4.	Shale, gray, sandy		2
3.	Sandstone, white, fine above; light buff and soft below, cross bedded, with bedding planes dipping S 30° W.	14	
2.	Apparently shale, imperfectly exposed	3	
1.	Not exposed	38	
	River bed		
	Total	65	2

The strata in the bluff dip 6° in a direction S. 30° W. There are two sets of joints, one vertical, that extends N. 8° W. The other, dipping 83° N., extends N. 75° E.

South from Crystal Lake the sandstone and a white shale appear by the roadside (southwest quarter of the southwest quarter of section 15). Farther south and east it appears in a small exposure by the roadside (northeast quarter of the southeast quarter of section 22). A mile to the northeast (northeast corner of section 23) about five feet of a dark brown sandstone appears in the side of a trench. By the roadside half a mile south of Lewis the dark brownish sandstone has been quarried (east half of the southeast quarter of section 15).

West of Griswold, and west of the county line, there is for half a mile along the west side of Nishnabotna river a bluff of Dakota sandstone twenty-five feet high the base of which is beneath the level of the water in the river. At the north end of this picturesque region and just over the county line west of section 31, Cass township, is an excellent exposure of about eight feet of shale beneath the sandstone. In the upper portion of this shale iron concretions are interstratified; at the base of the exposure fragments of lignite are to be found in the shale. The sandstone above the shale is of variable thickness, and in one place slopes down northward over the shale. At a house near by the well is said to reach sandstone at a lower level than the sandstone by the river. Perhaps this shale is a lenticle in the sandstone. The lignite gives evidence that it is Cretaceous; at this place it must be close to the top of the Carboniferous. A similar shale is found in section 16 of Pleasant township.

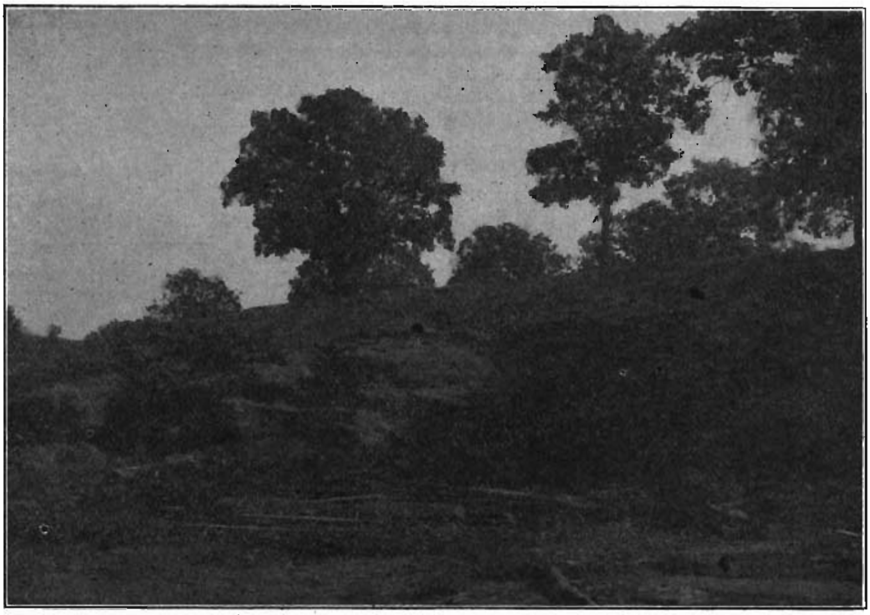


FIG. 30.—On the east side of the road a mile south of Lewis a dark brownish sandstone has been quarried.

Still another exposure of this Dakota sandstone, giving a touch of ruggedness to the general type of the topography, is located near Galion in section 35 of Beargrove township, extending for an eighth of a mile along the south side of the creek through the section. At one place there is a small amphitheater about fifty feet across, where the sandstone rises perpendicularly to a height of thirty feet. The base of the sandstone is covered with mud from the adjacent creek; the lower portion that can be seen is white, and the upper portion is red.

Four miles to the south (northwest quarter of the southwest quarter of section 17, Noble township) nine feet of soft white sandstone, in a knoll twenty feet above the bed of the ravine to the west, is quarried for sand.

Three miles farther southwest (south one-half of the southwest quarter of section 31, Noble township) the sandstone is visible close to the county line, where it evidently forms a lobe of a sandstone hill under the drift, and is exposed along small ravines cut in the southwest corner of the section. Here are small sandstone cliffs rising twelve feet above the bed of the ravine.

Four feet of sandstone exposed in two other places (southwest quarter of the northeast quarter and northeast quarter of the northwest quarter of section 32, Pleasant township) mark the site of another hill of Dakota sandstone beneath the drift. In section 16 of the same township is a shale, like that already described as included in sandstone northwest of Griswold, marking the site of still another hill.

Along West Nodaway river the Dakota sandstone is visible south of Reno. In a small ravine in section 32 (northeast quarter of the northwest quarter) about six feet of brown sandstone appear in the ravine side a few rods south of the road. Near the road the fine, white, soft sandstone beneath the brown has been dug into for sand. In the southeastern quarter of section 30 there is evidence of it above the limestone. In section 17 (southwest quarter of the southwest quarter) there is the following section:

EXPOSURE IN SECTION 17, EDNA TOWNSHIP.

		FEET	INCHES
5.	Sandstone, dark brown	4	
4.	Hematite		3
3.	Shale, arenaceous, light brown	6	
2.	Sandstone, fragments, brownish yellow	3	
1.	Not exposed; but fragments of limestone (Missouri) are to be seen about a foot above low water River bed	4	
	Total	17	3

In the northern part of section 20 of the same township a brownish yellow stratified sand is exposed in the river bank for a distance of perhaps fifty feet up to a height of twenty feet. This is unquestionably a weathered Dakota sandstone. Likewise farther up the stream water comes from Dakota sandstone along trenches of ravines in sections 10, 12, 14 and 15. The sandstone is said to have been exposed in section 10, but it is now concealed so that its character is not known. So, too, along this river there are numerous springs in section 6 of Victoria township and farther up nearly to Massena (sections 32 and 33 of Massena township) though conditions here indicate that a part of the water may come from Aftonian deposits.

Away from these exposures the records of wells that pass through the drift reveal the presence of sandstone in all directions excepting where the Missouri formation is exposed to view along river valleys as previously described. As the sandstone is an important water carrier wells do not often penetrate far into it, generally but a few feet. Of thirty-nine revealing the presence of Dakota sandstone and also passing through it, or so far into it as to make it possible the entire deposit may have been penetrated, the average thickness is forty feet, the greatest thicknesses being 120 and 147 feet. Even if the two excessive records be eliminated as possibly not correct, the remainder give a very uneven thickness ranging from three and one-half to ninety feet.

It will be noted that exposures of Dakota sandstone do not parallel the exposures of Missouri limestone and shale. The sandstone is exposed along Nishnabotna river even where the limestone is beneath the river bed. Between the valley of this river and that of the West Nodaway it appears exposed by erosion of the drift in eight places. In the county as a whole 108 wells at or near the level of the upland give the surface of the Dakota sandstone as varying from 30 to 250 feet, with the average depth from the surface of the upland down to the surface of this sandstone as 140.8 feet. Assuming these figures to be approximately correct the maximum relief carved in the Dakota sandstone is 220 feet.

The steepness of the slopes carved in the sandstone has been mentioned in the description of outcrops. It is evident also in the well records. In Brighton township the surface of the sandstone is 220 feet below the level of the upland in the northeast part of the township and 100 feet in the southwestern portion of it. At one point eight feet of brownish sand exposed along Indian creek (northwest quarter of the northwest quarter of section 32) is thought to be from the Dakota sandstone. In Pymosa township it is at a depth of 200 feet at the county line and at a depth of 176 feet two miles south. In Grant township it is 220 feet down on the east side of the creek and 87 on the west side. In Washington township it is 31 feet beneath the upland in section 15 and 212 feet a mile and a half to the northeast. In section 3 of Franklin township it is 99 feet below the upland. Half a mile south it is 125 feet, and a mile east of the latter place it is 176 feet. At Lewis it is 70 feet below a low upland, and two miles east it is 170 feet. In section 10 of Beargrove township it is 52 feet beneath the upland at one point and 132 feet a few rods away. In section 10 of Union township a record on the west side of the section gives 60 feet; one on the east side gives 174 and another 200 feet. In section 6 of Massena township one record gives 175 feet and another 254 feet. In section 2 of Pleasant township it is 62 feet below the upland; a mile southward it is 144 feet. In section 8 of Edna township it is 40 feet; half a mile to the south it is 150 feet. In section 13 it is 106 feet, and a mile and a half east in Victoria township it is 200 feet below the upland.

Not far from Lewis the depth to the sandstone is generally less than 100 feet, and exposures of it are most numerous in this part of the county. In the eastern part of the county exposures would certainly be as common as they now are near Lewis if valleys there were as large and deep as near Lewis.

Ridges of Dakota sandstone are recognized concealed beneath the drift here and there throughout the county; but so complete is the dissection into steep sided valleys that there is little chance to select the lines of preglacial drainage. The general slope of the surface of the Dakota sandstone suggests a general drainage toward the southwest. Doubtless the surface of the sandstone as developed during the long intervals of erosion from the Cretaceous to the Pleistocene was changed during Aftonian interglacial times by further erosion; but so far as can now be ascertained a rugged surface as above described is that over which the earliest ice sheet, the Nebraskan, advanced. With fainter relief, because of imperfect erosion of Nebraskan drift from hillsides and valleys, it suggests the topography over which the Kansan ice sheet also spread and left the bowlder clay now so conspicuous on the hillsides.

The Fault

A continuation of that reported near Thurman, Fremont county.

In 1889 J. E. Todd[34] stated that "The sharp fold. . . .which has

[34]J. E. Todd, "On the Folding of the Carboniferous Strata in Southwestern Iowa," Proceedings of the Iowa Academy of Science, Vol. I, Part 1, p. 61, 1889.

been noted at Jones' Point (Nebraska) may become a fault south of Wilson's (Iowa)''. In 1906 he[35] again called attention to the facts that had in the meantime been overlooked, and located the fault on the Iowa side close to the south line of section 23, between Thurman and Wilson's quarry, Fremont county. G. L. Smith[36] calls attention to this displacement. He states that, ''Recent examinations of exposures at Lake Wabonsie and in the vicinity of Thurman confirm the views of Todd and show that at a short distance south of the Wilson section of White a fault of about 300 feet[37] throw with an uplift to the north is present''. He further, on page 636 of the same report, states the following: ''The line of disturbance if extended in a direction north of east through Jones Point on the Missouri river in Nebraska and south of the Wilson section at Lake Wabonsie in Fremont county would pass a short distance south of Stennett. The fault near Lake Wabonsie has, probably, in the eastward extension, become an anticline, and the dip to the north at Stennett would indicate that the line of disturbance lies not far to the south of this place.'' The facts presented in this present report prove that this ''line of disturbance'' does extend past Stennett and Fox quarries, and that the facts warrant the recognition of a normal fault, rather than a monocline or a symmetrical anticline, though a slight anticline does, here at least, parallel the western side of the fault.

Charles R. Keyes in his map of the "Controlling Fault Systems of Iowa (Proc. Iowa Acad. Sci., Vol. XXIII, p. 103, 1916) maps this line of disturbance as a fault line but mentions no data for considering it a fault except by referring to Todd's statement with reference to relations near Wilson in Fremont county. His discussion of the "Extent and Age of the Cap-au-Gres Fault" in the Proceedings of the next year (p. 61) is certainly of interest and importance in connection with this present discussion. The line of disturbance which he traces parallels the eastern side of the Missouri escarpment through Illinois and Missouri into Iowa. The data on age of fault here presented, and the direction of the fault are worthy of attention in comparing the two fault lines, and noting the effect on Iowa topography near their possible intersection, which is four or five miles east of Earlham.

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[35]J. E. Todd, "Some Variant Conclusions in Iowa Geology," Proceedings of the Iowa Academy of Science, Vol. XIII, p. 184, 1906.

[36]G. L. Smith, "Carboniferous Section of Southwestern Iowa," Iowa Geological Survey, Vol. XIX, p. 612, 1909.

[37]In plate 22 he gives it as 320 feet. In the computation in this paper I have considered it to be 300 feet.

Amount of Displacement.[38]—The amount of displacement can be ascertained by comparing relations in the southcentral part of the county with descriptions and well records such as are given by G. L. Smith in his "Carboniferous Section of Southwestern Iowa."

At Briscoe the shaft is reported to be 125¾ feet deep. It is 120½ feet to the bottom of the coal, which places the bottom of the Nodaway coal at this point at 1,014.5 feet above sea level, while the top of the limestone No. 9[39] in the side of the excavation at Fox quarries is at 1,135 feet above sea level, a difference of 120.5 feet, which must be added to the thickness of the strata between the two horizons as recorded in well borings and sections, noting that the limestone at Fox quarries is Oread limestone (No. 78 of the Clarinda record).

PAGE[40]		FEET		FEET
618	Clarinda diamond drill hole..............	164	+120½=	284½
629	College Springs core drilling (above No. 8)	83½	+120½=	204
632	Coin, core drilling (above No. 4)........	126	+120½=	246½
616	Todd's Missouri river section (Nos. 3-10)..	148	+120½=	268½
614 and 623	Broadhead's general section for the Missouri (Nos. 151-214)	231	+120½=	351½
	Average			271

Of these places Clarinda is nearest to Cass county; so that the displacement is considered to be 284½ feet. This happens to be near the average in the above table.

ARGUMENT WITH REFERENCE TO THE FAULT.

The question whether there is a fault or only a monocline involves a somewhat technical discussion that may prove of little interest to the general reader of a county report, but the facts are so important to the geological worker that a discussion of the evidence cannot be omitted, especially when the presence of a fault in this part of Iowa has only been surmised, never substantiated. Indeed, in the literature of Iowa there is very little of exact evidence bearing on faults, except a few small ones found in coal mines. The practical importance with reference to the distribution of coal will receive further attention under the heading, Coal, in the chapter on Economic Deposits.

1. The displacement of 284.5 feet occurs within a maximum distance of two miles in a direction at right angles to the general dip through the entire region. This displacement is along the line of strike, and not due to local variation

[38]The facts given in the discussion of Correlation also bear on the question of the amount of displacement.

[39]No. 5, used in local comparisons in a preceding chapter, is seven feet below No. 9.

[40]Pages refer to G. L. Smith's "Carboniferous Section of Southwestern Iowa." Iowa Geological Survey, Vol. XIX. Broadhead's section is more completely given in Hinds and Greene's "Stratigraphy of the Pennsylvanian in Missouri," pp. 112-113.

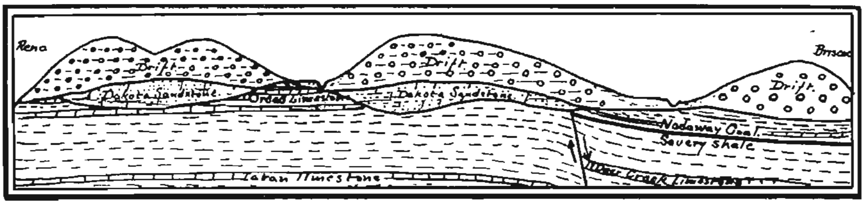

FIG. 31.—Diagram representing conditions from near Reno, Edna township, Cass county, southeast to Briscoe, Adams county, across the fault plane.

in the general dip of the region. The fracture itself is parallel, or nearly parallel, to the general direction of dip, and is thus to be classed as a dip fault, or slightly oblique normal fault. Work to the northeast by the writer indicates a curve in the direction of displacement due to multiple faulting "en echelon."

2. A line of disturbance running N. 62° E. between Briscoe and Fox quarries with a displacement of 284.5 feet within a maximum distance of two miles would, if the dip were uniform the entire two miles, require a slope of but 1° 32′ 45″, or 142.5 feet to the mile. If the dip in the strata changed from one level to another across the displacement the dip in the steepest place must be several times this amount, but the dip at the extreme ends could not, in a monocline, be several times the average dip for the whole distance.

At Fox quarries the dip is about what the average dip should be for a monocline; but at Briscoe it is nearly twice too much and at Stennett, located similarly to Fox quarries with reference to the plane of disturbance, the dip is also nearly twice too much for a monocline. Under this second heading, then, the argument favors the presence of a fault, though it is not fully conclusive.

3. Stretching resulting in a monocline tends toward uniformity in direction of dip. Along a thrust fault the strata are mashed and contorted, the angle is low, and the uneroded remnants of resistant strata on the upthrow side may extend far beyond exposures of downthrow strata in the valleys. Along a normal fault the strata are not mashed and contorted, though accompanying irregular pressure may vary the direction of dip near the fault. The angle is high and the uneroded remnants of successive beds of resistant strata may zigzag across the surface, but the border does not depart from the plane of fracture.

The dips measured at the different locations do not agree in direction. The dip found at Stennett makes an angle of only 28° with the general direction of the plane of disturbance and that angle is toward the east side. At Fox quarries the direction of dip makes an angle of 52° with the general direction of the plane of disturbance and that angle is toward the west side. The dips at the two places thus make an angle of 100° with each other; and the dip at Stennett is about at right angles to the dip at Briscoe.

At Spring creek and Lewis, about eight miles from the line of disturbance, the dip is in the opposite direction from that at Fox quarries.

Smith also records a "heavy dip to the north" at Stennett. This seems to be at some place near Stennett having a relation to the fault plane similar to that at Lewis. The measurement of dip recorded in this present report was made about half a mile north of the railroad station, on thick limestone in an old quarry close to the track.

4. If a fault is present the Nodaway coal seam, wherever it is below the level of the Dakota sandstone and the preglacial surface, stops against the fault plane. If there were a monocline instead of a fault, the coal would come to the Dakota sandstone or to the glacial drift, between Briscoe and Fox quarries. The absence of evidence of coal along this line favors the presence of a fault; but the lack of well records in this area and the presence of high ground a part of the way leave evidence here far from satisfactory.

It is not possible to apply this test to the east and west of the above named location because of the following relation: A mile west of Fox quarries the Nodaway coal outcrops along Williams Branch[41] where it was formerly mined. Here it has risen fifty-eight feet above the level of its position at Briscoe, only three miles away, and it is not reported further west in Montgomery county. Here, on the south side of the fault, the strata have a large component of their dip, or all of it, in an easterly direction, from Williams Branch toward Briscoe, where the dip found is to the south. In the opposite direction from the Briscoe-Fox quarry region, northeast of Briscoe, the Nodaway coal is still deep in the ground up to the fault plane across the southeast half of Victoria township, Cass county. On to the northeast the strata rise till the base of the Missouri appears near Winterset.

5. The dip at Williams Branch has not been measured; but from the relation between conditions at Williams Branch and those at Briscoe it is clear that there is at least a large component of dip straight east, at right angles to the dip at Briscoe three miles away. This is an extreme of irregularity.

6. The dip of 3° E. at Stennett has a component of five-sixths of that amount toward Williams Branch. This component of 2.5° would give a displacement of 253.6 feet, which is five times too much for the actual displacement between Deer Creek limestone at Stennett and Nodaway coal at Williams Branch. This again indicates some cause of excessive local dip—slipping rather than monocline.

7. Comparing relations between conditions at Williams Branch with those at Fox quarries the argument is still more conclusive. These places are only a mile apart in a direction diagonal to the plane of disturbance and making an angle of 27° with it, giving a distance of half a mile as measured perpendicularly to the plane of disturbance. Within this half mile lies the plane of disturbance having a displacement at this point of close to 232 feet, which would require an average dip of 5° 8′ 27″, which is nearly three times the dip found at Fox quarries and nearly two times the dip found at Briscoe.

In the above, 1 is strongly for the presence of a fault, 2 is somewhat of value, 4 is worthy of notice but of little value in evidence, and 3, supported by 5, 6, and 7, forms a strong argument in favor of a fault.

8. If the plane of disturbance were vertical the plane would outcrop across the country with direction independent of the topography. If the plane dipped to the northwest, the plane at the more resistant strata on the northwest side

[41]E. H. Lonsdale, "Geology of Montgomery County," Iowa Geological Survey, Vol. IV, p. 403.

would curve southeast, and the plane at the outcropping of less resistant strata on that side would curve to the northwest of the general direction of the line of disturbance, the amount of variation from the general direction depending on the angle of dip of the fault plane. With the downthrow on the southeast side this relation would be that of a thrust fault. If the plane dipped to the southeast the plane of resistant strata, the preglacial high ground on the southeast side, would curve northwest, and the plane at the outcropping of the less resistant strata, the preglacial low ground on the southeast side, would curve southeast of the general direction of the line of disturbance, in amount inversely to the angle of dip.

In the field it seems clear that the line of outcrop does not vary much from a straight line, or one that gradually curves, which corresponds to conditions where the angle is high.

With the downthrow on the southeast side, and with excessive folding and crushing absent though there is local variation in direction of dip at different points along the plane, it is evident that the fault is a normal fault, with the fault plane between Briscoe, or the old coal mine on Williams Branch on one side and Fox quarries on the other, with fault plane not far from vertical, and dipping steeply to the southeast. This judgment can be tested whenever the operators of the Briscoe mine care to extend their entries sufficiently far to the northwest, apparently 2,454 feet, to find out how the coal ends in that direction. Unfortunately there are some conditions common to both possibilities. If there were a monocline the coal would thin out with stretching, breaking and weathering, but not reach sandstone because of weathering in pre-Dakota time. Possibly it might reach bowlder clay at points where the sandstone and Missouri strata have been removed by erosion in preglacial time. With a fault plane present the coal may end squarely against the fault plane, or, with coal either weathered or not weathered, end against sandstone or bowlder clay south of the fault plane; but it would not thin out with stretching and breaking.

Todd[42] states, "A careful comparison of sections on both sides of the (Missouri) river shows two anticlines, the higher with its crest near Plattsmouth, and the other about one and a fourth miles above Jones' Point." G. L. Smith distinctly figures a normal fault on the Iowa side in Plate 22[43], but represents a thrust fault on page 649. Assuming the fault to be a normal one at Thurman, as seems probable, and with throw of 300 feet recorded by Smith, this fault continues northeastward with little diminution through the space between Fox quarries and Briscoe, where the throw is 284½ feet on the same side as at Thurman. To the northeastward the fault line crosses the county line at the northeast corner of Victoria township, but no more data with reference to it are at present obtainable in Cass county. In the next county east, Adair, it lies close north of Bridgewater, passes close to Fontanelle, and, bending slightly northward, lies a short distance northwest of Greenfield and of Arbor Hill[44]. It seems to be completely concealed beneath the Dakota sandstone and the drift in this part of the state.

[42]J. E. Todd, "Some Variant Conclusions in Iowa Geology," Proceedings of the Iowa Academy of Science, Vol. XIII. p. 184, 1906.
[43]Iowa Geological Survey, Vol. XIX, p. 646.
[44]In the report on the Geology of Adair County, Iowa" may be found a continuation of this discussion based on data found in that county.

Southeast of this fault line the coal found at Bridgewater is correlated with the Nodaway coal; and the successive limestone beds outcrop farther to the east than the same beds outcrop on the northwest side of the line. Northwest of this fault line the Eureka shaft (section 4, Eureka township, Adair county) had a depth of 212 feet below the upland[45] and passed completely through the Missouri stage into the Des Moines stage. The Des Moines stage itself comes to the surface three miles beyond Stuart,[46] and the northern boundary of the Missouri stage curves off to the west.

If the throw along the fault plane were to continue to diminish at the same small rate with which it diminishes between Thurman and Fox quarries, and the direction were to hold as constantly, the fault would continue northeastward beyond the limits of the state. It would pass five miles east of Earlham, would lie four or five miles north of Des Moines, in which region it may at some time be encountered in mining for coal. Possibly near the surface it dies out rapidly in the Des Moines shales. Possibly it may meet an extension of the Cap-au-Gres fault, which Keyes thinks extends northward from Missouri to Leon, and both may die out abruptly near their intersection. Here are problems in Iowa Geology for future study, with important bearing on the question of depth and continuity of coal seams.

Note also the northeastward extension and high position of the Winterset and other limestone in Madison county. Heretofore it has been recognized as an uneroded remnant; but why its peculiar attitude? This has been a puzzle. The presence of the limestone and accompanying shale so far to the northeast in Madison county is explained by its relation to the Thurman fault plane whatever bearing future developments may have with reference to an extension of the Cap-au-Gres fault. The limestone and shale are not an uneroded mass of uplifted strata, but are the uneroded remnant of a mass of limestone and shale on the downthrow side, left high and further to the northeast because of the greater erosion and peneplanation on the upthrow side to the northwest and north, in which directions erosion brought to the preglacial surface the less resistant shales of the Des Moines stage. We must await further evidence with reference to conditions in the drift-filled valleys along the eastern side of the escarpment.

To the northeast, along the general direction of the fault plane described in this report, there are peculiarities in the distribution of the Devonian, Silurian and Ordovician strata that need explanation. It cannot at present be affirmed whether the fault, or a series of parallel faults is responsible for that distribution, or whether the disturbance there becomes a symmetrical anticline.

AGE OF THE FAULT.

Since the Dakota sandstone lies on both sides of the fault plane and rests on the truncated surface of various strata of the Missouri stage with no evidence of a fault scarp beneath the Dakota sandstone, it appears that the faulting began in the

[45] Charles R. Keyes, "Coal Deposits of Iowa," Iowa Geological Survey, Vol. II, p. 442; also, Henry Hinds, "The Coal Deposits of Iowa," Iowa Geological Survey, Vol. XIX, p. 379.

[46] H. F. Bain, "Geology of Guthrie County," Iowa Geological Survey, Vol. VII, Map.

interval between the deposition of the Missouri strata and the deposition of the Dakota sandstone, that the fault scarp was well removed before the subsidence that accompanied the deposition of the Dakota sandstone, and that any additional faulting since that time has not been very pronounced. That there has been some later movement is evident, since at Crystal Lake the sandstone strata are found to dip in the general direction of the dip of the Missouri limestone. If there was any movement along the fault plane any escarpment formed at the surface of the sandstone has since been removed by erosion.

Variations in dip of the sandstone that correspond to variations in dip of the limestone along the fault plane have not been detected. It therefore appears from this argument also, that about all faulting with accompanying disturbance was completed before the Dakota sandstone was laid down. In this interval of time there was one marked age of disturbance, the Permian. In distant regions, the Appalachian and Ouachita mountains, the faulting was of the reversed type. Here it is of the normal type. The reversed faulting of the Permian may have been accompanied or followed by relaxational movements in the same or the next period. To this interval of time (Permian-Triassic) it seems at present necessary to refer the major part of the faulting and perhaps all of it.*

Joints

In the Dakota sandstone at Crystal Lake, a mile south of Lewis, two sets of master joints are to be seen in the sandstone, the first of the two sets being the more prominent:

Direction of joint plane N. 75° E., with dip of 83° in a direction N. 15° W.

Direction of joint N. 8° W., with dip of plane vertical.

The sandstone is crossbedded, but included shale dips 6° in a direction S. 30° W.

A simple movement bringing the shale into a horizontal position would throw the vertical joint plane 2° 32′ out of plumb and leave the other plane with a dip of 86°.

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*See also John L. Tilton, "The Thurman-Wilson fault through southwestern Iowa and its Bearings": The Journal of Geology, Vol. XXVII, pp. 383-390, 1919.

A depression in a direction N. 8° W., the direction of the vertical joint, sufficient to bring the direction of dip in the shale into a horizontal plane would require a depression of 10° 23′, the axis (strike) of the movement lying N. 82° E., and would give the shale a dip to the northwest. This depression is 2° 45′ too much to bring the other plane into a vertical position, and would at the same time change the direction of the strike slightly toward the north. This approximate adjustment is so close that if a part of the dip of the shale had been due to a slight local variation in amount or direction, or both, the chief need would be met. This local variation seems possible where the shale is between crossbedded sandstones, as at Crystal Lake. To further effect an adjustment a variation in the nature of a warping also seems necessary. The conclusion seems warranted that, reversing the movement for the above adjustment, these joints in the Dakota sandstone were caused by uplift toward the northwest, the direction of which changed in warping from a westward toward a northward direction (N. 15° W. to N. 8° W.) Such an estimate based on present dip includes not only post-Cretaceous movement but also such later movements as may have occurred. Uplift toward the northwest might not only affect, in the underlying limestone, joints at right angles to this direction but even lead to some additional faulting along the fault plane.

In the Missouri stage limestone at Spring creek two miles northwest of Crystal Lake, the directions of the joints were found to be as follows: N. 39 1-3° E. and N. 20 2-3° W., where the dip of the limestone was found to be 3° 45′ in a direction N. 5° E. If these limestone beds were subjected to the same movement that was suggested for the overlying sandstone the dip of the limestone would be increased. Furthermore, the dip of the limestone is found to be different in places distant from each other. It is therefore evident that the limestones were subjected to movement prior to those that affected both the limestone and the sandsone.

The two sets of joints in the limestone do not correspond exactly to those in the sandstone, but are even more closelv related to the direction of the fault plane, and to the uplift toward the northeast. The joint that extends N. 39 1-3° E. is nearest in direction to that of the fault plane, which locally extends N. 62° E., and to the direction of the uplift, that is northeast. The joint that extends N. 20 2-3° W. is approximately at right angles to this general direction of the fault plane and the uplift.

The jointing in the Missouri stage thus seems related to the faulting and to the Permian uplift toward the northeast, while the jointing in the sandstone is related to the post-Cretaceous uplift toward the northwest, though it is affected by the presence of the fault plane and the existing joint planes, and also affects those planes.

CENOZOIC GROUP. TERTIARY SYSTEM.

Pliocene Series (Ozarkian)

The last part of the Tertiary Period is marked by uplift and accompanying erosion, both in the East and in the West. In eastern Iowa it is marked by valleys 100 to 200 feet[47] below the level of the present stream beds. In southcentral Iowa it is marked by valleys sixty-five feet[48] below the present stream beds, containing deposits that were recognized as preglacial. In Cass county it is marked by valleys that are twenty-five feet below the present stream beds. In some of these deep valleys are silts that are beneath Nebraskan drift and hence are of preglacial deposition. Whether they were laid down long prior to the advancing continental glaciers, or were laid down immediately in front of the advancing Nebraskan ice sheet, cannot be affirmed; but certain it is that as the Nebraskan ice advanced it covered up in these old valleys bodies of silts which were rich enough in vegetable matter to become sources of abundant carbon dioxide even to the present time, and hence are recognized as bogs beneath Nebraskan drift, and at too great depth to be Aftonian deposits.

Ten wells (numbers 2, 4, 5, 9, 10, 11, 12, 13, 17, 18 in the table below) reach boglike deposits beneath Nebraskan drift or at depths that seem undoubtedly to lie beneath the level of Aftonian deposits. Two other wells (numbers 7 and 8) in Franklin township which lie close to wells that undoubtedly reach the base of the Nebraskan drift and which appear to reach the same deposits though at different depths, are included as reaching preglacial deposits. In the other records there is not the degree of certainty that there is in the above twelve, as the depths are not so great. In some of them there appears to be a distinct record of the presence of a weathered clay beneath the water-bearing sand and gravel. Though a pocket of sand within drift might prove a fairly good water-carrier, an abundance of water

[47]C. H. Gordon, "Buried River Channels in Southeastern Iowa," Iowa Geological Survey, Vol. III p. 239, 1893.
Charles R. Keyes, "Geology of Lee County," Iowa Geological Survey, Vol. III, Plate 28, 1893.
J. Ernest Carman, "The Mississippi Valley between Savannah and Davenport," Bull. No. 13, Illinois State Geological Survey, p. 28, 1909.
James H. Lees, "Earth Movements and Drainage Lines in Iowa," Proceedings of the Iowa Academy of Science, Vol. XXI, pp. 176-177, 1914.
[48]John L. Tilton, "The Pleistocene Deposits of Warren County, Iowa," p. 16, 1911.

would indicate that the sands are extensive, and generally either preglacial or Aftonian. Because of the depth at which abundant sands were encountered it is thought best to list these wells also with those that reveal the presence of preglacial deposits.

PREGLACIAL BOGS AND OTHER DEPOSITS

No.	Twp.	Section	Data
1	Pymosa	Ne. ¼ of the Se. qr. of section 17.	12 feet of red sand are beneath 177 feet of yellow and blue clay, on yellow clay.
2	Benton	Ne. ¼ of the Sw. qr. of section 9.	Gas comes into water in a well 263 feet deep.
3	Benton	Ne. ¼ of the Nw. qr. of section 26.	18 feet of quicksand are under 174 feet of yellow and blue clay; and rest on yellow clay.
4	Grant	Ne. ¼ of the Ne. qr. of section 5.	Wood said to be "petrified" at depth of 87 feet, in white sand beneath blue clay and above hard rock. Much gas bubbles out, and water seems oily in the winter time. Water rose 50 feet.
5	Grant	Anita, old city well, Nw. ¼ of the Se. qr. of section 21.	"Mineral" water at 180 feet, just below the blue clay. The water may come in part from Dakota sandstone.
6	Washington	Se. ¼ of the Nw. qr. of section 11.	Coarse gravel and sand are under a thick blue clay in a well that is 187 feet deep.
7	Franklin	Se. ¼ of the Nw. qr. of section 23.	12 feet of sand are beneath 155 feet of yellow and blue clay; and on clay.
8	Franklin	Se. ¼ of the Ne. qr. of section 23.	The well stops at 167 feet in water-bearing sand on clay.
9	Franklin	Sw. ¼ of the Sw. qr. of section 24.	There was a strong flow of gas as the operator struck the sandstone at a depth of 175 feet.
10	Franklin	Se. ¼ of the Sw. qr. of section 36. also Ne. ¼ of the Nw. qr. of section 36.	Gas troubled them as they left the blue clay (at 178 feet) and entered what is supposed to be limestone. The water appears oily after standing. The gas puts out the flame of a lantern (carbon dioxide).
11	Lincoln	Se. ¼ of the Sw. qr. of section 3.	Ends in sand beneath 232 feet of blue and yellow clay. The water is hard and stands at 120 feet deep in well.
12	Lincoln	Se. ¼ of the Nw. qr. of section 4.	The well stops in 20 feet of sand below 220 feet of yellow and blue clay.

No.	Twp.	Section	Data
13	Lincoln	Center of section 35.	Quicksand and gas were found.
14	Beargrove	Nw. ¼ of the Nw. qr. of section 11.	12 feet of sand and gravel are beneath 160 feet of yellow and blue clay, and rest on a clay.
15	Union	Se. ¼ of the Ne. qr. of section 9.	Well ends in sand and gravel at a depth of 100 feet.
16	Union	Creek bed, sections 10 and 11.	For two miles the creek bed has springs in it, and there are springs in the low ground.
17	Massena	Sw. ¼ of the Sw. qr. of section 4.	Well 250 feet deep; stopped in something that had oak in it.
18	Massena	Sw. ¼ of the Se. qr. of section 6.	The well ends in sand and gravel beneath 254 feet of yellow and blue clay.
19	Edna	Sw. ¼ of the Nw. qr. of section 21.	14 feet of quicksand are under 114 feet of yellow and blue clay, and rest on yellow clay.

Some of the above wells mark two areas where there are bogs covered by drift. One group is near the southeast corner of Franklin township; the other, in the northeast corner of the county, in an area apparently extending into both Audubon and Adair counties. They also mark areas where shale rather than limestone is beneath the Dakota sandstone, where the latter is present, and the drift (see geological map of the county), thus marking preglacial low ground. Because of this relation it seems very possible that the "clay" recorded in several instances as beneath the water-bearing sand is not bowlder clay but water-soaked shale.

In section 36 of Franklin township a lighted lantern lowered into the covered pit above the well was quickly extinguished, proving that the gas would not burn[49] nor support combustion. From the amount of decomposition that has led to an abundant flow of carbon dioxide in this region (sections 24, 25, 35 and 36, Franklin township) it is evident that here is the site of an ancient bog.

In the northern part of Grant township the two wells where gas was reported and two others in which logs were encountered at or near the level at which gas was found, indicate a consider-

[49]For fear of possible explosion the writer did not consent to this test till he was informed by those present that they had taken a lantern into the pit before that time when at work upon the well.

able distribution of such conditions. Apparently a bog extends into Audubon county on the north and into Adair county on the east.

In northern Union township also there are conditions that can be satisfactorily explained only by the presence of deposits similar to those in the above named regions. Here for two miles (sections 11 and 12) the trench of the creek was well supplied with water from springs in and close to the creek bed during hot weather when all else was dry. That it was not entirely the drift that supplied this water seems evident, for the owner of one of the springs said he had pushed a twelve-foot pole down into one of the springs without reaching the bottom of the mud. This spring is but two miles southwest of the well where the gas was tested, and at the same level as the beds that supplied the gas.

Southwest of Massena for a distance of six miles there are numerous springs of water that make the West Nodaway an unfailing stream, the water coming from sand and Dakota sandstone at the base of the drift.

Preglacial Relief.—The highest hills of Dakota sandstone that have been noted are fifty feet below the level of the upland, and the lowest preglacial deposit found is in a well 254 feet deep. This gives a maximum preglacial relief of 204 feet. It may have been somewhat greater because of Aftonian erosion of exposed hills.

CENOZOIC GROUP. QUATERNARY SYSTEM.

Pleistocene Series

General.—The bowlder clay, or drift, is composed of a mixture of clay, sand and gravel with pebbles and bowlders in it here and there that were left in a confused mass by continental glaciers of former times. Material of this character may be seen in many of the ravines in all parts of the county, particularly in such parts as have been gullied in time of rain. The material of the drift stands in marked contrast with the stratified limestone, shale and sandstone above which it lies. While it varies greatly in its composition from place to place, in some places containing lenses of sand, in others being almost free from sand and pebbles, and in still others being full of pebbles and of clay cemented with iron oxide, it may generally be recognized as simply an intimate mixture of clay and many kinds of pebbles. To this there is one important exception. Where the drift has undergone long continued weathering[50] without disturbance of residue, the product is called a gumbotil.[51] The planes of gumbotils are marked horizons, indicating the upland portion of the particular drift considered (Nebraskan or Kansan for Cass county).

The average thickness of Pleistocene deposits beneath the upland as found in 108 wells that reach through these deposits is 150 feet. The separate records vary from 30 feet in Grant and Edna townships to 250 feet in Grant and Massena townships and one of 254 feet in Massena township, and are very variable throughout the county. The averages by townships vary from 111 feet in Cass township, to 195 feet in Massena township.

In Iowa as a whole there are materials representing five distinct glacial stages, separated by evidences of four interglacial stages. The relation of these is expressed in the following table, in which the oldest is at the bottom:

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

Of the glacial stages but two are represented in Cass county: the Nebraskan and the Kansan. Of the interglacial stages but two can be distinctly recognized: the Aftonian and the Yarmouth. Deposits of the other stages are found elsewhere in the state. In Cass county the various post-Yarmouth changes are

[50]George F. Kay, "Some Features of the Kansan Drift in Southern Iowa," Bulletin Geological Society of America, Vol. 27, pp. 115-117.
[51]George F. Kay, "Gumbotil, a New Term in Pleistocene Geology," Science, New Series, Vol. 44, 1916. See also Iowa Geological Survey, Vol. XXVI, p. 217.

marked by valley cutting and filling, affording a means of correlation of events here with events in the central and eastern parts of the state, and also in other parts of the country.

NEBRASKAN STAGE

The first ice sheet that is recognized is the Nebraskan,[52] which, gradually accumulating and pushing southward, brought to the confines of the county its load of mingled soil, clay, sand, gravel and bowlders from the north, mixed with local material gathered from nearer at hand. After the melting of the ice the surface material that was left behind was subjected to long-continued chemical change without marked disturbance of material, so that a gumbotil was developed. Since this long-continued weathering, changing the surface deposits of a glacial drift into a gumbotil, occurred in Aftonian time, the gumbotil is considered an Aftonian product of weathering, and is not classified as Nebraskan drift.[53]

The general body of the Nebraskan drift is well exposed along the east and west road a mile south of Atlantic (south of section 8, Grove township). Here beneath the Nebraskan gumbotil the blue Nebraskan drift contains pebbles of red quartzite, greenstone, light granite and quartz, such as are found in the Kansan drift, except that no dark decomposed granites were seen, and at this point the yellowish, oxidized upper portion was absent. The Kansan drift is here present above the Nebraskan gumbotil, but the Kansan gumbotil has been eroded away.

Well Records.—All of the wells listed as presenting evidence of the presence of preglacial deposits also contain evidence of Nebraskan drift below the level of the Aftonian stage. To that list may be added two other records that reveal the presence of this deep-lying drift without evidence as to the character of the preglacial deposits, though the inference is certain that the wells derive water either from preglacial deposits or from the Dakota sandstone beneath the drift.

[52]B. Shimek, Aftonian Sands and Gravels in Western Iowa," Geological Society of America, Vol. 20, 1909, p. 408.
[53]W. C. Alden and M. M. Leighton, "The Iowan Drift, a Review of the Evidences of the Iowan Stage of Glaciation," Iowa Geological Survey, Vol. XXVI, p. 57, 1915.

No.	Twp.	Section	Data
20	Grant	Se. 1/4 of the Ne. qr. of section 2.	Went through a "stump" far down in a well 252 feet deep.
21	Washington	Ne. 1/4 of the Ne. qr. of section 7.	50 to 60 feet of sand and gravel lie between two blue clays in a well that is 210 feet deep.

Thickness of Nebraskan Drift.—The Nebraskan drift extends from about ninety feet below the upland, just beneath the Nebraskan gumbotil, to twenty-five feet, or a little more, below the river beds, a maximum for the county of about 176 feet. Six of the wells that reach the bottom of it give thicknesses varying from 120 to 173 feet, with an average of 148 feet. The minimum thickness is zero, where the hills of Dakota sandstone reach above the Nebraskan gumbotil plane, and where, especially along the river and larger creeks, erosion has proceeded to such an extent as to remove the Nebraskan drift. Because of the irregular preglacial surface, and also because of post-Kansan erosion, the present thickness of the Nebraskan drift differs greatly from point to point.

With a maximum thickness of 176 feet the drift would not completely obliterate a preglacial relief of 204 feet and control the early Aftonian topography. The difference between the two, twenty-eight feet, would mark here and there depressions in the early Aftonian surface, to guide the early drainage in a general way along preglacial lines, or mark swamplike depressions (kettles).

AFTONIAN STAGE

After the disappearance of the Nebraskan ice sheet the upper part of the drift left by the ice was subject to weathering and later to erosion till the advance of the Kansan ice sheet. The interval of time is known as the Aftonian interglacial age. In this time the upper part of the Nebraskan drift lost its small pebbles by solution, and the large ones were reduced till there were left only small smooth ones of the more resistant rock, such as quartz, chert and greenstone. During the same time the clayey portion of the drift was weathered to a gray to drab colored tenaceous clay called gumbotil.[54] This gumbotil is now exposed here and there as a result of later erosion.

In the present stage of erosion the Aftonian upland surface of Nebraskan gumbotil can be seen along the roads well down the hillsides of large ravines where there are freshly cut ditches, revealing the horizontal dark band of gumbotil in contrast with the bowlder-bearing drift above and below. It outcrops by the roadside between sections 25 and 26 of Brighton township, along the southern boundary of sections 2, 3, 4 and 7 of Pymosa township, the east sides of sections 7, 18 and 25 and the south side of 23, Benton township, the east side of sections 29, 32 and 33 and the south of 19, the center of 28 and the north center of 29, Grant township. In the next tier it is seen in abundance in the northwest part of Washington township in sections 5, 6, 7, 8, 17, 18 and 19. In Grove township it was detected in sections 8 and 17, and sections 25 and 26. In Franklin it appears in the northern part of section 10. In Cass township it is seen in the southeast quarter of section 7. In Union township it is exposed along the west and north sides of section 24; in Pleasant township along the north side of section 36; and in Victoria in the southeast quarter of section 6. These are by no means all the places, but they are sufficient to reveal the distribution. Exposures are, of course, wanting where the road is above the level of the gumbotil and where loess and washed material is banked in upon it, and the character of the material is doubtful in places not here included, where the road is at the level of washed material from the hillsides. It is only where the cut is deep enough to reveal the horizon of soil-like material that exposures are clear. In some of the places where it was not found it may have been removed in erosion during the Aftonian interglacial interval.

In the southern part of the county the level of the Nebraskan gumbotil is approximately 80 feet below the common level of the upland. Immediately south of Atlantic it is 58 feet below a low upland, and is here at 1,234 feet above sea level. At Cumberland it is at 1,228 feet above sea level, and at Bridge-

[54]See the previous general discussion of the Pleistocene Series. A further discussion of gumbotil is presented under the Yarmouth Stage. The Nebraskan gumbotil, here discussed, was first recognized by Professor George F. Kay, State Geologist, and traced across a considerable portion of the state.

water it is at 1,218 feet above sea level. In the county as a whole it is at approximately 1,220 feet above sea level. It appears to be higher in the northwestern part of the county than in the southeastern part.[55]

In wells that reached deposits of sand or muck with an abundance of water the deposits are definitely preglacial, or so closely related to that horizon that variations in depth seem dependent on variations in level of the preglacial surface. There are two wells[56] in which quantities of sand were found at about the horizon of the Aftonian stage, but these deposits are local. There are elsewhere extensive bodies of sand, but they are found to be post-Yarmouth in age, and are described under that heading. No sections of Aftonian bogs have been recognized where the surface of the Nebraskan drift and gumbotil are exposed.

For the Aftonian surface, then, we are left in this county with evidence only of the horizon of the Nebraskan gumbotil. The measurements from the general level of the upland mark this as a plane gently sloping to the southeast, but the conditions of measurement are not such as to record in this county such undulations and valleys as may have existed in the Aftonian surface. No evidence of the presence of former kames and gravel ridges associated with the Nebraskan gumbotil has been detected. All such features seem to have disappeared in the weathering to which the surface of the Nebraskan drift has been subjected.

For comparison it may be noted that two miles west of Murray, Clarke county, there is an extensive Aftonian bog. The Nebraskan gumbotil is at a level of sixty feet below the level of the upland, the top of the bog deposits ninety feet, and the bottom of the bog about one hundred eighteen feet. This gives a final Aftonian relief of thirty feet, and a valley filling of twenty-eight feet, a total of fifty-eight feet. There are no beds of limestone or sandstone that rise above the level of the gumbotil plain.

At Indianola, Warren county, the gumbotil plain, as seen in a valley northwest of the city, is forty-four feet below the top of the Simpson College well, in which, at a depth of one hundred twelve feet, a foot of water-bearing gravel and pebbles rests on limestone and lies beneath twenty-five feet of Aftonian

[55] This seems to correlate with the general uplift to the northwest, as described by G. K. Gilbert for the area of the Great Lakes.

[56] Washington township, Ne. qr. of the Ne. qr. of section 7: 50-60 feet of sand lie between two blue clays, deep in a well that is 210 feet deep. Franklin township, Se. qr. of the Ne. qr. of section 36: There is a gravel at 70 feet with large volume of water. It is beneath yellow and blue clay.

muck. Here the well is at or near the deepest portion of the Aftonian valley. This gives a final local Aftonian relief of forty-three feet, and a valley filling of twenty-five feet, a total of sixty-eight feet, under conditions that mark an erosional valley rather than a constructional depression.

KANSAN STAGE

Following the Aftonian age[57] there came again an age in which an ice sheet advanced not only over the county but also over the whole of the continent to the north and pushed its way far to the southward into northern Missouri and into Kansas. On melting, the ice left over the Aftonian topography which it had concealed, a deposit of mingled clay, gravel, pebbles and bowlders, known as the Kansan drift, completely mantling the Aftonian topography.

The upper portion of the deposit for more than twenty feet above the typical drift has been so altered by subsequent chemical action, which converted it into the Kansan gumbotil, that this portion will be classed under the Yarmouth stage, and there considered, just as the Nebraskan gumbotil was considered under the Aftonian stage.

The Kansan drift sheet is the conspicuous one to be seen all through the upper portion of the hilly parts of the county. It is this drift which, from thirty to eighty feet below the upland, contains the numerous pebbles and bowlders of all sizes up to three feet in diameter, and of such variety as to attract attention by the exceedingly miscellaneous character of the assemblage. There are granites of many kinds, including especially a dark granite so decomposed by long continued weathering that it crumbles in the hand. Other granites, especially the light colored ones, are of a more resistant character. With these are various quartzites, among which those of a reddish color are most noticeable. Other very resistant rocks are of a dark greenish color and are known as greenstones of various kinds, generally diorites. With these are pebbles of quartz, chert and schist of various kinds, material from distant sources mingled with fragments of shale and sandstone of more local

[57]Age is the time equivalent of stage.

origin, all scattered heterogeneously through a mixture of clay, sand and gravel, everything that an ice sheet could scrape up as it moved over hills and valleys.

The upper, oxidized portion of the typical drift is stained yellowish red. Where this has been subjected to erosion other than weathering the finer material is washed away leaving an accumulation of the more resistant gravel, pebbles and bowlders, such as may be seen along ravines where stream action is vigorous in time of rain. Beneath the filling of the large valleys there are undoubtedly such bowlders and pebbles from both the Kansan and Nebraskan drifts as were too large for transportation by water when the valleys were excavated; but since their excavation the deposition of sediment has concealed the bowlders that are left.

Beneath the zone where weathering has been marked the Kansan drift is progressively darker in color, till deep beneath the surface it is deep blue in color, generally with sand, gravel and bowlders scattered through it, though the mixture is far from uniform. In places it is dense and dark, almost free from grit; in other places it is less dense, and of a more sandy texture.

The largest bowlders noted along the hillsides are chiefly of granite and of red quartzite, of the following dimensions:

7 granites:
- 3 ft. in diameter.
- 2 ft. x 1 ft. x 2 ft.
- 20 in. x 15 in. x 15 in.
- 2 ft. 8 in. in diameter.
- 1 ft. 6 in. in diameter.
- 1 ft. 6 in. in diameter.
- 1 ft. in diameter.

3 red quartzites:
- 3 ft. x 3 ft. x ½ ft.
- 1 ft. 6 in. in diameter.
- 1 ft. in diameter.

1 greenstone:
- 1 ft. in diameter.

Of these but one, the greenstone, had striations (scratches due to glacial action) still preserved, though polished surfaces and subangular shapes were present.

The following pebble count was made east of Lewis about fifty feet below the upland (southwest quarter of the southeast quarter of section 12, Cass township):

Red quartzite	8	Hornblende schist	1
White quartzite	2	Dark argillaceous rock	1
Quartz	13	Sandstone, dark	1
Quartz schist	1	Sandstone, gray (native)	14
Decomposed granite	7	Chert, dark	1
Coarse, light colored granite	7	Chert, gray	8
Dark granite	4	Chert, white	1
Greenstone	27		—
Mica schist	4	Total	100

Thickness of the Kansan Drift.—The typical Kansan drift lies between forty feet below the upland, just below the Kansan gumbotil, and the level of the Nebraskan gumbotil, which is about eighty feet below the upland. In such relation the Kansan drift has a thickness of forty feet. It is wanting along all the rivers and large creeks, and along all the smaller ones wherever they have cut down into the Nebraskan gumbotil and drift.

THE YARMOUTH STAGE

It has long been recognized that the surface of the Kansan drift presented a series of flat topped divides[58] reaching across southern Iowa from near the Mississippi on the east to the Missouri river on the west. The trend of these divides changes with the direction of stream erosion across the state, so that in the eastern half the divides appear more like a series of steps, while in the western part the divides slope more uniformly toward the west. They clearly mark a dissected Kansan plain; but why should that extent of glacial plain present no evidence of kames, kettles, drumlins and gravel ridges, such as are to be found in younger ground moraines, even within a few miles to the north within our own state? Such features were sought in vain. The uniformly fine material through the upland was loess in the east near the Mississippi river and in the west near the Missouri river. It was also loess in places in the center, and was likened unto loess in other portions. A careful examination of this upland "gumbo", as it was called, revealed that in the divides it was a part of the Kansan drift[59] into which it graded. Even if composed of surface material from the Kan-

[58]See physiographic descriptions in volumes IV to VIII, Iowa Geological Survey, chiefly by H. F. Bain; also p. 448 of Vol. VI.
[59]John L. Tilton, "A New Section South from Des Moines, Iowa," Science, Vol. 38, July 25, 1913, p. 133-135.

san ice sheet, why did it not contain bowlders such as are found in the oxidized drift so commonly seen by the roadside? This absence of bowlders presented a difficulty that led to emphasis upon the superglacial material that a glacier might carry; and the various washed sands and gravel along valleys seemed related to the drainage lines formed immediately on the melting of the Kansan ice sheet.[60] Still there was no explanation for the complete absence of bowlders from the surface. It was at this stage that Professor Kay took up the problem and interpreted the small pebbles found here and there in this deposit as the remnants of former bowlders, the remainder of them having been dissolved away in the course of a long lapse of time in which the surface of the drift was converted into a "gumbotil".[61] To further test this conclusion a series of analyses of this gumbotil from the surface downward was undertaken by Professor J. N. Pearce,[62] with results revealing clearly that the soluble portions, the lime and potash, were dissolved from the upper portion of the drift, to be redeposited lower down. The amount of insoluble material, such as aluminum oxide, is greater in the gumbotil than in the underlying drift. Clearly in the course of a long lapse of time even such quartzite, greenstone and granite bowlders as were in this drift before it was converted into a gumbotil have been dissolved away.

There are places in which bowlders are more abundant than in other places, but no knolls of bowlders have been located rising above the level of the upland. In the eastern and western portions of the state such knolls could easily be concealed by beds of loess; but along the divides, away from streams in south-central Iowa, regions free from accumulations of loess, no such topographic features are known to exist. The lime in the bowlder clay as it was dissolved out, and the lime and potash from the weathering of the feldspar and mica in the granite, furnished the very alkali material necessary to dissolve the silica, even of quartzite bowlders. A portion of the undissolved silica is still to be found in portions of the gumbotil.

[60] It was for these various deposits that the name Dallas Deposit was suggested before the significance of the weathering of the drift had been worked out. John L. Tilton, Proceedings of the Iowa Academy of Science, Vol. XX, p. 218.

[61] George F. Kay, "Some Features of the Kansan Drift in Southern Iowa," Bulletin of the Geological Society of America, Vol. 27, pp. 115-117; also "Gumbotil, a New Term in Pleistocene Geology," Science, New Series, Vol. 44, 1916.

[62] The analyses are soon to be published.

This explanation of the conversion of the surface deposits of a bowlder clay into a gumbotil emphasizes the length of time required in the Yarmouth stage for the gumbotil to develop before the advance of the next ice sheet, the Illinoian, for the Kansan gumbotil plane is traced eastward beneath the Illinoian drift, and northward beneath the Iowan and the Wisconsin drift sheets. While the gumbotil is chiefly the result of weathering of drift, the change to a gumbotil is the important feature that needs emphasis; consequently this deposit is classified as Yarmouth in age.[63]

In Cass county this Kansan gumbotil may be seen in cuts along the edge of the upland, and the gradation may be noted from the surface soil, through the subsurface soil and subsoil to the more distinct drift below, where slumping and creeping have not obscured the gradation, and where loess has not covered the surface. Its lower limit is approximately thirty feet below the level of the upland, down to which level it is a common feature. Low uplands along valleys have been eroded below the horizon of the Kansan gumbotil.

POST-YARMOUTH STAGES

After the surface of the Kansan drift had been converted into a gumbotil stream action was hastened by uplift till valleys were finally cut beneath both the Kansan and Nebraskan gumbotils to a depth even a little greater than the present level of the streams (about twenty feet), and an erosional topography was well developed with broad flood plains and gently sloping valley sides. On this surface there are four classes of deposits that claim attention: the sand beneath the river beds, the sand beneath the loess, the loess itself, and the alluvium.

The Sand Beneath the River Beds.—As the drift sheets were eroded the clay was transported away by the rivers, but a part of the sand and gravel, mingled with other sand from eroded Dakota sandstone, was worked along the stream channels and is now beneath the river beds. Sand which was dredged from the river near Griswold was largely of rounded quartz grains, ap-

[63]As previously stated the explanation of the Kansan gumbotil was applied to the surface of the Nebraskan drift, leading to the discovery of the Nebraskan gumbotil plane.

parently derived from Dakota sandstone. Above this is another sand of a fine yellowish character, that is related to the sand found beneath the loess.

The valley filling thus consists of three parts: the lower sand, the fine yellowish sand, and the alluvium.

The Sand Beneath the Loess.—Near Atlantic there is a sheet of yellowish sand of considerable extent. It is well exposed in the southwestern part of section 28, Pymosa township, in the bluffs along Troublesome creek. Here, five feet above the creek bed and just above Nebraskan bowlder clay, rise bluffs of horizontally stratified sand twelve feet high, brown in general color, gray in places, containing pebbles of light colored quartz, red and gray chert and red quartzite. Wells to the north, northwest and northeast in neighboring sections appear to reach this same sand. In section 33 (northeast quarter of the northeast quarter), Pymosa township, yellow sand appears in abundance by the roadside. Across the valley of Troublesome creek to the south and just east of the Fair Grounds the Rock Island Railroad Company has an extensive excavation for ballast (southeast quarter of the southeast quarter of section 4, Grove township). These beds of sand lying exposed in a northwest-southeast direction seem to have been connected formerly, though now separated by the valley of Troublesome creek, and to lie in a valley eroded in Nebraskan drift. They are at a somewhat higher level than the river sand at the city pumping station, and are covered with loess.

In section 10, Grove township (northeast quarter of the northwest quarter), close to the west gate of the Atlantic cemetery, about three feet of a light yellowish sand may be seen in the ditch by the roadside. Though somewhat higher than the sand near the railroad, the base of this bed lies at about the level of the topmost layers at the pit. Here also the top of the sand is covered by loess. On the opposite side of the city (northeast quarter of the northeast quarter of section 7) lies a similar deposit of sand, at the same level and beneath the loess. Between these two points wells in the city reach a similar bed of sand. In the ravines immediately south of the city Kansan drift appears in the hillsides without sand either above or below it. It is thus not between the two drifts, that is, it is not Aftonian, but extends down over the sides of two drifts, and is most abundant in shallow valleys carved in the Nebraskan drift, at too low a level for the Aftonian horizon.

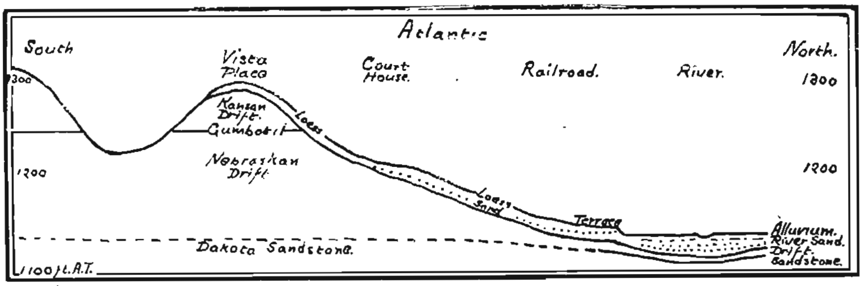

FIG. 32.—Interpretation of relations found at Atlantic, Cass county.

This sand is not river sand, even if it is continuous with that deposit. It appears to have been blown from early river flats out on the side of the post-Yarmouth valleys, and washed into the drainage lines of the region.

The Loess.—Loess is a wind deposit of fine dustlike material High winds blowing over local hills and river flats and over dry plains farther west sweep into the air from soil of all kinds clouds of dust that settles chiefly along the valleys and on the edge of the upland. In general character the deposits are clayey, though rendered porous by an abundance of minute flakes of quartz whose partly rounded chipped edges and points are evidence of wear as it was blown along. The material contains considerable lime and iron, so that later when it is deposited in beds the upper portions weather further into a light yellowish porous deposit free from lime, while the material two or three feet beneath the surface is less weathered and has a reddish cast due to a larger proportion of the oxide of iron. In deep portions the loess has a grayish tinge of color, where there is considerable lime and where the iron is not oxidized. In many localities the loess is free from shells and especially is this true of the weathered loess, where the shells have been dissolved out. But in some places it contains an abundance of minute and delicate shells[64] generally like those of animals that still live near by and feed in sheltered places upon vegetation at the roots of grasses and weeds. Often there are found lime concretions which are composed of lime brought in solution from elsewhere, generally in the loess of this region from higher up in the loess.

Loess is most in evidence in the west half of the county. The southwesterly winds that for ages have blown up the valleys of Nishnabotna river and Indian creek have left deposits at many places where deposition has been favored and erosion prevented. At the railroad station at Marne is the most typical bed to be found in the county. The part that is exposed is twenty-seven

FIG. 33.—The bed of loess near the railroad station at Marne, Cass county.

feet thick, laminated, fossiliferous, and bearing concretions. It possesses the mealy character, the vertical cleavage, and the porosity common to loess found in the bluffs along Missouri river. The upper eight or ten feet is of a brown color; that in the lower, unoxidized portion is of a gray color.

A mile west of Marne the upper eight feet of the railroad cut consists of brownish weathered loess, which is here free from lamination and from lime concretions and shells. So, too, in

[64]For a discussion of loess fossils see B. Shimek, "The Significance of Pleistocene Mollusks," Science, N. S. Vol. 37, April 4, 1913, pp. 501-509; "Alluvial Fossils and Modern Drifted Shells," Supplement to the address of the chairman of section E, Geology, American Association for the Advancement of Science, Cleveland, Ohio, 1912; "Geology of Harrison and Monona Counties," Iowa Geological Survey, Vol. XX, 1909, pp. 395-8.

the cut between Indian creek and the west county line, the uppermost portions are composed of loess, which is now mostly grassed over. A mile and a half east of Marne, at the highest point in the divide, a gray loess is found for six feet below the grass. It is free from lamination, from fossils and from concretions, and is sandy. On lower ground north and west the sides of a gully are distinctly not loess.

At Atlantic the pit ten feet deep for the base of the soldiers' monument was dug in loess that showed lamination up to four feet from the soil. It here contains no fossils and no concretions. The excavation for the basement of the new high school building is in loess of the same character. At Vista Place loess caps the upland; only toward the bottom of excavations for the roadway does the weathered Kansan drift with a few pebbles appear. At the clay pit west of town the deposit is a loess, though very clayey and free from fossils and concretions. The lamination noted seemed due to slumping. So, too, at Lewis the clay pit is in a gray loess banked in on the west side of the valley and rising ten feet above the second bottom. This loess is noted along the western slope of the Nishnabotna, and along the highest ground to the east, as in section 24 of Cass township (southeast quarter of the southeast quarter) and section 26 (southwest quarter of the southwest quarter); in section 6 of Beargrove township (northwest quarter of the northwest quarter), section 7 (southeast quarter of the southeast quarter) and section 27 (southeast quarter of the southeast quarter); section 11 of Pleasant township (southwest quarter of the southwest quarter) and section 13 (northwest quarter of the northwest quarter); section 18 of Noble township (northeast quarter of the northwest quarter) and section 27 (southeast quarter of the southwest quarter). On the other hand it is not recognized as a distinct loess deposit on the highest ground in the northwestern part of Pymosa township, nor in the various cuts from Atlantic along the railroad to the east county line, nor in the divides in the eastern half of the county.

In general the loess is banked in on the east side of the valleys of Indian creek and of the Nishnabotna as far as Atlantic, and against the highest ground half way across the county, especially the highest ground facing the west and southwest. From Atlantic northward along the river valley the west side of the valley is favored with loess because of the turn in the valley by which the west side is brought into the line of air movement of the prevailing southwesterly winds up the valley. The same is true along the northern side of Turkey creek in the lower part of its course; but in the northeastern part of the county the eastern side of the valley is more favored by deposition. Loess is abundant south and southwest of Adair. Along the west branch of the Nodaway and its tributaries the deposition of loess is not so pronounced.

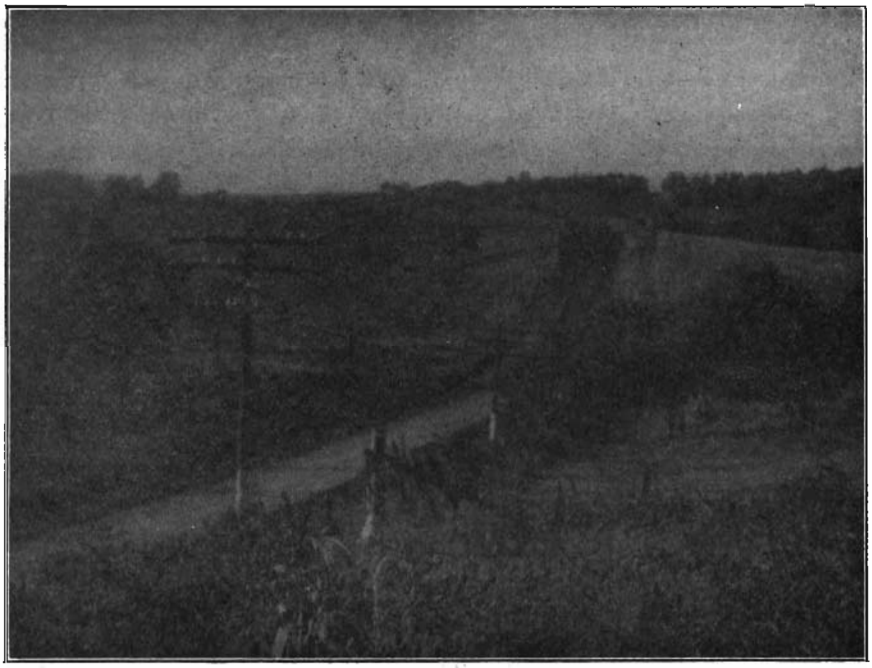

FIG. 34.—Where the loessial topography ends and the erosional topography in the upland begins. View southeast from Vista Place, Atlantic, Cass county.

Along ravines everywhere, except where they emerge near low ground close to the Nishnabotna, loess has been eroded away if it was ever deposited.

It is possible that on the high ground to the east of Troublesome creek and to the southeast of Turkey creek there are beds concealed in favored places, and that loess forms an inconspicuous portion of the soil. As traced from one divide to another east from the creeks the loessial characteristics became less distinct, and in the place of loess was noted a deposit of indefinite character that may result from gumbotil or from a thin loesslike deposit, the two forming black soils that are much alike.

From Atlantic southwest along the east side of the Nishnabotna the loess seen was completely leached of its lime through the action of ground water. This, with the loss of silica and iron carried away in solution, would account for the especially clayey character where the action of ground water has been pronounced.

The Alluvium.—A considerable area of bottom land along Nishnabotna river and Indian, Troublesome and Turkey creeks, has been frequently inundated by high water. The deposit laid down in time of flood is a fine dark colored laminated clayey silt. There are numerous oxbows along these streams, and places that are scoured by concentrated flow at high water. In such places the water stands for considerable time after the floods are over, till in the course of years they are gradually filled by a dark, fine clay of uniform composition.

The Terrace.—The terrace is composed in places of Nebraskan drift left uneroded and in places of a dense dark deposit washed in at a former time when the river flowed at a higher level than at present. Loess is found also in places on the terrace, and also in places banked in against it as previously described.

Sequence of Post-Yarmouth Events.—From the beginning of the uplift that hastened the erosion of valleys in the Kansan and Nebraskan drifts till they reached a depth of twenty feet below the present level of the streams, until the present time there is in Cass county no distinctly separate effect traceable to the existence of Illinoian, Iowan and Wisconsin drift sheets, nor to the presence of Sangamon and Peorian interglacial intervals, and no separate effect traceable to changes in elevation[65] either

[65]C. H. Gordon, Buried River Channels in Southeastern Iowa; Iowa Geological Survey, Vol. III, p. 239, 1893.
Charles R. Keyes, Geology of Lee County; Iowa Geological Survey, Vol. III, Plates 27 and 28, 1893.
J. A. Udden, Geology of Muscatine County; Iowa Geological Survey, Vol. IX, Plate 7, p. 332, 1899.
W. H. Norton, Geology of Scott County; Iowa Geological Survey, Vol. IX, pp. 413-418, 1899.
Frank Leverett, The Illinois Glacial Lobe; Monograph XXXVIII, U. S. G. S., Chap. 12, 1899.
J. Ernest Carman, The Mississippi Valley between Savanna and Davenport; Illinois Geological Survey, Bull. 13, pp. 57-78, 1909.
James H. Lees, Earth Movements and Drainage Lines in Iowa; Proceedings of the Iowa Academy of Science, Vol. XXI, for 1914, especially pages 177-179.

to the north or to the south of Cass county. All such effects are lost as minor details in the general trend of events, all merged into one long-continued time of erosion. It is to a time preceding the silting up of the valleys, perhaps to the early part of it, that it seems necessary to refer the deposition of sand blown out over the low ground of Nebraskan drift, and, following this, the beginning of the deposition of a considerable body of loess out over the sand. A portion of the loess is undoubtedly related to thick beds of loess in central and eastern parts of the state, which beds are found to be Peorian in age. Deposition of loess in some places and erosion of it in other places is judged to have continued with varying rapidity even up to the present time. On the melting of the Wisconsin ice sheet there was an immediate and pronounced effect, traceable in the terrace.

The terrace along the Nishnabotna and the Nodaway, and along streams of southwestern Iowa, is continuous with the terrace along Missouri river, which in turn is traced to the same causes that produced the terrace deposits along Mississippi, Des Moines and Middle rivers:[66] namely, the flooding of the valleys on the melting of the Wisconsin ice sheet, and the partial filling of the valleys with sediment. The great volume of water that sought an outlet southward through Missouri river into the Mississippi and thence to the gulf is well attested by the river gravels, terraces and deltas through which the present streams of comparatively insignificant size have since cut their trenches.[67] The backwater thus produced in the tributaries led to the silting up of their channels, such as those in Cass county, to the level of the present terrace.

In Cass county the drainage has a peculiar relation to drainage from the Wisconsin ice, and affords a chance to test the conclusion above stated. Neither the west branch of Nodaway river nor any of its tributaries, which drain the southeastern half of the county, rises near the area of the Wisconsin drift, drainage now, and probably formerly, being cut off on the northeast by Raccoon, North and Middle rivers with their tributaries. Conditions are different for the East Nishnabotna which flows

[66]John L. Tilton, The Age of the Terrace South of Des Moines, Iowa; Proceedings of the Iowa Academy of Science, Vol. XXII, for 1915, pp. 233-236.

[67]The various folios of the Geologic Atlas of the U. S. Geological Survey covering parts of eastern North and South Dakota are very significant in this regard.

through the western part of the county. This stream rises not far from the margin of the Wisconsin drift. Though Brushy Fork in Carroll county now cuts off from this river the drainage from the area of the Wisconsin drift, the Nishnabotna may formerly have secured part of its sediment from the outwash area southwest of the Wisconsin drift. While the silting up of the Nishnabotna channel would lead to silting up along Indian creek, it would not lead to the silting up found in the Nodaway valley. To accomplish this Missouri river itself must be affected. It thus appears that a common cause was operative affecting this whole region.

After the melting of the ice the streams diminished in volume to their present size, and assumed the new task imposed upon them of removing the clay, silt and sand that clogged their courses and of establishing a new grade below the former terrace level. Whether this renewal of erosive stream action was due in part to a slight uplift, or wholly to a lessening of the load carried by streams, is not clear from data here obtainable. The task is now accomplished to such an extent that we find the streams flowing on gradients fairly well established; but the difficulty of accomplishing the task is still evident in the presence of numerous bayous and the marshy ground along the rivers, and in the cutting as well as filling that has resulted in the present flood plain eight feet below the level of the old flood plain. Parts of the old flood plain are now left as a terrace through which the water from the various ravines in the upland has trenched its way. Ridges from the terrace now reach out into this bottom land in places, while along the eastern side of Nishnabotna loess is still banked against the terrace.

Recent natural changes are insignificant in comparison with those above described. The most pronounced is the renewal of erosion along the edge of the upland, less marked here than farther east, which is traceable to effects of cultivation of the soil, and particularly to the destruction of the old blue-stem prairie grass with its long roots.[68] Along ravines deposits are forming in some places and disappearing in others, under the changing influences of the hand of man. Along the river bottoms

[68]John L. Tilton, Pleistocene Deposits of Warren County, Iowa, pp. 39-40.

the streams occasionally cut horizontally, and in time of flood scour and fill. They have reached their grade, and show no present effects of changing elevation. The wind sweeps the dust up the valleys, adding an increment to the loess beds that during the year is inappreciable, though in the course of many years it is considerable. The chief factor now influencing change is Man.

ECONOMIC GEOLOGY

Soils

The distribution of the Pleistocene deposits just described is the key to the character of the soil.

Loess.—On the upland bordering the east side of the river valleys (chiefly the west side north of Atlantic and along Turkey creek as previously stated) and down the western slope of the upland, is the yellow loess, thin in the upland, and thicker on gentle hill slopes, with little distinction between soil and subsoil, but with the upper two feet darkened by humus that has been forming for ages. This soil is naturally well drained because of its porosity, while this property, due to the loose arrangement (structure) of the fine quartz and clay, also permits water to rise by capillarity from below to the roots of the plants. It is only when stirred while there is water on it that the clayey portion settles forming an impervious stratum over the bottom of the pool. Such land is the richest corn land in Iowa. This loess soil is the Marshall silt loam of the government classification of soils.

Along the western edges of the upland lies the Kansan gumbotil beneath the loess, and close enough to form a subsoil where the loess is thin. The leaching of ages has removed the lime formerly a part of it, and has removed other portions, not only the more readily soluble portions of a bowlder clay but even much of the silica from decaying pebbles and bowlders that may formerly have been present, leaving the remainder more clayey than before. Concealed beneath the loess it cannot readily dry out and thus serves as somewhat of a reservoir of moisture and also as a base to the more porous loess above. The slight change in the character of the subsoil from loess to gumbotil is not sufficient to affect the character of the soil.

Loess is found also in beds at lower levels, especially in the terrace east of the Nishnabotna. Here it is the same class of soil as in the upland, but the surface of the loess lies nearer the general level of the water table.

Gumbotil.—Along the upland where the loess is thin, especially along the upper slopes on the western sides of the valleys, the Kansan gumbotil forms a soil much like that formed by the loess, but with a subsoil more clayey than loess. The change in color from a light yellowish to a yellowish red is due to the increase of iron from the surface down into the deeper portions of the subsoil; with this change there is an increase in lime and potash. In classification this soil has been included in the southern Iowa Loess.[69] By the United States Bureau of Soils it is called the Putnam silt loam[70] and at times the Shelby silt loam. It is also called the Marshall silt loam.[71] Mr. Coffee in discussing this soil recognizes its clayey character as not like that of a true loess.

When the gumbotil is charged with humus it makes a rich porous soil second only to that of loess, but the gradation downward into a distinct weathered bowlder clay reveals its true relation. The clay beneath serves as an imperfect water carrier to retain moisture for the plants above, and serves also as a reservoir of mineral matter that can by capillarity reach the plants above in solution. The treatment of this rich soil of gumbotil is readily mastered. The roads composed of it must be dragged while the gumbotil is drying, and corn planted in it must be cultivated after the soil is too dry to stick and not dry enough to cake. By cultivation rapid evaporation of moisture is prevented, while capillarity still brings up to the roots the moisture needed.

The Nebraskan gumbotil, which is found about eighty feet below the upland, is the same kind of soil material as the Kansan gumbotil, and deserves to be classed with it.

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[69]W. H. Stevenson, "The Principal Soil Areas of Iowa," Bull. 82, p. 378, 1911, Agricultural Experiment Station, Soils Section, Ames, Iowa.

[70]George Nelson Coffee, "A Study of the Soils of the United States," Bureau of Soils, Bull. No. 85, p. 51, 1913.

[71]Jay A. Bonsteel, "Important American Soils," Yearbook of the Department of Agriculture, 1911, p. 225. In "Soil Survey of Pottawattamie County, Iowa," U. S. Bureau of Soils, 1916, pp. 15-16, Marshall silt loam is said to be derived from Missouri loess, but seems to include the gumbotil, for which there is no special designation.

Drift Soil.—In places along the hillsides the bowlder bearing portion of the drift lies close to the surface, the pebbles in places showing in the thin soil along the slopes. This type of soil in Cass county is not so abundant as it is farther east in south-central Iowa where there is no loess. Where these patches of soil are so inconspicuous as not to interfere with cultivation the soil may still be considered a Putnam silt loam, though thin. Where the surface is too rugged for cultivation, and the soil now as before the advent of the white man is given over to timber, this light colored timbered soil is classed in the Miami series of soils.

Colluvial Soil.—from loess, gumbotil and drift. Along the bases of gentle slopes in ravines a thick soil has gradually accumulated due to the creep of soil from the hillsides as the material alternately froze and thawed, and was alternately water soaked and dry. At times surface erosion supplied material that rain washed down the slope. All such deposits along the valleys and ravines are classed as colluvial deposits. Inasmuch as they partake of the general character of material in the upland, and are equally well drained, they also are classed as Putnam silt loam where the gumbotil is the chief source, and as colluvial Marshall silt loam where loess is the chief constituent. This deposit is to be distinguished from the beds of loess that are banked against the eastern valley sides along Nishnabotna river and Indian and Turkey creeks, which are of true loess undisturbed.

Alluvial Soil.—The terrace along the rivers is in places more sandy than the colluvial deposits, and in places more clayey, consisting of material brought down by the river when it flowed at this higher level, mingled with material washed from slopes nearer at hand. The terrace is high enough now to be well drained. Thus drained and aerated the material forms a soil that seems a continuation of the colluvial soil. It is recognized as an alluvial silt loam from dark colored prairie soils. The terrace generally has water bearing sand fifteen to twenty feet beneath its surface, giving an ever present supply of moisture near at hand. This soil is to be distinguished from loess banked in against it.

Near the stream the flood plain receives, especially in the spring time, the present alluvial deposits of the stream. These form a slightly higher deposit close to the stream where the coarsest deposits are laid down, building up the natural levee. Back from the natural levee the low ground has favored the formation of swamp soils, especially in bayous, or old stream channels. Even this swamp soil becomes good soil for cultivation when properly drained. The straightening of the courses of Indian creek and of the Nishnabotna and the use of lateral ditches and tiling here and there to drain low places, is not only preventing floods but also opening to cultivation thousands of acres that prior to the drainage of these low places were unfit for cultivation.

Old soils from weathered Dakota sandstone and from Missouri limestone and shale are so concealed by the drift that they do not deserve consideration in this connection. It is only occasionally that over a few square feet their products are a considerable constituent in the soil.

CROPS.

In the past twenty-seven years corn[72] has averaged 32.3 bushels per acre, the amount per year varying with the character of the season. The maximum of 38 bushels per acre was obtained in 1916. Wheat has averaged 15.8 bushels per acre, the variations between spring and fall wheat in a measure off-setting each other, the maximum reaching 23 bushels per acre. Oats has averaged 27.7 bushels per acre with a maximum of 47 bushels. Barley has averaged 25.4 bushels with a maximum of 34. Potatoes have averaged 75.6 bushels, with a maximum of 177 bushels. Rye has averaged 21.3 bushels in the past fourteen years, with a maximum of 45 bushels. Tame and wild hay together have averaged 1.5 tons per acre. In the past few years alfalfa has been grown with an average of 3.5 to 4 tons per acre.

There is no record of the amount of yield of the different types of soil. With a continuation and an extension of the modern careful selection of seed corn and care in the selection of other grain for seed the average yield will undoubtedly increase. This average will be still further increased by the tiling of wet

[72]From the Annual Reports of the Iowa Weather and Crop Service.

places and by the drainage of the bottom land, thus saving the acreage in places that in other years has been too wet to mature a crop. The chief factors determining the yield are variation in precipitation combined with duration of high temperature, which in a measure operate together, the highest temperature occurring when precipitation is least. Already the farmers not only seek to maintain a good average yield by planting fields that give their best yields under different conditions, one when the season is wet and another when the season is dry, but they study the most suitable methods for cultivation under the different conditions. Even with this care the effects of drought with long periods of intense heat cannot be fully offset. Fortunately, however, such instances as the drought of 1894 and of 1910 are extremely rare, and the high temperature of 1901 is unusual. In 1901 potatoes and corn were the only crops affected noticeably. Generally, and almost without exception, the precipitation occurs in sufficient abundance during the growing months to meet the needs of the crops.

Meteorology

The location of Cass county upon the western side of the "Missouri divide" places it in Section 52 of the Weather

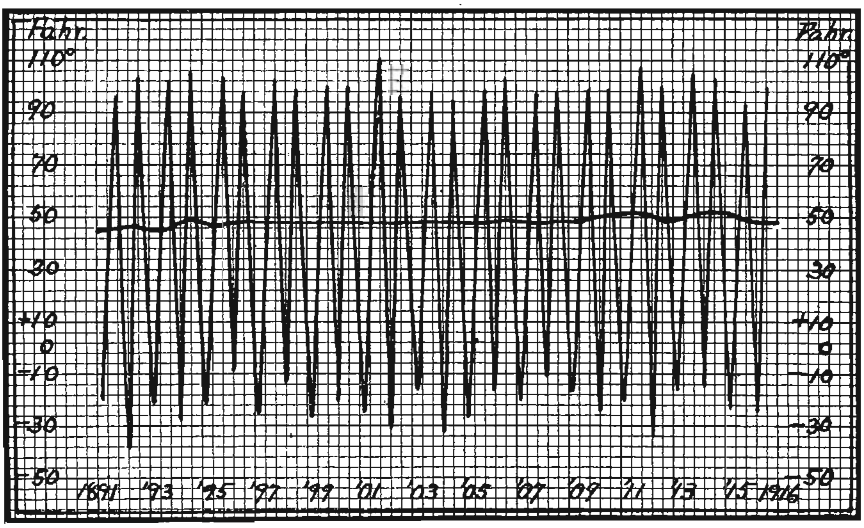


FIG. 35.—Diagram of maximum, minimum and mean temperatures for Atlantic, Cass county, 1891 to 1916.

Bureau, United States Department of Agriculture; it is also classed in the "Southern Division" in the reports of the State of Iowa. From the records of J. W. Love and of T. H. Whitney of Atlantic, which cover the years since 1890, the mean annual temperature is found to be 48.3° Fahr., ranging from an average maximum of 99.8° for these years to an average minimum of minus 12.2° for the same length of time. The variations are best given in the form of a diagram.

The mean annual precipitation is 31.87 inches, distributed by months as follows:

January	.90 inches	July	3.82 inches
February	1.14 inches	August	3.53 inches
March	1.63 inches	September	3.67 inches
April	2.91 inches	October	2.55 inches
May	4.41 inches	November	1.21 inches
June	4.99 inches	December	1.18 inches

In sixteen years the direction of the wind has averaged Nw. 5, Sw. 6, S. 4, Se. 1. In the same number of years there has been an average of ninety days per year with one one-hundredth of an inch or more of precipitation. In character the days have averaged as follows per year: clear, 109; partly cloudy, 108; cloudy, 148.

RECORD OF PRECIPITATION[73] IN INCHES AT ATLANTIC, IOWA.

ALTITUDE 1164 FEET ABOVE SEA LEVEL.

Year	Jan.	Feb.	March.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1891	1.48	1.66	1.61	2.16	6.68	8.78	6.16	1.72	1.94	3.35	.77	1.88	38.19
1892	.45	.66	2.01	3.88	8.08	1.07	5.52	2.38	.79	1.27	.12	1.70	27.93
1893	.28	1.22	1.58	2.68	3.64	7.56	2.58	3.12	2.58	.36	.77	1.95	26.03
1894	.95	1.15	1.43	1.52	1.18	3.95	1.23	.56	3.99	3.78	.20	.97	20.91
1895	.10	.47	.44	5.16	1.20	5.06	.92	7.69	4.59	.30	1.52	.66	28.11
1896	.56	.39	2.05	3.59	6.52	7.89	7.14	3.07	3.23	4.26	1.54	1.23	41.47
1897	.88	.63	3.67	6.80	2.68	3.76	2.39	2.68	2.31	2.11	•T	1.50	29.41
1898	1.48	1.10	2.02	2.42	4.61	8.74	2.60	.63	2.72	2.11	1.05	.58	30.06
1899	----	.65	1.24	1.69	6.08	5.70	4.71	4.66	.56	3.66	.72	1.58	31.25
1900	.40	1.30	2.04	2.33	2.35	2.09	8.20	4.81	3.68	5.15	.30	1.24	33.89
1901	.78	1.70	3.02	2.85	2.48	6.70	1.44	1.13	3.71	2.80	.72	.60	27.93
1902	1.70	.59	2.08	1.37	4.48	6.89	9.36	4.75	4.44	2.51	2.68	2.66	43.51
1903	----	2.10	1.11	2.26	12.37	3.34	3.68	9.10	2.01	2.12	1.24	.25	39.58
1904	1.36	.19	2.23	4.35	4.20	3.84	5.47	3.80	3.06	1.40	.08	1.05	31.03
1905	1.55	2.10	.50	3.72	3.03	5.59	2.38	4.54	9.23	4.79	2.54	.10	40.03

[73]The meteorological records at Atlantic were kept by Mr. J. W. Love till November, 1908, and by Mr. T. H. Whitney since November, 1908.

RECORD OF PRECIPITATION. (Continued)

Year	Jan.	Feb.	March	April	Map	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1906	.80	.99	1.97	4.34	2.65	5.87	3.91	2.53	6.53	1.15	1.53	1.30	33.57
1907	.10	.98	.77	.94	2.19	5.13	5.93	2.56	3.00	1.77	.88	.26	24.51
1908	.22	1.60	.85	.93	8.80	7.22	2.23	3.57	.73	3.96	.29	.46	30.86
1909	1.90	1.40	.97	3.63	3.43	9.08	6.00	.44	6.03	2.90	8.66	1.94	46.58
1910	1.17	.28	----	.30	3.37	2.71	.82	11.22	2.95	1.15	.39	.16	24.52
1911	.35	2.69	.86	3.40	4.32	.31	.89	3.95	2.14	1.85	.53	3.40	24.69
1912	.52	1.74	2.61	3.59	.72	3.38	1.82	2.88	6.05	4.38	.40	.36	28.45
1913	.89	.69	3.35	3.29	6.82	3.10	.49	1.49	3.75	1.78	1.28	1.53	28.46
1914	.86	.78	2.17	4.84	1.28	6.60	1.20	2.71	6.49	4.46	.16	1.40	32.95
1915	2.13	2.15	1.29	1.53	8.27	3.01	9.58	3.88	3.65	1.49	1.54	1.02	39.54
1916	2.54	.53	.47	2.22	3.20	2.51	2.65	1.81	5.31	1.43	1.61	.96	25.24
Means	.90	1.14	1.63	2.91	4.41	4.99	3.82	3.53	3.67	2.55	1.21	1.18	31.87

RECORD OF PRECIPITATION[74] IN INCHES AT CUMBERLAND, IOWA.

ALTITUDE 1223 FEET ABOVE SEA LEVEL.

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1900	.10	.73	2.12	1.91	2.78	1.89	4.33	3.59	4.63	4.40	.20	.30	26.98
1901	.40	1.50	1.55	2.22	2.33	5.14	1.39	.71	2.87	2.46	1.24	.80	22.61
1902	1.10	.21	4.33	.51	2.26	6.06	8.99	5.36	5.46	3.23	1.37	1.80	40.68
1903	T	1.00	1.10	1.65	8.27	2.96	6.69	9.32	1.70	2.15	.78	.20	35.82
1904	2.10	.10	3.20	4.10	3.42	3.71	4.71	3.25	2.03	1.32	----	1.20	29.14
1905	1.00	2.25	.90	3.52	4.94	5.81	4.02	3.73	8.22	2.85	2.31	.04	39.59
1906	1.40	.50	2.62	2.40	1.73	5.67	3.17	1.86	3.33	1.10	1.32	2.00	27.10
1907	.73	1.11	.38	1.24	2.46	6.28	10.76	1.87	3.38	2.81	1.42	1.37	33.81
1908	.80	1.80	2.31	.77	12.00	8.28	4.42	6.19	1.52	4.14	.76	.08	43.07
1909	2.12	.85	1.10	5.36	3.59	6.92	4.73	.50	4.14	4.70	3.36	1.80	39.17
1910	.90	.60	----	.20	2.73	1.39	2.50	7.10	5.00	1.56	1.03	.20	23.21
1911	.40	2.64	.35	3.65	2.86	.27	.63	3.93	3.65	.77	.51	3.45	23.06
1912	.35	1.70	2.50	3.15	1.29	3.54	1.57	3.61	4.94	2.90	.42	.13	26.10
1913	.90	.70	1.97	2.10	7.61	4.12	.11	2.25	4.71	6.27	.87	1.71	33.32
1914	.61	.70	2.28	3.11	1.10	3.56	1.10	2.50	5.07	2.51	----	.80	23.34
1915	.76	1.45	.40	1.98	8.44	4.26	7.70	2.58	3.28	.89	.62	.11	32.47
1916	1.27	.60	----	2.04	3.18	2.58	1.41	1.71	2.47	.97	2.13	.91	19.57
Means	.88	1.08	1.69	2.35	4.18	4.26	4.01	3.53	3.91	2.65	1.08	.99	30.53

From these tables the precipitation during the growing months is found to be as follows:

[74]The meteorological records at Cumberland have been kept by Mr. J. H. Reppert.

	ATLANTIC INCHES	CUMBERLAND INCHES
May	4.41	4.18
June	4.99	4.26
July	3.82	4.01
August	3.53	3.53
September	3.67	3.91
	20.42	19.89

The dates of the last killing frost in the spring and the first killing frost in the fall are as follows, for Atlantic:

	LAST KILLING FROST IN SPRING.	FIRST KLLING FROST IN FALL
1904	April 28	September 14
1905	May 26	October 11
1906	May 28	September 27
1907	May 27	September 25
1908	May 9	September 28
1909	May 10	October 11
1910	May 4	September 27
1911	May 2	October 21
1912	May 17	September 26
1913	April 28	September 22
1914	April 20	October 15
1915	May 9	October 5
1916	May 18	September 15

The earliest date of the last freezing temperature in the spring is April 20 (1914), and the latest date is May 28 (1906). The earliest date of freezing temperature in the fall is September 14 (1904); the latest date is October 15 (1914).

Native Flora and Fauna

Here as elsewhere in southwestern Iowa the native timber is confined to ravines and river valleys, where the ground is protected from the intense rays of the summer sun and the dry southwest winds. The groves that now beautify the homes on the uplands and add comfort there are all planted by man. Here the soft maple, because of its rapid growth, is a favorite for groves, while the red and white elms, the box elder, sometimes the cottonwood, and occasionally the spruce, are used for ornament and individual shade. The native grasses are largely replaced by blue grass, timothy and clover on the upland, but on the low ground a wild hay is harvested in about the same quantities as the tame hay. In out-of-the-way places, along the shady hillsides and along roadways may still be seen the native flora; but it is undergoing a rapid change because of cultivation of the soil. This fact is emphasized in the appended list of some of the plants of Cass county. As the boggy ground along the larger streams is now drained the habitat of the cattail flag, water leaf and arrow leaf is also restricted in area.

The large forms of the wild fauna that frequented these valleys before the advent of the white man are now completely gone, except the pair of deer protected in the wilds of a small park of native plants preserved for years through the foresight and love of nature of Mr. F. C. Pellett and Mr. T. H. Whitney. Of the smaller forms the fox squirrel still peers through the branches, and the ground squirrel scurries to his hole. Amid the trees and brush the catbird, thrasher, oreole, wren, song sparrow, robin and bluebird contribute their abundant labor to the welfare of man and add the beauty of their song. The ever-present crow rivals the noisy blue jay and pugnaceous English sparrow for supremacy in the feathered tribe. The busy flicker, red headed and downy woodpeckers search for their hidden prey, the barn swallow, martin and chimney swift flit about, while in the quiet shades by the river the kingfisher and heron patiently wait their chance. The quail, protected by the game laws, is the last of the important game birds of the early days, excepting those that in migration pause on their way north or south.

SOME OF THE COMMON PLANTS OF CASS COUNTY, IOWA.[75]

For the following list of plants I am almost entirely indebted to Miss Besse S. Tilton, teacher of science at the Atlantic High School, 1913 to 1917, and to Mr. Frank C. Pellett of Atlantic, a

[75]In the various proceedings of the Iowa Academy of Science may be found many papers on the fauna and flora of Iowa. Those which wholly or in part relate to the plants or animals of southwestern Iowa are as follows, in the order of their publication:

Vol. I, Part 2, 1890-91. L. H. Pammel, "Report of the Committee on State Flora," pp. 88-92. Herbert Osborn, "Catalogue of the Hemiptera of Iowa," pp. 120-131.

Vol. II, 1894. H. F. Wickham, "Coleoptera of Iowa," pp. 45-51.

Vol. III, 1895. L. H. Pammel, "Notes on the Flora of Western Iowa," pp. 106-135.

Vol. V, 1897. T. J. and M. F. L. Fitzpatrick, "Flora of Southern Iowa," pp. 134-173.

Vol. VI, 1898. T. E. Savage, "A Preliminary List of the Mosses of Iowa," pp. 154-164. T. J. and M. F. L. Fitzpatrick, "The Flora of Southern Iowa, Part 2," pp. 173-202.

Vol. VIII, 1900. James E. Gow, "Preliminary List of the Flowering Plants of Adair County," pp. 152-159. L. H. Pammel, "The Thistles of Iowa," pp. 214-239.

naturalist whose writings are widely known throughout the middle West. To his long familiarity with the local flora is due the valuable comment stating plants that are now less abundant than formerly in this region.

Acer dasycarpum Ehrh.	Soft maple. Common in groves.
Aesculus hippocastanum Linn.	Common horse chestnut or Buckeye. Rare.
Agrostis vulgaris Thurb.	Redtop.
Aletris farinosa Linn.	Star Grass.
Allium tricoccum Ait.	Wild Leek. Common in woods along streams.
Allium cernuum Roth.	Wild Onion. Common in open woods near water.
Alopecurus pratensis Linn.	Meadow Foxtail.
Amaranthus	Pigweed. There are several species.
Amaranthus albus Linn.	Tumbleweed.

T. J. and M. F. L. Fitzpatrick, "Betulaceae of Iowa," pp. 169-176; "The Fagaceae of Iowa," pp. 177-196.

Vol. IX, 1901. L. H. Pammel, "Preliminary Notes on the Flora of Western Iowa Especially from the Physiographical and Ecological Standpoint," pp. 152-180. H. H. Hume, "Ustilaginae of Iowa," pp. 226-240.

Vol. X, 1902. T. J. and M. F. L. Fitzpatrick, "The Scrophulariaceæ of Iowa," pp. 136-176.

Vol. XII, 1904. Fred J. Seaver, "An Annotated List of Iowa Discomycetes," pp. 105-120.

Vol. XIII, 1906. Charles E. Bessey, "The Forest Trees of Eastern Nebraska," pp. 75-87.

Vol. XIV 1907. J. P. Anderson, "Iowa Erysiphaceae," pp. 15-46. Robert E. Buchanan, "Notes on the Algae of Iowa," pp. 47-84. L. H. Pammel and Estelle D. Fogel, "A Catalogue of the Poisonous Plants of Iowa," pp. 147-172.

Vol. XVII, 1910. B. Shimek, "Prairie Openings in the Forest," pp. 16-19. L. H. Pammel, "The Problem of Weeds in the West," pp. 34-46. A. G. Ruthven, "Contributions to the Herpetology of Iowa," pp. 198-210. T. Van Hyning and Frank C. Pellett, "Annotated Catalogue of the Recent Mammals of Iowa," pp. 211-218.

Vol. XVIII, 1911. M. P. Somes "Notes on Some Iowa Reptiles," pp. 149-159.

Vol. XIX, 1912. T. H. Macbride, "Twenty-five Years of Botany in Iowa," pp. 43-63. Harriette S. Kellogg, "Native Dye-plants and Tan-plants of Iowa, with notes on a few other species," pp. 113-128. A. G. Ruthven, "Contribution to the Herpetology of Iowa," p. 207. S. B. Fracker, "A Systematic Outline of the Ruduviidae of North America," pp. 217-247.

Vol. XX, 1913. Frank C. Pellett, "Food Habits of the Skunk," pp. 307-309.

Vol. XXI, 1914. D. H. Boot, "Comparison of Field and Forest Flora in Monona County, Iowa, pp. 53-58.

Vol. XXII, 1915. L. H. Pammel, G. B. McDonald and H. B. Clark, "The Native and Cultivated Forest Trees and Shrubs of the Missouri River Basin," pp. 23-56.

Vol. XXIII, 1916. E. L. Palmer, "A Seed Key to Some Common Weeds and Plants," pp. 335-394.

Vol. XXIV, 1917. Lloyd Wells, "Odonata of Iowa," pp. 327-333. Dayton Stoner, "Notes on Some Iowa Rodents," pp. 353-356.

Of the Iowa Geological Survey there is one report of special interest to this part of the state: B. Shimek, "Geology of Harrison and Monona Counties," Vol XX, pp. 426-483.

L. H. Pammel and others, "Grasses of Iowa," Bull. No. 1, 1901; and Part 2, 1903. L. H. Pammel and others, "The Weed Flora of Iowa," Bull. No. 4, 1913. Dayton Stoner, "The Rodents of Iowa," Bull. No. 5, 1915. B. H. Bailey, "Raptorial Birds of Iowa," Bull. No. 6, 1918.

The interesting and valuable writings of Frank C. Pellett of Atlantic assume a new attraction to the people of Cass County since Mr. Pellett is a resident of Cass County. "Our Back Door Neighbors" deserves special mention.

Ambrosia artemisiaefolia Linn.	Ragweed.
Amorpha fruticosa Linn.	False Indigo. Occasional, usually in moist places, occasional on higher ground.
Ampelopsis quinquefolia Michx.	Woodbine; Virginia Creeper. Extremely common climber.
Anemonella thalictroides Spach.	Rue Anemone.
Aquilegia canadensis Linn.	Wild Columbine. Once common; disappearing.
Anemone virginiana Linn.	Anemone. Disappearing.
Arisema triphyllum Torr.	Indian Turnip; Jack in the Pulpit. Common in woods.
Asarum canadense Linn.	Wild Ginger. Extremely common in moist woods.
Asclepias purpurascens Linn.	Common.
Asclepias syriaca Linn.	Common.
Aster sagittifolius Willd.	Aster. Common.
Salicifolius Alt.	Willow Aster. Common.
Astragalus caryocarpus Ker.	Milk Vetch. Common on roadsides.
Baptisia tinctoria R. Br.	Wild Indigo.
Belamcantha chinensis Adans.	Blackberry Lily. Occasional; escaped.
Brassica	Two or three species.
Capsella bursa-pastoris Moench.	Shepherd's purse. Common.
Cassia chamaecrista Linn.	Partridge Pea. Common along sandy roadsides.
Castilleia coccinea Spreng.	Painted Cup.
Caulophyllum thalictroides Michx.	Blue Cohosh. Common in woods.
Celastrus scandens Linn.	Bittersweet. Common climbing vine in woods.
Celtis occidentalis Linn.	Hackberry. Common in high ground .
Cephalanthus occidentalis Linn.	Buttonbush. Occasional on wet land.
Claytonia virginica Linn.	Spring Beauty. Common spring flower in open woods.
Clematis virginiana Linn.	Virgin's Bower. Common.
Clemetis viorna Linn.	Leather Flower; Small Flowered Clematis. Common.
Cnicus lanceolatus Hoffm.	Bull Thistle.
Convolvulus arvensis Linn.	Bindweed.
Cornus stolonifera Michx.	Red Osier Dogwood. Common.
Corydalis	Corydalis.
Corylus americana Walt.	Hazelnut. Common in woodland borders.
Crataegus coccinea Linn.	Scarlet Haw. Common in woodland borders.
Datura stramonium Linn.	Jimson Weed. Common.
Delphinium tricorne Michx.	Larkspur. Disappearing.
Dentaria laciniata Muhl.	Toothwort. Occasional in woods.
Dicentra cucullaria DC.	Dutchman's Breeches. Once very common in woods.
Echinospermum virginicum Lehm.	Beggar's Lice. Common in woods.
Erythronium americanum Ker.	Adder's Tongue. Once extremely common in woods.

Eupatorium perfoliatum Linn.	Boneset. Common.
Euphorbia cyparissias Linn.	Graveyard Moss.
Feniculum	
Fragaria virginiana Duchesne.	Wild Strawberry. Common.
Geranium maculatum Linn.	Wild Geranium; Cranesbill. Occasional in open woods.
Hicoria ovata Britt.	Shell Bark Hickory. Common in some places, entirely absent in other woods but a few miles distant.
Hicoria glabra Britt.	Pignut Hickory. Common.
Humulus lupulus Linn.	Hop. Common along fences along roadsides and gardens.
Hypoxis erecta Linn.	Star Grass.
Hydrophyllum virginicum Linn.	Waterleaf. Common in open woods.
Impatiens pallida Nutt.	Touch-me-not. Common in moist woods.
Ipomoea hederacea Jacq.	Morning-glory.
Juglans nigra Linn.	Black Walnut. One of the most common native trees.
Lactuca canadensis Linn.	Wild Lettuce.
Lepidium	Peppergrass.
Lillium philadelphicum Linn.	Wood Lily. Occasional in open woods, but disappearing.
Lithospermum hirtum Lehm.	Hairy Puccoon.
Lonicera	Honeysuckle.
Malva	Mallow.
Menispermum canadense Linn.	Moonseed. Common climbing vine.
Melilotus alba Lam.	Sweet Clover.
Mirabilis	Four-o'clock.
Monarda fistulosa Linn.	Wild Bergamot. Common along roadsides and pastures.
Morus rubra Linn.	Red Mulberry. Occasional in native woods.
Negundo aceroides Moench.	Box Elder. Common.
Nepeta cataria Linn.	Catmint.
Oxalis violacea Linn.	Woodsorrel. Common.
Oxalis stricta Sav.	Woodsorrel. Common.
Panicum capillare Linn.	Tumble Grass.
Pastinaca sativa Linn.	Parsnip.
Phlox maculatum Linn.	Sweet William. Very common woodland flower.
Phlox pilosa Linn.	Downy Phlox.
Phlox glaberima Linn.	
Plantago major Linn.	Plantain.
Poa pratensis Linn.	Blue Grass.
Podophylum peltatum Linn.	May Apple. Formerly common; disappearing.
Polygonum	Knotweed. Numerous species of smartweed, heartsease, lady's thumb, etc.
Polygonatum biflorum Ell.	Solomon's Seal. Very common in open woods. Disappearing.

Populus deltoides Marsh.	Cottonwood. Common along streams.
Potentilla canadensis Linn.	Five-finger. Common.
Prunus americana Marsh.	Wild Plum. Common in thickets along streams.
Prunus virginiana Linn.	Choke Cherry. Common.
Prunus serotina Ehrh.	Wild Black Cherry. Common.
Quercus rubra Linn.	Red Oak. A common native tree.
Quercus macrocarpa Michx.	Bur Oak. Common. Only two oaks are common in Pymosa township.
Ranunculus abortivus Linn.	Buttercup.
Ranunculus fascicularis Muhl.	Buttercup.
Rhus glabra Linn.	Smooth Sumac. Common.
Rhus toxicodendron Linn.	Poison Ivy. Common.
Ribes	Wild Gooseberry.
Robinia pseudacacia Linn.	Black Locust. Common.
Rosa setigera Michx.	Wild Rose.
Rubus occidentalis Linn.	Black Raspberry. Common in open woods.
Rudbeckia hirta Linn.	Blackeyed Susan. Common.
Rumex	Sorrel.
Sagittaria variabilis Engelm.	Arrowhead. Common in marshy ground.
Salix	Willow. Common. Several species.
Sambucus canadensis Linn,	Common Elder.
Sanguinaria canadensis Linn.	Bloodroot.
Sanicula marilandica Linn.	Black Snakeroot.
Scrophularia marylandica Gray.	Figwort; Simpson Honey Plant. Common.
Silene stellata Ait.	Starry Campion. Disappearing from woodland.
Silphium perfoliatum Linn.	Cup Plant. Common.
Silphium laciniatum Linn.	Compass Plant. Common.
Smilacina racemosa Desf.	False Solomon's Seal. Common in open woods.
Smilax ecirrhata Watson.	Smilax. Native.
Smilax rotundifolia Linn.	Greenbriar. Common in woods.
Solidago	Golden-rod. Several species. Common.
Staphylea trifolia Linn.	Bladder Nut. Formerly common.
Stellaria media Smith.	Chickweed.
Symphoricarpus vulgare Michx.	Coral Berry; Indian Currant. Common.
Taraxacum officinale Weber.	Dandelion.
Teucrium canadense Linn.	Wood Sage; Germander. Common in open woods.
Thalictrium	Meadow Rue.
Tilia americana Linn.	Basswood; Linden. Common tree.
Tradescantia virginica Linn.	Spiderwort. Common on moist ground.
Trifolium pratense Linn.	Red Clover.
Trifolium repens Linn.	White Clover.
Trifolium agrarium Linn.	Yellow Clover.
Trillium nivale Riddell.	Dwarf White Trillium; Wake Robin. Getting rare.
Triosteum perfoliatum Linn.	Horse Gentian. Common in woods.

Typha latifolia Linn.	Cat-tail Flag.
Ulmus americana Linn.	White Elm. Very common.
Ulmus fulva Michx.	Slippery Elm. Common.
Verbascum thapsus Linn.	Mullein.
Verbena urticæfolia Linn.	White Vervain. Common.
Verbena stricta Vent.	Hoary Vervain. Common.
Vernonia	Ironweed.
Vibernum prunifolium Linn.	Black Haw. Disappearing.
Viola canadensis Linn.	Blue Violet. Common.
Viola pedata Linn.	Birdfoot Violet.
Viola pubescens Ait.	Yellow Violet. Common in woods.
Vitis cordifolia Michx.	Frost Grape.
Xanthoxylum americanum Mill.	Prickly Ash. Common shrub.

SOME OF THE BIRDS OF CASS COUNTY, IOWA.

For this list of birds I am indebted to Miss Besse S. Tilton, teacher of science at the Atlantic High School, 1913 to 1917, and to Mr. Frank C. Pellett[76] of Atlantic.

NO.
201 Butorides virescens virescens (Linn). Little Green Heron.
289 Colinus virginianus virginianus (Linn.). Bob-white.
316 Zenaidura macroura carolinensis (Linn.). Mourning Dove.
331 Circus hudsonius (Linn.). Marsh Hawk.
337 Buteo borealis borealis (Gmel.). Red-tailed Hawk.
339 Buteo lineatus lineatus (Gmel.). Red-shouldered Hawk.
360 Falco sparverius sparverius (Linn.). Sparrow Hawk.
373 Otus asio asio (Linn.). Screech Owl.
387 Coccyzus americanus americanus (Linn.). Yellow-billed Cuckoo.
388 Coccyzus erythrophthalmus (Wils.). Black-billed Cuckoo.
390 Ceryle alcyon (Linn.). Kingfisher.
394c Dryobates pubescens medianus (Swains). Downy Woodpecker.
406 Melanerpes erythrocephalus (Linn.). Red-headed Woodpecker.
412 Colaptes auratus auratus (Linn.). Flicker.
417 Antrostomus vociferus vociferus (Wils.). Whip-poor-will. Formerly common, now rare.
423 Chaetura pelagica (Linn.). Chimney Swift.
428 Archilochus colubris (Linn.). Ruby-throated Hummingbird.
444 Tyrannus tyrannus (Linn.). Kingbird.
456 Sayornis phoebe (Lath.). Phoebe. (Very rare, formerly abundant).
461 Myiochanes virens (Linn.). Wood Pewee.
477 Cyanocitta cristata cristata (Linn.). Blue Jay.
488 Corvus brachyrhynchos brachyrhynchos (Brahm). Crow.
495 Molothrus ater ater (Bodd.). Cowbird.
498 Agelaius phoeniceus phoeniceus (Linn.). Red-winged Blackbird.
501 Sturnella magna magna (Linn.). Meadowlark.
506 Icterus spurius (Linn.). Orchard Oriole.
507 Icterus galbula (Linn.). Baltimore Oriole.
511b Quiscalus quiscula aeneus (Ridgw.). Bronzed Grackle.
Passer domesticus domesticus (Linn.). English Sparrow.
529 Astragalinus tristis tristis (Linn.). Goldfinch.
552 Chondestes grammacus grammacus (Say). Lark Sparrow.

[76]My attention has recently been called to the list published by Mr. Pellett in Bird Lore, Vol. 15, No. 5 (1913), pp. 305-307.

560 Spizella passerina passerina (Bech.). Chipping Sparrow.
563 Spizella pusilla pusilla (Wils.). Field Sparrow.
567 Junco hyemalis hyemalis (Linn.). Slate-colored Junco.
581 Melospiza melodia melodia (Wils.). Song Sparrow.
587 Pipilo erythrophthalmus erythrophthalmus (Linn.). Tohee.
593 Cardinalis cardinalis cardinalis (Linn.). Cardinal.
595 Zamelodia ludoviciana (Linn.). Rose-breasted Grosbeak.
598 Passerina cyanea (Linn.). Indigo Bunting.
604 Spiza americana (Gmel.). Dickcissel.
608 Piranga erythromelas (Vieill.). Scarlet Tanager.
611 Progne subis subis (Linn.). Purple Martin.
613 Hirundo erythrogaster (Bodd.). Barn Swallow.
616 Riparia riparia (Linn.). Bank Swallow.
622 Lanius ludovicianus ludovicianus (Linn.). Loggerhead Shrike.
631 Vireo griseus griseus (Bodd.). White-eyed Vireo.
652 Dendroica aestiva aestiva (Gmel.). Yellow Warbler.
681 Geothlypsis trichas trichas (Linn.). Maryland Yellow-throat.
687 Setophaga rusticilla (Linn.). Redstart.
704 Dumetella carolinensis (Linn.). Catbird.
705 Toxostoma rufrum (Linn.). Brown Thrasher.
721 Troglodytes aedon aedon (Vieill.). House Wren.
727 Sitta carolinensis carolinensis (Lath.). White-breasted Nuthatch.
735 Penthestes atricapillus atricapillus (Linn.). Chickadee.
755 Hylocichla mustelina (Gmel.). Wood Thrush.
761 Planesticus migratorius migratorius (Linn). Robin.
766 Sialia sialis sialis (Linn.). Bluebird.

Water for Farm Use

Along the river valleys sand points placed at a depth of forty feet reach an abundance of water in the sands beneath the river beds. Apparently this water is free from ammonia, but it should be given a sanitary analysis to prove that it is suitable for domestic use. The only analyses available are those of the Central Iowa Poultry and Eggs Company of Atlantic, whose wells apparently penetrate this sand. The analyses of this water prove that at this point it is of a most excellent quality. The analyses are as follows, obtained through the courtesy of Mr. P. A. Casey, the Manager, and of the "Bureau of Animal Husbandry," Washington, under whose direction the analyses were made.

SAMPLE COLLECTED MAY 2, 1916.

CHEMICAL EXAMINATION	PARTS PER MILLION	COLONIES PER CC. ON AGAR.
Total Solids	794	
Chlorine	52	
Nitrogen as albumenoid ammonia	trace	
Nitrogen as free ammonia	none	5
Nitrogen as nitrites	trace	
Nitrogen as nitrates	26.0	

BACTERIOLOGICAL EXAMINATION

Colon not present in 10 cc. portions.

SAMPLE COLLECTED MAY 18, 1916.

CHEMICAL EXAMINATION	PARTS PER MILLION	COLONIES PER CC. ON AGAR.
Total Solids	820	
Chlorine	52	
Nitrogen as albumenoid ammonia	none	
Nitrogen as free ammonia	0.10	16
Nitrogen as nitrites	trace	
Nitrogen as nitrates	22.0	

BACTERIOLOGICAL EXAMINATION
Colon not present in 10 cc. portions.

In the western part of the county wells on the upland and hillsides which pass through the loess into the Kansan drift reach water that is excellent in quality and is sufficient in abundance for all times except those of drought. Commonly, however, wells in the upland are drilled down into the Dakota sandstone, where there is always an abundance of water, generally of an excellent quality, at a depth of 117 to 170 feet beneath the upland. In the next two ranges of townships to the east there are in the upland many wells that penetrate the Dakota sandstone and loose sand that is described as quicksand. In the east range of townships there are also wells averaging 189 feet in Grant and 248 feet in Lincoln township; but in Massena and Victoria townships the inhabitants do not at present choose to go beneath the Kansan drift, which is here very thick. In Victoria township the eleven wells of which records were obtained have an average depth of 47 feet, the deepest being 109 feet deep and the shallowest 32 feet. The water in all of these wells is of excellent quality, when the top of the well is properly cared for; and the quantity is said to be ample in the case of those wells situated along the sides of shallow ravines.

There are four areas in which deep wells have supplied carbon dioxide gas or other evidence that the source was in an abundance of decaying vegetation. In section 5 of Grant township (northeast quarter of the northeast quarter) a well 105 feet deep penetrates a deposit that contains wood. Carbon dioxide gas bubbles out in quantity sufficient to extinguish a lamp. The water is soft and at times seems oily. In section 24, Franklin township (southwest quarter of the northwest quarter), a well 184 feet deep, penetrating nine feet of sandstone, gave a strong flow of gas from the sandstone. The nine feet of water obtained is described as hard and as containing iron. In section 25 (southeast quarter of the southwest quarter) a well of about the same depth gave a constant flow of carbon dioxide gas. Across the road south (section 36, northeast quarter of the northwest quarter) a well 178 feet deep which goes through the drift also gives a flow of this same gas. A severe stomach trouble associated with the drinking of water from two of the above wells seems due to the presence of ammonia in abundance from decaying vegetation. While strong men may be able to stand the irritating effect of water charged with ammonia, such wells yielding gas should be condemned as unsafe for drinking purposes for human beings although not for cattle, until on sanitary analysis they are found to be free from ammonia.

There is little to be gained from a tabulated list of records of wells that stop in the Kansan gumbotil or in the Kansan drift. Such wells, thirty feet or so in depth, are to be found everywhere in the upland. Records of deeper wells that reach through the drift have already been given. A few other wells that are especially deep will be described under deep wells and test borings.

DEEP WELLS AND TEST BORINGS.

At Atlantic a prospect hole was drilled in 1888 by the Rust Artesian Well Company of Ithaca, New York, for the Atlantic Coal and Mining Company. The prospect hole is 1,310 feet deep, reaching from 1,150 feet above sea level to 160 feet below sea level. It is located just east of the pumping station and electric light plant, and a few rods north of the railroad track, in section 5 of Grove township (northeast quarter of the southeast quarter). The record of the well, published on pages 1121-1122 of volume XXI, Iowa Geological Survey, by H. E. Simpson and W. H. Norton, is here reproduced in full.

RECORD OF STRATA IN DEEP WELL AT ATLANTIC, IOWA

	THICKNESS FEET	DEPTH FEET
Pleistocene (no sample)	125?	125?
Carboniferous:		
Pennsylvanian (725 feet thick; top, 1,025 feet above sea level.)		
Shale, blue	35	160
Shale, gravelly	35	195
Shale, red and blue, gravelly	5	200
Limestone, gray, sandy	15	215
Shale, red and blue, with soapstone	5	220
Shale, gravelly	5	225
Shale, purple, dark drab and green, fine, unctuous; with pebbles (five limestone, one vitreous sandstone and one coal)	35	260
Shale, gravelly	50	310
Clay, mottled red and blue	30	340
Shale, blue	15	355
Shale, red and blue, with gravel	5	360
Shale, blue, with slate	5	365
Sandstone and shale	50	415
Slate, black; soapstone, blue and green	5	420
Shale, varicolored, green and reddish; fissile, practically noncalcareous	10	430
Sandstone	5	435
Shale	15	450
Shale and limestone	15	465
Shale, varicolored, green and reddish; fissile, practically noncalcareous		
Clay and soapstone	15	480
Sandstone	25	505
Shale, blue	12	517
Shale, dark gray, very finely laminated, somewhat calcareous	23	540
Sandstone, or sandy limestone	10	550
Shale, dark gray	15	565
Shale, dark brown-gray, noncalcareous, arenaceous, pyritiferous	20	585
Sandstone, brown, highly ferruginous	5	590
Sandstone	10	600
Shale, sandy	30	630
Sandstone, very fine	30	660
Shale and slate	15	675
Shale, iron gray, finely laminated, noncalcareous	10	685
Sandstone, white, very fine	10	695
Clay, blue, with gravel	15	710
Shale, sandy	15	725
Sandstone	5	730
Shale, finely arenaceous, ocherous, some black	10	740
Shale, black, carbonaceous	10	750
Shale, blue, and slate	10	760
Shale, yellow, gravelly	40	800
Sandstone, gray, of finest grain, with much black shale; samples at 810 and 815	25	825
Limestone, sandy	5	830
Sandstone, brown	5	835
Sandstone, gray	15	850
Mississippian (420 feet thick; top, 300 feet above sea level)—		
Limestone, white, nonmagnesian; white chert constitutes the bulk of the sample	35	885

	THICKNESS FEET	DEPTH FEET
Limestone, blue-gray, argillaceous; quartzose residue, with large fragments of dark shale; probably from above....	75	960
Limestone, yellow-gray; sample chiefly dark brown flint with some chalcedonic silica; a very little quartz sand...	5	965
Flint, brown-gray, calcareous; some chalcedonic silica; much shale in fragments	10	975
Flint, gray and black chalcedony; drusy quartz; some shale	5	980
Flint, brown, calcareous; some chalcedony; a little shale....	5	985
Flint and chalcedony; 5 samples; drillings largely milk-white translucent chalcedony, with brown calcareous flint and some limestone.	45	1,030
Limestone, nearly white; much white chert; 2 samples....	15	1,045
Chalcedony and flint; drillings remaining after original washing made up of chalcedonic silica and blue-gray and yellow siliceous fragments which effervesce with cold dilute hydrochloric acid, but do not disaggregate; pure limestone practically absent	30	1,075
Shale and flint; shale blue-gray, somewhat calcareous......	5	1,080
Limestone, soft, light yellow-gray; with silica as above, and some fragments of shale; 4 samples...................	40	1,120
Limestone, brown; much white chert......................	5	1,125
Limestone, lighter colored; drillings chiefly chert; only finest sand is limestone and even this is siliceous......	5	1,130
Limestone, light yellow, nearly pure; considerable shale in small fragments	5	1,135
Limestone, as above; much chalcedony and chert..........	5	1,140
Limestone, white, chalky, and light yellow...............	5	1,145
Chert; drillings of chert and chalcedony; at 1,145 feet a few rounded grains of crystalline quartz and particles of fine-grained sandstone; 4 samples, all of which in mass effervesce freely in acid................................	25	1,170
Flint, black, yellow and red flint and jasper, with sand of rounded grains of quartz; fragments of limestone, chert and chalcedony	10	1,180
Limestone, blue-gray, cherty, and argillaceous..............	10	1,190
Chert, white and brown; some shale in sample............	10	1,200
Limestone, cherty, gray in mass.........................	25	1,225
Limestone; siliceous material constitutes one-tenth of sample by weight	20	1,245
Chert and shale, buff; chert effervescent; shale pink, in fine grains, but slightly calcareous	10	1,255
Limestone, highly arenaceous and siliceous; chert and chalcedony; two-fifths of sample by weight insoluble......	5	1,260
Sandstone, highly calciferous; limestone arenaceous; quartz in minute angular particles; white and yellow-gray; 2 samples	10	1,270
Devonian ? (40 feet penetrated; top, 120 feet below sea-level)—		
Shale, fine, light gray, calcareous	15	1,285
Limestone, cream-yellow, rather hard; in angular sand....	25	1,310

There are six other wells in the county or close to it that reach a depth of three hundred feet or more. The meagre information now obtainable concerning them is as follows:

LOCATION	LOG IN FEET	REMARKS
T. 76 N., R. 26 W., Sw. ¼ of the Sw. qr. of section 9, Grove township.	600 feet deep............	Drilled in 1902 by Park Meridith, Atlantic.
T. 76 N., R. 25 W., Se. ¼ of the Se. qr. of section 36, Franklin township. Mr. Spees; on low upland.	370 feet deep............	Drill hole was for coal. Gravel is reported at 70 ft., Coal is reported at 193 ft., in 1 in., 30 in. and 40 in. seams (probably old soil horizons).
A few rods west of T. 75 N., R. 37 W., Sw. ¼ of the Sw. qr. of section 7. C. H. Rossell in Pottawattamie county. On upland.	520 feet deep. At 200 ft. struck top of limestone. At 400 ft. struck bottom of limestone. At 530 ft. got water; of salty taste.	Water rose 190 ft.; has to be pumped 340 ft. It is good for washing and cooking.
T. 75 N., R. 37 W., Se. ¼ of the Se. qr. of section 10, Cass township. Old city well at Lewis.	70 ft. Soil; clay and pebbles; sand, white. 3½ ft. Sandstone, hard, dark brown. 188½ ft. Limestone, shale, etc. ——— 562 ft. In black shale.	Old city well, drilled in 1900 by Wm. Britton, Cedar Rapids, Ia. Struck water at 83 ft., and none below that; well not now in use. Struck 4 in. of coal at 410 ft.
T. 75 N., R. 34 W., Sw. ¼ of the Nw. qr. of section 27, Massena township. On upland.	306 ft. deep: mostly blue clay, a little sandstone, no heavy limestone, some coal.	
T. 74 N., R. 34 W., Se. ¼ of the Se. qr. of section 5, Victoria township. On upland.	385 ft. deep. (At this depth found thin coal under sandstone).	

Water for Municipal Use

Atlantic, Anita, Cumberland, Griswold, Lewis and Marne have municipal water systems each owned by the city and managed by the city council through a waterworks committee. At Wiota and Massena the inhabitants are dependent on wells and cisterns.

To reach the deep waterbearing strata penetrated at Stuart, Iowa, the deep well at Atlantic must be sunk 1,746 feet deeper than its present depth; but when that increased depth is reached the water to be obtained here is so saline that it is not acceptable. The present solution of the problem for a municipal water supply at Atlantic is much more satisfactory. The same fact holds with reference to deep wells at each of the towns in the county. The water from river sand properly guarded is better than the saline water found in such deep wells in this part of Iowa.

ATLANTIC[77]

Population 5,039

The wells which supply the city of Atlantic are located in the northern part of the city, on the terrace that borders the south side of Troublesome creek. There are forty six-inch wells in all, some of which are fifty-five feet deep and some ninety-two feet deep. The first twenty to twenty-five feet is said to be of "filled in material," then comes five feet of blue clay and five or six feet of sand and gravel. Beneath this is a sandstone, and shale, regarding which there is no complete record. From these wells the water is pumped through the city mains under a pressure of 85 to 90 pounds per square inch. The railroad uses 150,000 gallons per day, at a cost of three cents per thousand, and the city 600,000 gallons per day, on which the charge is thirty cents per thousand for the first five thousand, and ten cents per thousand for the next five thousand. In the city there are at the present time one hundred and twenty-five hydrants and twelve hundred users. A five mill tax for water and a five mill tax for light are expected to liquidate the indebtedness in ten years.

In the following table a series of analyses of the city water is given, together with a standard analysis and an analysis of water from the creek near at hand for comparison. These give the changes in the tests while the plant was being perfected. At times of flood, water from the creek formerly contaminated the wells, but the difficulty is now overcome.

[77]Data furnished by T. E. Nichols, City Clerk.

ANALYSES OF CITY WATER, ATLANTIC, IOWA.

Parts Per Million	Standard Maximum Allowed[78]	Creek Aug. 17 '16[78]	Aug. 27 1913[78]	Oct. 21 1913[78]	Nov. 9 1913[78]	Nov. 24 1914[78]	Aug. 17 1916[79]	Tap City Jan. 10 '17[79]	Pump Station Jan. 10 '17[79]
Free Ammonia	.0250	.085	.6500	.0590	.0850	.0950	.025	.060	.080
Nitrogen in Nitrites	.00010	.008	*	.00010	.00015	.00005	.003	.006	.002
Albumenoid Ammonia	.1750	.075	.0025	.0165	.0075	.0450	.010	.010	.004
Nitrogen in Nitrates	.7500	3.0	1.2000	1.25	1.55	2.0000	3.0	4.0	4.5
Chlorine	3.50	4.	3.15	8.00	8.15	9.50	9.0	10.	9.
Phosphates	1.75	---	.75	.15	†	†	---	---	---
Residue on evaporation	350.	---	333.	251.	231.	264.	---	---	---
Volatile solids	---	---	91.	151.	97.	105.	---	---	---
Fixed solids	---	---	242.	100.	134.	159.	---	---	---
Iron, ferrous	2.50	---	4.98	---	---	---	---	3.0	2.5
Hardness	150.	---	---	---	---	---	---	---	---
Quality	---	---	‡	---	§	¶	---	---	---

	Tap City	Pump Station
Bacteria per c. c. at 37° C., on litmus lactose agar	5	26
Bacteria per c. c. at 20° C., on nutrient agar	300	35
Colon Bacilli, acid colonies per 1 c. c.	0	2
Gas	0	0

*None.
†High.
‡Not very satisfactory.
§Sewage indications.
¶Poor.

Significance of Water Analyses.—In water analyses the free ammonia represents organic material that has already decayed; the albumenoid ammonia represents organic matter that has not yet decayed. The nitrites are formed during incomplete decay, and the nitrates are formed in the final step of decay. Consequently a perfectly pure water would give no traces whatever of ammonia, nitrites and nitrates. An excess, especially of ammonia, is an irritant to the digestive tract which may not affect a person in good health but prove harmful to a person who is not strong. Such water may also contain food for disease germs amid which they will multiply. There is a small amount of chlorine in even the best of well water, the amount varying for different localities. Excess of chlorine is an indication of contamination from the surface. In the case of wells for domestic purposes surface contamination is indicated also by minute living organisms than can be seen swimming and crawling about in water pumped from the well, which some

[78]Analysis made by C. N. Kinney, Des Moines.
[79]Analysis made by State Board of Health, Iowa City.

people seek to exclude by straining the water, instead of carefully cleaning the well out, making the planking tight, and grading around the well so that water flows away from the well and does not stand in pools.

In the case of the city wells at Atlantic there has been an endeavor to exclude surface water by cementing carefully the openings from the pits into the wells and to keep as far as possible all surface and creek water out of the pits in time of flood. The last two analyses, those of January 10, 1917, were made after the final cementing of the pits. A comparison of them indicates that flushing of the pipes had not been completed. A statement of the last bacterial analyses is included in the above table. To attain the elimination of bacteria it is in some places customary to inject into the water a small amount of chlorine gas, a precaution that is not taken at Atlantic. The last analysis given indicates that Atlantic now has a municipal supply that may be considered satisfactory, though it will require the continuance of the present care to keep the water unimpaired.

ANITA[80]

Population 1,210

Anita gets its municipal water supply from eight bored wells six inches in diameter, thirty-six feet deep, extending into the sand and gravel beneath Turkey creek in the southwest part of the town. The water is pumped by a 25-horsepower St. Mary (Ohio) gasoline and oil engine operating a Gardiner pump (Quincy, Illinois) the capacity of which is rated at 250 gallons per minute. It is pumping 6,000 gallons per day into two pressure tanks (Curtis, St. Louis, Missouri) 34 feet in length, nine feet in diameter, with rated capacity of 18,000 gallons each, at 120 pounds pressure. Thirty-five dollars per month cover the entire cost of operating this plant. There are twenty hydrants and at present seventy-one users. There is a minimum rate of two dollars per year, which allows the use of 4,000 gallons at fifty cents per thousand gallons, beyond which the price is forty-five cents per thousand gallons up to 6,000 gallons, and forty cents per thousand gallons from 6,000 to 10,000

[80]Data furnished by J. C. Jenkins, City Clerk.

gallons, above which there are special rates. There is a five mill tax for running expenses, and a sinking fund of three mills for interest on the $19,000 bonds.

At the wells there are twenty feet of black washed soil, ten feet of gray sand and yellow clay, and five feet of sand and gravel. Apparently this bed of sand is not a lens of small extent if we may judge by the abundance of water that it carries. The water-bearing sand and gravel appear to be post-Kansan. Immediately beneath the five feet of sand and gravel is blue Nebraskan clay which extends to a depth of 100 feet, at which depth there was encountered a layer of preglacial sand that contained water saturated with iron. Consequently the boring was closed and the supply was taken from the sand and gravel at thirty feet. No analysis of the water is available.

At the old city well in the northeastern part of town at a depth of 180 feet there was reached a water-bearing bed of sand at the base of the blue clay. The pumping of water from this well has been discontinued.

CUMBERLAND[81]

Population 574

Cumberland gets its water from a six-inch well near the business portion of the town, drilled to a depth of 163 feet. To obtain the 10,000 gallons of water needed per day a Rawleigh-Schryer ten-horsepower gas-oil engine is used to run a Gould's pump, diameter 3¾ inches, 16-inch stroke, speed 275 revolutions per minute. The water is pumped into a steel tank placed on a tower sixty feet high on ground which is sixty feet above the main street.

A windmill with twelve-foot wheel has been placed over a well 214 feet deep close by the stand pipe with a view to obtaining as much water as possible by windpower. This pump has a cylinder three inches in diameter and an eight-inch stroke. There are thirteen street hydrants on a six-inch main. The cost of running is such that the ninety users will yield a profit

[81]Data furnished by W. R. Noland, Superintendent of Water System.

of seventy cents per thousand, without allowance for hydrants. To obtain the plant complete the town has been bonded for $12,500.

The log reported for the well is as follows:

FEET.	
80	Clay, dark yellow with some layers of sand.
40	Clay, blue and yellow, in alternate layers.
1½	Rock, hard, reddish brown.
1½	Muck, hard, reddish brown.
40	Sand, with water.
163	

The water is soft enough to be used without breaking it; pumping at the rate of three gallons per minute does not lower it in the well. The water is judged to come from preglacial deposits.

The following is a copy of an analysis by Professor C. N. Kinney, reported December 5, 1914.

	PARTS PER MILLION.	MAXIMUM ALLOWED FOR DEEP WELLS.
Free ammonia[82]	.0350	.0250
Nitrogen in nitrites	.00015	.0001
Albumenoid Ammonia	.001	.1750
Nitrogen in nitrates	.1000	.7500
Chlorides	1.15	3.50
Phosphates	1.00	1.75
Residue on evaporation	244.	350.
Volatile solids	122.	
Fixed solids	122.	
Iron	Slight amount.	
Quality	Good.	

GRISWOLD[83]

Population 1,148

The municipal supply of Griswold is obtained from an eight-inch cased well sunk to a depth of 140 feet from the level of the terrace on which the town is situated. A twelve-horsepower Hercules gas engine (Evansville, Ind.) operates a Deming (Salem, Ohio) pump having an eight-inch cylinder and a twenty-four inch stroke, twenty-four revolutions per minute, thus delivering 120 gallons per minute. The water is pumped into a standpipe, capacity 58,000 gallons, from which 117 consumers are supplied. The flat rate is $5,00 per year for general domes-

[82]See previous discussion of significance of water analyses.
[83]Data furnished by D. H. Scott, City Clerk.

tic purposes and $2.50 per bath room. There is also a five mill water tax. The entire receipts net $1,500 per year, with cost of running but $500. Under such receipts and expenditures the original cost of $13,000, was paid long ago, the city now having a yearly income of $1000 from the plant.

The log of the well is as follows:

FEET.	
50	Soil and clay.
10	Sandstone.
80	Limestone.
140	

Evidently the water comes from the Dakota sandstone. Unfortunately the water has not been analyzed. It is heavily charged with iron.

LEWIS[84]

Population 652

The city well is located in the public square, 1,102 feet above sea level and about 105 feet above the level of the water above the dam. It is a well ten feet in diameter and sixty-four feet deep, dug in 1913, and walled with concrete blocks locked together.

A six-horsepower Fairbanks-Morse gasoline engine is used to run a Deming pump, diameter four inches, stroke two feet, at the rate of twenty revolutions per minute. The pump is kept running a considerable portion of each day, forcing water into the 40,000 gallon tank, which is 16 feet in diameter and 80 feet high. About 20,000 gallons are used per day. There are seven hydrants and 143 consumers; water rate $.75 per thousand gallons.

The log of the well is as follows:

FEET.	
54	Soil and clay.
10	Sand, white, and pebbles "size of pears and walnuts."
64	

The well constantly has seven feet of water that cannot be pumped out. The water apparently comes from preglacial sand and gravel and also from Dakota sandstone and sand de-

[84]Data furnished by Mr. Fletcher.

rived from it. From the record of Mr. J. C. Livingston given below it will be seen that the Dakota sandstone is immediately beneath where the new well stops. The Dakota sandstone is abundant in all directions.

Mr. J. C. Livingston reports the following log of the "old" city well drilled about 1900 by Mr. William Britton of Cedar Rapids, Iowa. The well is not now in use.

FEET.	
70	Soil; clay, with pebbles; sand, white.
3½	Sandstone, hard, dark brown.
499½	Limestone, shale, etc.
562	Stopped in black shale.

Water was struck at a depth of 83 feet, and none below that. Fourteen inches of coal was found at a depth of 410 feet.

MARNE[85]

Population 297

The municipal supply of water at Marne is obtained from a six-foot well dug thirty-five feet deep, on a small flat near the railroad track, about 1,200 feet above sea level. A six-horse-power combined pump and engine (The Thomas Company, Beloit, Wisconsin) pumps the water through a four-inch main to a tank in the northern part of the town which is twenty feet in diameter, sixteen feet high, with a capacity of 1,200 barrels and rests on a base twenty feet above the ground. The thirty users pay $7 per year flat rate. There are seven hydrants. The income from the water rates is $210 per year, to which is added a five mill tax which yields $160, making the total income $370, which just about pays the cost of operation. The plant cost as follows:

Tank and foundation	$ 450
Piping	1,500
Engine	350
House and well	500
	$2,800

[85]Data furnished by Andrew Lastime, City Clerk.

The following analysis was made by Professor C. N. Kinney of Des Moines, January 15, 1913:

	PARTS PER MILLION.	MAXIMUM ALLOWED FOR DEEP WELLS.
Free ammonia[36]	.0008	.0250
Nitrogen in nitrites	trace	.00010
Albumenoid ammonia	.0008	.750
Nitrogen in nitrates	12.0000	.7500
Chlorides	10.	3.10
Phosphates	.10	1.75
Residue on evaporation	969.	350.
Volatile solids	595.	
Fixed solids	374.	

Quality—Not a good water; past condition of water poor. Some algæ and silt were present, and a slight odor noticed.

One reason, and probably the only reason, why the water was not a good water was evident in the former lack of care of the top of the well. The difficulty has been remedied.

Springs

At Crystal Lake, a mile south of Lewis, the base of the Dakota sandstone is about fifteen feet above the bottom of the ravine near at hand. From the base of the sandstone pipes lying on the shale beneath carry streams of the purest water into a bathing pool made by damming up a portion of the ravine. The further addition of lunch counters, swings and various accessories of a picnic ground have converted this shady retreat beneath the sandstone cliff into a delightful pleasure resort.

Not so fortunate is that other old Indian spring at Spring Creek a mile west of Lewis where the special beauty of sandstone cliffs is not so extensive as at Crystal Lake. At Spring Creek the water from the sandstone seeps through a heavy deposit of talus on the side of a ravine in a pasture.

Near Galion at a point three miles south of Lewis and four and a half miles east, the cliff and the grove are as attractive as at Crystal Lake, but the base of the sandstone is near the level of the creek bed. With considerable labor it would be possible to remove the mud and protect the springs at the base of the sandstone.

Along the Nodaway river from the central part of Edna township (section 15) to Massena there are numerous springs giving the Nodaway a never-failing supply. Nearly all of this

[36]See previous discussion of significance of water analysis.

water comes from the Dakota sandstone, which is visible at numerous places along the course of the stream; but near Massena it is possible that water from preglacial deposits mingles with that from the Dakota sandstone. In several places along the stream small ponds have been easily prepared to the delight of ducks, swine and cattle. Half a mile east of Cumberland water from a similar source forms pools in the river bed in dry seasons.

North of Cumberland the creek is abundantly supplied with spring water for two miles upstream from the west center of section 15. As wells in this portion of the township go to sandstone it is probable that a considerable portion of this water comes from the sandstone. A portion of the water on the north side of the river comes from the preglacial deposits, which locally are evident and two miles to the northeast furnish an abundance of carbon dioxide gas to the wells.

Oil

No evidence of oil is reported at the prospect hole at Atlantic which as stated on page 253 is 1,310 feet deep. Scum caught back of sticks in the water of ravines was tested and found to give no trace whatever of oil. The so-called oil reported on the water from wells was not accompanied by any evidence that it was due to other cause than decay in swampy deposits penetrated by the wells. The accompanying gas was carbon dioxide. Two of these three wells (section 36, Franklin township and section 5, Grant township) have already been mentioned with reference to preglacial swamps. The other well reached the Dakota sandstone in Pleasant township (northeast quarter of the northeast quarter of section 20) at a depth of fifty to sixty feet.

Coal

The fault plane which is traced northeast-southwest from section 33, Edna township, to section 1, Victoria township, divides Cass county into two distinct but unequal parts.

North of the Fault Plane.—Nowhere north of the fault plane does the Nodaway coal exist, it having been eroded away ages ago. The coal nearest the surface in the northeast half of the county is the four-inch seam at the base of the Bethany Falls (Earlham) limestone. Near Anita this seam is close to the base of the Dakota sandstone and glacial drift at a depth of 189 feet below the upland. Hence it is absent to the northeast of the place named. At Atlantic it is the coal recorded at a depth of 260 feet in the test boring. At Griswold it is estimated to be about 724 feet below the town, or 430 feet above sea level.

About seventy-one feet below the above named seam is the horizon of the twenty-inch seam of coal mined at the Eureka coal shaft, located two and a half miles east of the northeast corner of Lincoln township, where it was found at a depth of 260 feet below the upland. With an average increase in depth of 21 feet per mile to the southwest this seam of coal is at a depth of 783 feet beneath the level of the upland, or at 534 feet above sea level, along a line from northwest to southeast, near the center of Cass county, and at a depth of 984 feet below Griswold, or at 114 feet above sea level. In the record of the Atlantic test-boring this coal is not mentioned, but the slate recorded at a depth of 365 feet, 105 feet below the first mentioned coal seam, may possibly be related to this second seam. Variations in dip and in thickness of shale make up the difference of 34 feet between 71 and 105 feet.

The possibility of the presence of coal at greater depths must for the present be treated as a rumor.[87] Slate at 675 feet, at 740 to 760 feet and at 825 feet, are all that is mentioned in the record of the Atlantic test boring. These records of slate are where coal should be expected if it is present at all. It is evident that a "chuck drill" and not a core or "diamond drill" was used, for samples were taken only occasionally.

According to the record of the Clarinda diamond drill hole[88] there are two other thin seams of coal that should be encountered in the southwestern part of the county. The first is a six-inch seam 200 feet above the coal at the base of the Bethany Falls (Earlham) limestone. This seam reaches the base of the Dakota sandstone, or the base of the glacial drift where the Dakota sandstone is absent, at about the middle of the area of

[87]C. R. Keyes, "Coal Deposits of Southwestern Iowa," Iowa Geological Survey, Vol. II, p. 443.
[88]George L. Smith, "Carboniferous Section of Southwestern Iowa," Iowa Geological Survey, Vol. XIX, p. 618.

the Douglas division (see map) or along a line northwest-southeast through a point about a mile southwest of Cumberland, and two miles southwest of Marne. It is at a depth of 524 feet at Griswold. The horizon of the second, a four-inch seam, is 104 feet above the base of the Oread limestone, or at a depth of 151 feet beneath Griswold.

It is evident that none of these seams of coal are worthy of consideration for mining at the present time, unless it be the twenty-inch seam, the second one named above, which in time of need can be reached in Grant township, and in the northeast half of Benton and of Lincoln townships. Water from the Dakota sandstone and from the preglacial sands will cause trouble in mining.

South of the Fault Plane.—In the portion of Victoria and Edna townships southeast of the fault plane the Nodaway coal seam is present at a depth of approximately thirty feet below the beds of the deepest ravines, except where it has been removed by preglacial erosion, the main lines of which are about ten feet deeper. Beneath the Nodaway coal the depth to the four-inch seam of coal above the Deer Creek limestone is 40 feet, or 104 feet above the base of the Oread limestone. The further depth to the six-inch seam in the Douglas formation is 372 feet, the further depth to the four-inch seam of coal beneath the Bethany Falls (Earlham) limestone is 200 feet, and the further depth to the twenty-inch seam (Eureka) about 71 feet.

The above figures are subject to some variation; but it is believed they are sufficiently exact to prevent useless prospecting, and to guide prospecting in Grant, Benton and Lincoln townships in time of need. It is possible that people in Massena and Union townships may think coal is easily accessible there because it is mined at Bridgewater in Adair county. Expenditure for prospecting will not be wise, for Bridgewater, like Briscoe, is on the opposite side of the fault plane and under conditions described for the southeastern parts of Edna and Victoria townships.

Well Records with Reference to Coal.—The record of the Atlantic test hole has already been considered.

At Lewis the deep well is said to have encountered at a depth of 410 feet a fourteen-inch seam of coal, which is apparently at the base of the Bethany Falls (Earlham) limestone. The thickness named, if correctly stated, is such that it includes considerable shale with the coal.

It is stated that coal was found in a well 385 feet deep in section 5, Victoria township. This is at the northeast border of the area of the six-inch seam that comes up beneath the Dakota sandstone in the area of the Douglas division. It dips to the southwest, and is too thin to be profitably mined.

It is stated that three seams of coal were encountered in a test boring 370 feet deep below a low upland, on Mr. Spees' farm, section 36 (southeast quarter of the southeast quarter), Franklin township. One seam was found at a depth of 193 feet. This is apparently the top seam, which in that locality is the six-inch seam in the Douglas formation and is not far below the base of the Dakota sandstone. Though depths are not given the second seam may well be that at the base of the Bethany Falls (Earlham) limestone, and the third the seam reached at Eureka.

In section 27 (southwest quarter of the northwest quarter), Massena township, is a well 306 feet deep. Here coal is said to have been encountered somewhere beneath a little sandstone, which was beneath a thick blue clay. The Nodaway coal seam is beneath Dakota sandstone and a little Missouri shale in this locality.

Analyses of Coal.—The following are analyses of coal[89] from the Plowman shaft at Briscoe. They indicate a good average coal as compared with other Iowa coal.

ANALYSES OF COAL FROM THE PLOWMAN SHAFT.

	TOP OF SEAM.	MIDDLE OF SEAM	BOTTOM OF SEAM
Moisture	8.97	9.09	8.72
Total combustibles	80.48	74.95	77.39
Ash	10.55	15.96	13.89
Volatile combustible matter	36.44	32.04	32.01
Fixed carbon	44.04	42.91	45.38
Coke—fixed carbon plus ash	54.59	58.87	59.27
Sulphur in sulphides	3.15	2.44	3.67
Sulphur in sulphates	.11	.13	.27
Total sulphur	3.26	2.59	3.94
Authority	G. E. Patrick	G. E. Patrick	G. E. Patrick

[89]Iowa Geological Survey, Vol. XIX, p. 497.

Sandstone

A mile south of Lewis are the old sandstone quarries where in the early history of the region the dark reddish brown Dakota sandstone was quarried for building purposes. A few buildings may still be found in which this stone was used. Though easily worked it is too soft, too porous and too unsatisfactory in color for a building stone, and is no longer quarried.

Limestone

Limestone has been quarried on the west bank of the Nishnabotna at Lewis; just south of section 32 (southeast quarter of the southeast quarter), Noble township; in the southern half of section 36, Noble township; and in the southern part of section 31, Edna township, at the Fox quarries; but quarrying has long since ceased at each place, and the old quarry faces are largely concealed by talus. All the limestone is a light grayish Fusulina limestone.

In the old quarries at Lewis (northeast quarter of the southeast quarter of section 9) only six feet of limestone and shale appear. The top of the limestone is seventeen feet above the water in the river and about three feet above the general level of the bottom land. The limestone is at present better seen just north of the bridge over Spring creek in section 9. The lower bed is four feet, ten inches thick, the upper five and a half feet thick. The two are separated by two feet of a gray shale.

What little quarrying has been done on Rose Branch was in Montgomery county. No strata in place are now visible, but the fragments at hand are of the same character of gray Fusulina limestone as that formerly quarried at Lewis, and are undoubtedly from the same beds.

The full section at the Fox quarries (northeast quarter of the northeast quarter of section 31, Edna township) is given in the chapter on stratigraphy. At this place there are several beds that have been quarried, all of which are of the same general character of gray Fusulina limestone as the beds already named.

The lowest beds, twenty-three feet above the river, offer layers four inches, ten inches, and twenty inches thick. Next above these lowest limestones are two heavily bedded layers with two feet between them not exposed. These beds of limestone are divided into three layers that are respectively two feet, one foot and two and one-fourth feet thick. Near the top of the bluff are two thin layers one of which is seven inches thick and one two inches thick. At the very top of the bluff is two feet of a decomposed limestone.

A small quantity of limestone could be obtained in sections 32 and 33, Grove township, where a stratum three feet thick outcrops in the side of the ravine.

The demand for the sandstone and limestone for building purposes has been replaced by a demand for the much more satisfactory cement and brick; but a new local use for the limestone has arisen. Limestone crushed fine is needed on ground that is acid, especially if alfalfa is to be raised on it.

The only deposits that are suitable for cement are those at the Fox quarries, where the right mixture of shale and limestone can be obtained; but the beds exposed are only twenty-three feet thick, and they are located too far from a market to deserve consideration.

Clay

The Atlantic Brick and Tile Company plant was operated by Mr. C. E. Taylor, whose clay pit[90] is located west of the city and close to the river. Here twenty-four feet of loess, the lower four feet of which is brown, the remainder yellow, lies exposed to view with base four feet above low water in the river. Beneath the loess is said to lie three or four feet of yellow sand, then two inches of gravel, which rests on four feet of a coarse river sand consisting of grains of various colors, indicating that the gravel is derived from glacial drift, and containing iron. Beneath this bed was something that Mr. Taylor could not penetrate. The plant is used for the manufacture of brick and tile. The manager is experimenting to obtain a mixture that will make a harder brick than the loess alone produces, and is evidently succeeding in his undertaking. At present he is operating four kilns.

[90]It has recently changed hands, and is now operated by the Atlantic Building Supply Company.

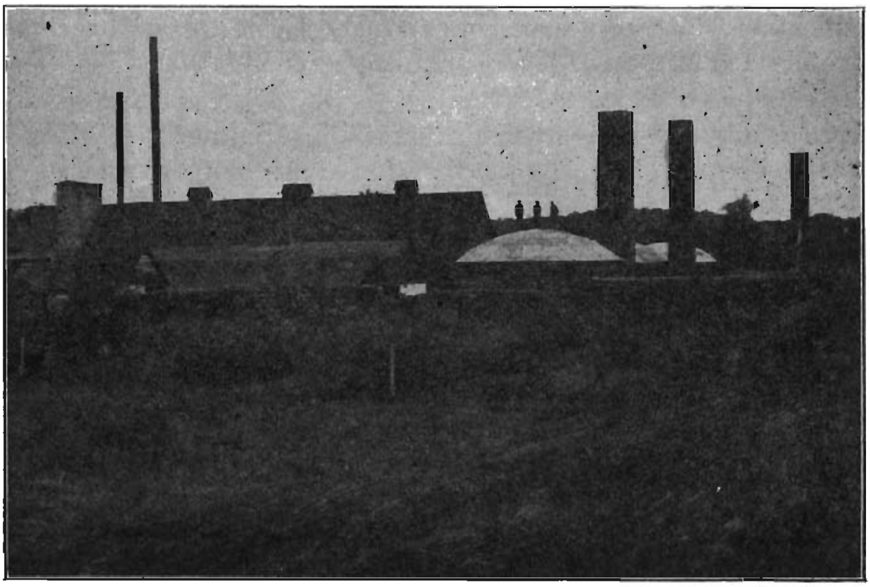


FIG. 36.—Brickyard at Atlantic, Cass county.

The pit at Anita is also in loess, from which Mr. C. L. Martin makes common brick.

The clay pit at Lewis is in loess banked against the side of the valley, on the second bottom, close to the river. As the brick made were too soft to compete with brick shipped in, the plant has remained idle since about 1912. The plant consists of a mill, two drying sheds, a rectangular kiln, two complete and two incomplete circular down-draft kilns.

There is a small body of shale one mile east of Griswold and nearly two miles south, and another body of shale two miles north and one mile west of Griswold than can be mixed with the loess to produce a harder brick than can be produced from the loess alone. Weathered Nebraskan drift is better material than loess for the manufacture of brick and tile. Drift generally contains too many pebbles, but places are common where there are few pebbles.

TABLE OF CLAY PRODUCTION IN CASS COUNTY SINCE 1900.

(Compiled from the various volumes of the Iowa Geological Survey).

YEAR	NUMBER OF PRODUCERS	THOUSANDS OF COMMON BRICK	VALUE OF COMMON BRICK	VALUE OF FACE BRICK	VALUE OF TILE	MISCELLANEOUS	TOTAL VALUE
1900	3	895	$ 5,275	....	....	....	$ 5,275
1901	5	2039	14,412	....	....	....	14,412
1902	5	1,670	12,405	....	....	....	12,405
1903	2	1,406	10,596	....	....	....	10,596
1904	4	·2,020	16,100	....	$ 825	....	16,925
1905	4	1,593	11,420	....	1,969	....	13,389
1906	......	....	....	....	....	....	....
1907	7	....	13,193	....	1,682	....	14,875
1908	2	5,500	....	$7,000	2,700	$4,000	19,200
1909	3	....	9,465	....	6,653	....	16,783
1910	1	....	....	....	....	....	....
1911	2	....	....	....	....	....	....

For 1912-1915 the only information published states there was one producer each year in the county.

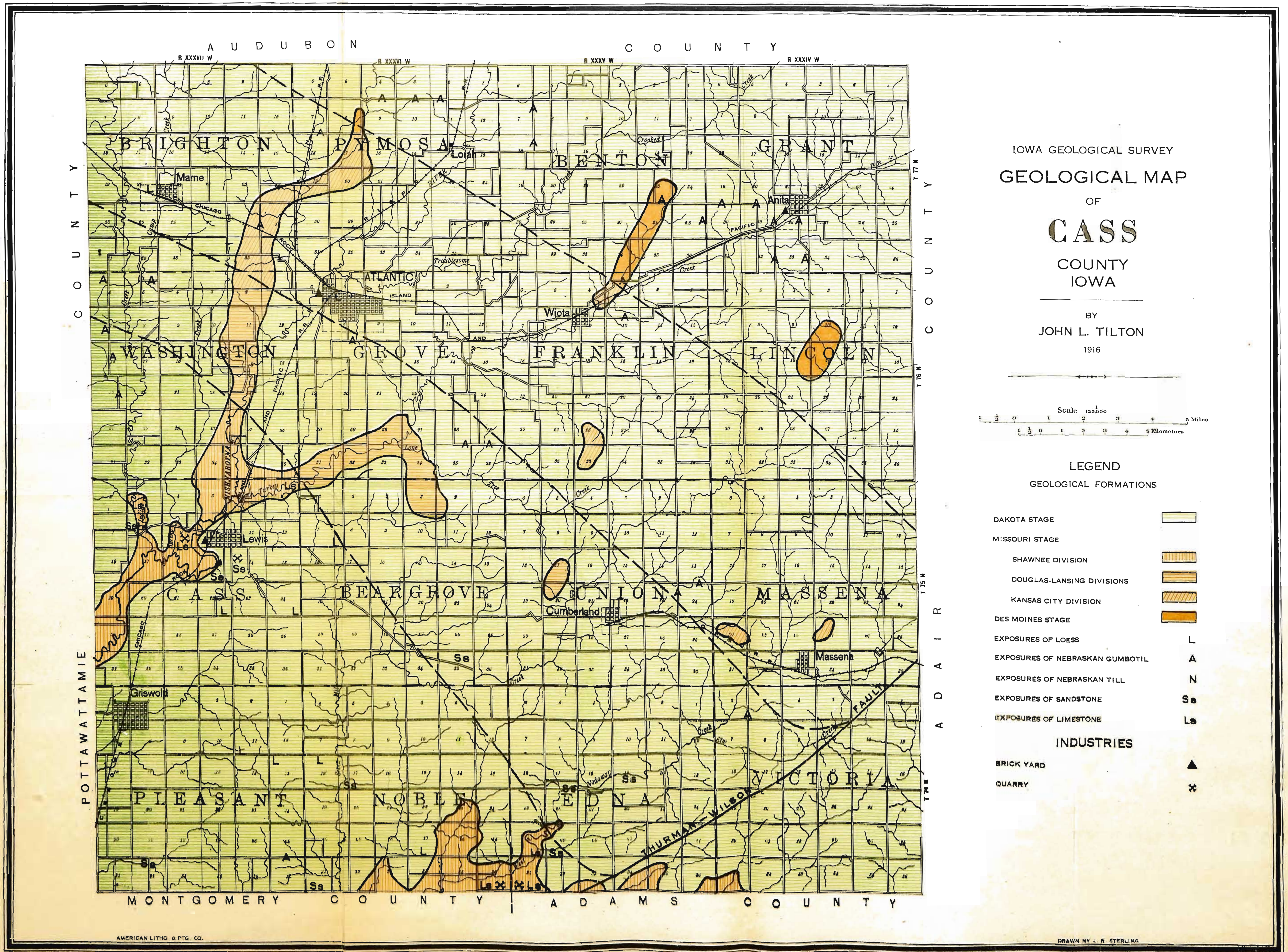
Sand

The sand beneath the river bed along the Nishnabotna affords an ample supply for all needs at Atlantic, Lewis and Griswold, and is accessible to all who reside in the western half of the county. At the present time there is a sand pump and outfit located a mile west of Griswold, just west of the county line, where it obtains a white sand of waterworn quartz pebbles.

A second source of supply is the white sand in the upper portion of the Dakota sandstone. In section 17 (southwest quarter of the southeast quarter), Noble township, a considerable bed of this sand, so incoherent that it is easily obtained with a shovel, is valuable for local use. In the northeastern part of section 29, Edna township, is a sand bed suitable for use. Generally along the Nodaway, as well as elsewhere, the sandstone exposed contains too much iron to be satisfactory in color, and is generally too consolidated for use without crushing.

ACKNOWLEDGMENTS

It has been the intention to acknowledge sources of information in the text as far as possible. In addition to this the writer wishes to express his appreciation of the universal courtesy which he has received from people in all parts of the county. He also wishes to express his appreciation of the care and skill of the Assistant State Geologist, Dr. James H. Lees, who has superintended the publication of the report.


IOWA GEOLOGICAL SURVEY
GEOLOGICAL MAP
OF
CASS
COUNTY
IOWA
BY
JOHN L. TILTON
1916
Scale 1/125,000
5 Miles
5 Kilometers
LEGEND
GEOLOGICAL FORMATIONS
DAKOTA STAGE
MISSOURI STAGE
SHAWNEE DIVISION
DOUGLAS-LANSING DIVISIONS
KANSAS CITY DIVISION
DES MOINES STAGE
EXPOSURES OF LOESS L
EXPOSURES OF NEBRASKAN GUMBOTIL A
EXPOSURES OF NEBRASKAN TILL N
EXPOSURES OF SANDSTONE Ss
EXPOSURES OF LIMESTONE Ls
INDUSTRIES
BRICK YARD
QUARRY
AUDUBON COUNTY
CASS COUNTY
ADAIR COUNTY
POTTAWATTAMIE COUNTY
MONTGOMERY COUNTY
ADAMS COUNTY
R XXXVII W
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BRIGHTON
PYMOSA
BENTON
GRANT
WASHINGTON
GROVE
FRANKLIN
LINCOLN
CASS
BEARGROVE
UNION
MASSENA
PLEASANT
NOBLE
EDNA
VICTORIA
Marne
Lorah
Anita
ATLANTIC
Wiota
Lewis
Cumberland
Massena
Griswold
CHICAGO ROCK ISLAND AND PACIFIC R.R.
NISHNABOTNA
Troublesome
Turkey
Crooked
Lone
Nodaway
THURMAN–WILSON FAULT
AMERICAN LITHO & PTG. CO.
DRAWN BY J. R. STERLING

GEOLOGY OF ADAIR COUNTY

BY

JAMES E. GOW AND JOHN L. TILTON

CONTENTS

THE GEOLOGY OF ADAIR COUNTY[1]

INTRODUCTION

Adair county is located in the third tier of counties north of the southern boundary of Iowa, and in the third tier east of the western boundary of the state. It is a square, consisting of sixteen geographical townships, and is bounded on the north by Guthrie county, on the east by Madison, on the south by Union and Adams, and on the west by Cass. To the northeast and northwest it corners with Dallas and Audubon respectively. Adair is essentially a prairie county. Lying well to the south of the Wisconsin glacial lobe, whose moraine passes through Guthrie county, it shows no trace of constructional topography. It is thoroughly dissected by streams and its drainage system is complete. Its soil consists of typical Kansan till, and its rolling topography is typically Kansan. The grand divide between the Mississippi and Missouri rivers passes through Adair county, in an almost due northwest-southeasterly direction, so dividing it that approximately one-third of the county lies to the northeast of the divide and two-thirds to the southwest. Owing to the extremely dissected character of the topography, the "draws", or shallow valleys in which the smaller streams take their rise, interlock along the crest of the divide, so that the latter is very crooked. The county drains to the north and east through North river, Middle river, and Grand river, on the south and west through East and Middle Nodaway rivers. North and Middle rivers flow into the Des Moines, and so form part of the Mississippi drainage system. Grand river and the Nodaways flow into the Missouri. Of these streams, Middle river (and Bush Branch, a small tributary of Middle river) are the only

[1]The manuscript which was submitted by the late Doctor Gow was revised after his death by Dr. John L. Tilton. Changes were made with regard to some phases of the Carboniferous rocks and the Pleistocene deposits.

ones that cut to bedrock in Adair county. Grand river cuts through rock in Madison county not very far from the county line. The Nodaway cuts into rock near Mount Etna, in Adams county, and north of that point flows over a clay bed.

PREVIOUS GEOLOGICAL WORK

In 1849 Owen probably passed through the southern part of Adair county, or skirted along its southern border, on his way from Des Moines to Council Bluffs. In his "Report of a Geological Survey of Wisconsin, Iowa and Minnesota," published in 1852, Owen thus describes this portion of his journey:

"On Grand River, in the vicinity of Pisgah, nothing but drift is to be seen. Some miles down the stream, however, near a mill-site, I was told by the Mormons that a kind of 'soapstone' could be found at a low stage of water, which I suppose to be an indurated argillaceous shale; these deposits being popularly known by that name in the west. This I was unable to examine in person; indisposition, from fatigue and exposure, having brought on a relapse of intermittent fever, contracted while exploring the Des Moines.

"The distances from Fort Des Moines to Pisgah are as follows:

To the crossing of North River	10 miles
To Middle River	12 miles
To the South or Clanton Fork of Middle River	2 miles
To Clanton's	2 miles
To Big Hollow	14 miles
To forks of road leading to Bellevue	4 miles
To Pisgah	6 miles
Total distance	50 miles

"On the route from Pisgah to Council Bluffs, I crossed Grand River, the Platte branch of Grand River, two branches of the Nodaway, a Hundred and Two River, and the east, middle, and west branches of the Nishnabotna River. It was only on this latter stream that any rocks were found in place."

The writer cannot find that the memory of any such place as "Pisgah" lives at this time, though he has not had the privilege of interviewing all the old settlers of the region in question.

From the somewhat detailed table of distances given by Owen the place can be approximately located, and it must have been at or near the site of the present village of Macksburg, in Madison county. Scattering exposures of shale occur in that neighborhood. The reference to the mill site would seem to indicate Macksburg as the site of Pisgah. Owen's journey from Pisgah to Council Bluffs probably took him through the southern edge of what is now Adair county, but in the latter region he found no indurated rocks.

In 1868 White made some observations on the Geology of Adair county, and these were published in his Geology of Iowa, Volume I, pp. 336 to 339. In this report he described in considerable detail exposures of Carboniferous rock found on sections 11 and 12 in Grove township, a bed of modern peat in section 22 of Summerset township, and other points of interest. White's work is useful to the geologist of the present day, and references will be made to it in the pages of this report.

In the late seventies a Geological Survey of Adair county was undertaken by Fox, but the work was barren of results and was soon abandoned.

In 1894 Keyes, in Volume II of the Reports of the Iowa Geological Survey, reported on the presence of coal in Adair county. Further reference will be made to this report.

In 1911 Norton and Simpson reported on the underground waters and deep wells of Adair county, in Volume XXI of the Iowa Reports. This article embodies data with regard to eighteen deep wells in various parts of the county.

The writer began work on the geology of Adair county in 1901, under direction of the State Geologist, the late Professor Samuel Calvin. In 1902 it was found necessary to drop the work for the time being, and it was not possible to take it up again until 1912, when it was resumed and pushed to completion.

ELEVATIONS ABOVE SEA LEVEL

The official elevation as given for Greenfield was taken as a standard, the figures being supplied by the officials of the Chicago, Burlington & Quincy Railway, and after the aneroid had been set in accordance with this datum readings were taken at the other points as indicated below. The readings for Stuart, Casey, Adair and Fontanelle were verified by comparison with Gannett's Index of Elevations, and were found to be in substantial agreement.

	FEET	
Railway station at Stuart	1,216	
" " " Casey	1,248	
" " " Adair	1,442	
" " " Orient	1,334	
" " " Greenfield	1,368	
" " " Fontanelle	1,244	(old station)
" " " Fontanelle	1,282	(new station)
" " " Bridgewater	1,188	
Summerset Township:		
Se. ¼ sec. 14	1,278	
W. line Nw. ¼ sec. 13	1,388	
Nw. corner sec. 13	1,298	
E. line Se. ¼ sec. 18	1,282	
Jackson Township:		
Se. ¼ sec. 34	1,198	
Washington Township:		
Se. ¼ sec. 16	1,155	
Union Township:		
Se. ¼ sec. 16	1,312	
Se. ¼ sec. 1	1,079	
Jefferson Township:		
Se. ¼ sec. 31	1,361	
Grove Township:		
Se. ¼ sec. 19	1,360	
Sw. ¼ sec. 1	1,098	
Nw. ¼ sec. 12	1,098	
Harrison Township:		
W. line Se. ¼ sec. 18	1,068	
Se. ¼ sec. 20	1,060	
Se. ¼ sec. 21	1,038	
Se. ¼ sec. 27	988	
Se. ¼ sec. 26	943	
Ne. ¼ sec. 36	940	

EXPOSURES AND DEEP SHAFTS

The Chicago, Burlington & Quincy railway in Adair county follows the crest of the divide as far north as Greenfield. The track is very crooked and heads practically every "draw" in the entire twenty miles from Creston to Greenfield, and there are consequently no cuts in that disance. At Greenfield it drops into the valley of the Nodaway, which it follows as far as Fontanelle, there being some culverts and bridges but no cuts in the seven miles between the two towns. West of Fontanelle are a few shallow cuts in the drift.

The Chicago, Rock Island & Pacific railway skirts the northern edge of the county, and there are a number of rather deep cuts along its right-of-way. These nowhere extend below the Kansan drift, but are useful as offering an opportunity to study the drift in vertical section.

The working of the roads in every part of the county has led to the making of many shallow cuts from two to fifteen feet in depth, and much of the information with regard to the surface clays of the county has been derived from this source. As a rule it is best to study the cut immediately after it has been made, as a very few rains cause a washing of the clay that obscures things, but very often a few minutes' work with a spade is sufficient to reveal the underlying materials in their natural relations. Natural gullies developing in pasture and meadows occasionally make it possible to secure information regarding the underlying materials.

The various branches of the Nodaway dissect the western half of the county but do not cut below the drift. At most points the drift is masked by alluvium, but there are some good exposures. In the eastern part of the county Middle river cuts through the Kansan drift and into the Carboniferous limestone below. At half a dozen points between Perry's quarry and the county line the river flows over a rock bottom, the bottom at intervening points consisting of clay, sand, or alluvium. Between the deposition of the Carboniferous strata and the advance of the ice sheet was an immense interval of elevation and consequent erosion, and the present exposures of Carboniferous rock represent the summits of the hills of the old eroded Carboniferous land surface. The Kansan drift rests unconformably upon this eroded surface. Nebraskan and Aftonian materials underlie the Kansan at many places in Adair county, but no trace of them is to be found in the Middle river exposures.

Most of the wells in this county do not penetrate into the bedrock, but merely reach "hardpan" or stiff, impermeable Kansan clay. The writer secured data with reference to eleven wells which penetrate below the level of the drift, reaching either Carboniferous or Cretaceous rock. Besides these eleven, eight more are reported by Simpson in Norton's report on the Ground Waters of Iowa. With regard to most of these nineteen wells the available data are extremely meager. In only one case was a complete and accurate record of the section preserved. Data regarding the shallower wells are more readily obtained, and throw some light on the relations of the various clays, sands and gravels making up the complex Kansan drift. It is through an examination of these wells also that the evidence as to the presence of the Aftonian in Adair county has been chiefly brought to light.

There is but one mine shaft in the county, and while it is not now accessible for examination the writer has been able to obtain an authentic record of the section.

SYNOPTICAL TABLE OF FORMATIONS.

GROUP	SYSTEM	SERIES	STAGE		SUBSTAGE	CHARACTER OF ROCKS
Cenozoic ..	Quaternary	Recent	....		....	Alluvium and other surface soil, clay and sand.
		Pleistocene.	Peorian ...		....	Deposits of loess.
			Yarmouth .		....	Kansan gumbotil.
			Kansan ...		....	Drift (bowlder clay).
			Aftonian ..		....	Nebraskan gumbotil.
			Nebraskan		....	Drift (bowlder clay).
	Tertiary ..	Pliocene ...	Ozarkian ..		....	Bog and other deposits.
Mesozoic ..	Cretaceous	Upper Cretaceous ...	Dakota ...		....	Sandstone, a little shale.
Paleozoic ..	Carboniferous...	Pennsylvanian ..	Missouri	(Shawnee Division)	Scranton ..	Shale.
					Howard ...	Limestone.
					Severy	Shale; Nodaway coal.
					Topeka	Limestone.
					Calhoun ..	Shale.
					Deer Creek.	Limestone.
					Tecumsey..	Shale.
					Lecompton	Limestone.
					Kanwaka ..	Shale.
				(Douglas Division)	Oread	Limestone.
					Lawrence .	Shale.
					Iatan	Limestone.
					Weston ...	Shale.
				(Lansing Division)	Stanton ...	Limestone.
					Vilas	Shale.
					Plattsburgh	Limestone.
					Lane	Shale.
				(Kansas City Division)	Iola	Limestone.
					Chanute ...	Shale.
					DeKalb (Drum) ..	Limestone.
					Cherryvale.	Shale.
					Winterset .	Limestone.
					Galesburg .	Shale.
					Bethany Falls.....	Limestone.
					Ladore	Shale.
					Hertha	Limestone.

Exposures East of the Divide

As has been said, the sections east of the divide include only two classes of materials, drift and Carboniferous rock. The Carboniferous rocks in the eastern central portion of the county belong somewhere in the Missouri stage above the Westerville limestone, probably with the Iatan limestone. The relations are discussed by Tilton in the section on Comment on Correlation and Structure.

The first exposure investigated is on the west side of Middle river at Perry's quarry in the northeastern corner of Grove township. The rock is exposed in a ravine which approaches the river from the west. At two points—near the river on the north side of the ravine, and about fifty rods back from the river on the south side of the ravine—quarrying operations have been carried on in the past but were discontinued some years ago. The bottom of the ravine is flat, being in fact the flood plain of an intermittent brook which has cut in the middle of the plain a narrow gully three to five feet in depth. In the bottom of this gully is exposed a stratum of brittle black shale. The section exposed on the south side of the valley, including the shale found in the gully, is as follows:

		FEET.
10.	Drift, Kansan	5
9.	Limestone, massive, nonfossiliferous, weathering rectangular	4
8.	Shale, soft, light gray	1
7.	Limestone, buff to white, with narrow partings of light shale	2
6.	Shale, soft, light gray	5/6
5.	Limestone, similar to No. 7	3
4.	Shale, soft, gray to brown	1
3.	Limestone, massive, without shale	3
2.	Hidden by alluvium	10
1.	Shale, hard, black	¼
	Total	30

The exposure nearer the river and on the opposite side of the gully is practically identical with the one just given, except that a band of chert is found in the massive limestone five feet above the foot of the cliff. At either end the chert is concealed by talus. It is probably a lenticular mass of no great extent Specimens of *Athyris subtilita, Spirifer cameratus,* and *Pro-*

ductus nebrascensis were found in the massive limestone of both these exposures. The shale is nonfossiliferous. Some calcite crystals are present in the massive limestone. The Perry's quarry exposures are mentioned by White in his "Geology of Iowa" page 336 of volume I, but no details are given. A third exposure, similar to those at Perry's quarry, is found in the same section (12, Grove township) and less than half a mile down the river. This is in the valley of the little tributary spoken of by White as "Drake's Creek". The elevation is the same as that of Perry's quarry, and the section is as follows:

	FEET	INCHES
4. Drift, Kansan	5	
3. Limestone, light buff, with frequent shaly partings, varying in thickness from ¼ inch to 1 foot	12	
2. Limestone, heavy, dark, cherty		5
1. Limestone, darker, without chert and without shaly partings	5	
Total	22	5

White, in the "Geology of Iowa" volume I, pp. 336-339, described another exposure on Drake's creek, which, according to his account, extended twenty-seven feet below the level of the exposure at Perry's quarry, and of the one just given. Of this the writer has been able to find no trace. The section as given by White is as follows:

	FEET.
6. Black carbonaceous shale, a few inches at top consisting of impure coal	2
5. Marly clay	½
4. Hard, bluish, impure limestone	1
3. Brownish clayey shale	1
2. Hard dark-colored impure limestone	½
1. Fine-grained, micaceous, sandy shale, becoming darker and more clayey at the top	22
Total	27

Passing down Middle river, the next exposure is on the Keating farm just above Port Union, and within sight of the mill at the latter place. On a sloping bank fifteen feet above the low-water level stands a large bowlder of hard, well cemented breccia. Although the hillside is badly masked by drift an examination shows that the bedrock at this point consists of similar breccia, but the exposure is so unsatisfactory on account of the mantle of drift that it is impossible to say how far up and down the valley it extends. It appears to dip sharply to the southwest. The fragments of which this breccia consists are of a fine-grained, light buff limestone, are quite angular, and vary in size from a quarter of an inch up to eight or ten inches in diameter. The cementing material is similar but somewhat coarser in texture, and inclined to be crystalline. A few broken specimens of *Athyris subtilita* appear in the angular fragments of the breccia.

FIG. 37.—Exposure at the west end of the dam at the Port Union mill (Arbor Hill), Adair county. Below the dam the stream flows over a rock bottom, No. 1 of the section as described.

The third exposure is at the west end of the dam at the Port Union mill. The section is as follows:

		FEET.
5.	Alluvium, black	10
4.	Till, yellow, somewhat gravelly	5
3.	Limestone, hard, light buff, varying to white or light gray, richly fossiliferous	2
2.	Shale, very soft, homogeneous, blue-black, richly fossiliferous	4
1.	Limestone, hard, light colored, fossiliferous	2
	Total	23

Below the dam the stream flows over a rock bottom consisting of limestone No. 1 of the section just given. At high water No. 2 is covered. Strata Nos. 1 and 3 bear the following fossils:

Spirifer cameratus
Productus (fragments)
Crinoid stems in great abundance.
Rhombopora lepidodendroides.
Composita subtilita.
Fenestella—sp.
Derbya crassa.
Myalina subquadrata.

Number 2 of the section at Port Union bears the following:

Nucula (ventricosa?).
Aviculopecten occidentalis.
Monotis (gregaria?).
Nuculana bellistriata.
Unidentified gasteropods.
Numerous molluscs.

A complete list of the fauna must be reserved for a future report. It is essentially molluscan in its character, and is characterized by the absence of *Productids, Spirifers,* and crinoid stems, all of which are present in the limestones both above and below, and by the absence of *Chonetes verneuilianus,* a fossil that is characteristic of the shales farther down the river.

Exposure No. 4 is on the south bank of the river, in section 21 of Harrison township. Twenty-two feet of limestone is here exposed.

		FEET.
6.	Till, blue below, yellow at surface, slightly gravelly in places	5
5.	Limestone, light-colored, massive	1
4.	Limestone, fragmental, fairly compact below, then with frequent partings of soft clay, finally shading up into a soft purple clay in which but few hard limestone fragments occur	14½
3.	Limestone, hard, light colored, fossiliferous	1
2.	Shale, soft, blue-black	2½
1.	Limestone, light buff, fossiliferous, largely concealed by talus	3
	Total	27

Stratum No. 1 of this exposure bears *Composita subtilita* and fragments of an unidentified *Spirifer.* The only fossil found in No. 2 is *Chonetes verneuilianus,* but the search was not long continued at this point. No molluscs were observed. In color and texture the shale is precisely similar to that found at Port Union. The limestone fragments of No. 4 are light in color, of variable hardness, and inclined to be angular. The clay is of about the consistency of the harder Kansan till, or "hard-pan," breaks in the same way, checks on drying, and loses color on exposure to the weather. The original color is not the blue-black of the typical shale, but a blue-purple which approximates the color of the deeper Kansan drift. On leaching it passes through the various shades of purple-brown, dark-brown, light-brown and yellow-brown. It is nonfossiliferous, and contains no rock fragments other than the nodular masses of limestone already mentioned. It seldom shows distinct marks of stratification. Strata Nos. 4 and 5 are again exposed in a ravine which comes down parallel with the course of Middle river and enters the latter a few rods below the exposure just described. The characteristics differ in no way from those already given, except that stratum 5 is two feet or more in thickness. On a small tributary in section 22 three feet of buff limestone is exposed, the underlying rock being hidden. In this exposure were found specimens of *Productus nebrascensis.*

The next exposure is in a narrow ravine on the Pemberton farm in section 27, Harrison township. A second section is exposed somewhat further down the ravine, and the two in combination give the following:

		Feet
10.	Till, Kansan, with small bowlders	3
9.	Clay, blue, similar to that found in stratum No. 4 of the fourth exposure	2
8.	Limestone, buff	1
7.	Limestone, fragmental, with much purple clay	6½
6.	Limestone, buff	1
5.	Limestone, fragmental	3
4.	Limestone, buff to dark brown	2
3.	Hidden by sand, clay and bowlders accumulated in stream bed	3
2.	Limestone, buff to dark brown	1
1.	Shale, dark blue-black	2
	Total	24½

Fig. 38.—Exposure near the mouth of a ravine on the Pemberton farm in section 27, Harrison township, Adair county.

Near the top of No. 9 is a band of very brittle black shale about half an inch in thickness. No. 10 is unconformable upon No. 9, the difference in color and texture being readily distinguishable at a distance of twelve or fifteen feet. The Kansan here is leached to a light yellow, and bears a few pebbles and small bowlders. The blue clay is nonfossiliferous. The blue shale (No. 1) contains specimens of *Chonetes verneuilianus*. This shale is almost black in color, and similar in texture to that found at Port Union. Limestone No. 4 contains an abundance of *Rhombopora lepidodendroides.* Many crinoid stems are present also.

In section 26 of Harrison township the following exposure is found in the valley of a small brook putting in to Middle river from the south:

		Feet	Inches
11.	Till, Kansan, gravelly, dark colored	3	
10.	Limestone, hard, brown-buff		8
9.	Clay, purple, weathered brown to yellow	1	6
8.	Shale, black, laminated, very soft		1
7.	Limestone, fragmental, grading upward into clay	10	
6.	Limestone, buff, with 2 shale bands	5	
5.	Limestone, fragmental	5	
4.	Shale, very fossiliferous, blue-black	2	
3.	Limestone, hard, bluish	5	
2.	Shale, very soft, blue-black	2	
1.	Shale, brittle, black		6
	Total	34	9

Stratum 6 of this exposure contains quantities of *Fusulina cylindrica.* Number 10 is entirely nonfossiliferous. Number 3 contains *Spirifer cameratus, Productus punctatus, P. costatus, P. longispinus, Derbya crassa, Rhombopora lepidodendroides,* many crinoid stems, and other fossils. Number 4 contains *Chonetes verneuilianus.* The last of the Middle river exposures in Adair county is near the east line of section 36, Harrison township. Several feet of blue-black shale occur capped by massive limestone.

On Bush's Branch, in section 13, Grand river township, occurs the following exposure:

		Feet
2.	Alluvium	3
1.	Soft black shale	5

The black shale is extremely rich in specimens of *Chonetes verneuilianus* which, when the spot was last visited, had weathered out clean and formed a small talus at the foot of the bank. This is the last of the Carboniferous exposures in Adair county. Near the old mill at the village of Webster, in Madison county, something over a mile east of the exposure found in section 36 of Harrison township, several feet of rusty-colored *Fusulina* limestone is exposed, but its relations to the beds above and below have not been traced by the writer.

The general dip of the limestone in Adair county is toward the south. Middle river, cutting in a southeasterly direction through these southerly dipping strata, gives them an apparent dip to the southeast. The apparent southeast dip is of course less than the actual southerly dip. The former amounts to about ten feet to the mile, or about the same as the gradient of the bed of Middle river.

Sections of Indurated Rock West of the Divide

The west half of the county is covered by a thick mantle of drift, and no streams cut to bedrock. Consequently the only obtainable evidence as to the nature of the indurated rocks is to be obtained from deep borings, and the number of the latter records of which have been preserved is all too small. The results indicate that the surface of the Missouri is at places covered by a veneer of Cretaceous sandstone belonging to the Dakota stage. The following shafts have been investigated.

On the farm of J. A. Hulbert, in Washington township, four and one-half miles southeast of Bridgewater, rock was encountered at the depth of 275 feet. After penetrating twelve feet of soft sandstone, further drilling was abandoned.

At the residence of J. G. Hendry, one mile south of Bridgewater, a well was sunk about 1897, and the record, carefully preserved by Mr. Hendry, reads as follows:

	Feet
Blue clay	65
White clay	40
Gravel	1
Dark, soft, sandstone	12
Hard clay, dark in color	2
Sandstone	18
Slate	2
Coal	1.8
Limestone	18
Quicksand and water	
Total	159.8

The gravel occurring just below the white clay is described as consisting of pebbles which were much water worn and very hard, and of rather uniform size. The white clay was of such a character as to color the water milky when it was first drawn from the well. Both it and the blue clay above contained few pebbles. Eighty feet lower down the hillside, and half a mile or less from the site of the first well another shaft was put down with the following result:

	Feet
Blue clay	177
Red clay with many pebbles	3
Blue-black Carboniferous shale	40
Total	220

The black shale contained two or three narrow bands of coal, but was otherwise homogeneous in its nature, and of a smooth even consistency. The "red clay with many pebbles" is probably a phase of the Dakota sandstone. In the first section the line of separation between the Missouri and Dakota is the two feet of black shale lying immediately above the stratum of coal.

On the farm of E. Stacey, one mile northwest of Bridgewater, in the digging of a well shaft a forest bed was struck at the depth of forty feet. After taking out a section of a good sized log, probably of cedar, digging was resumed. Ten feet lower the auger entered black shale. The water was dark in color, and had a bad taste. No indication of the presence of Cretaceous materials appeared in this well, the drift lying in immediate contact with the Missouri shale.

On the farm of W. W. Witham, in Summerset township, a short distance west of Greenfield, a well was sunk to the depth of 275 feet. At about 240 feet the drill passed into limestone with bands of black and blue shale. No Dakota gravels or sandstones were present. The Missouri limestone was covered by 240 feet of blue clay, with some small pebbles and bowlders.

A shaft sunk by the city of Greenfield for the purpose of securing a water supply for the municipal electric lighting plant passed through 208 feet of bowlder clay and 13 feet of Missouri limestone and shale. No gravels were encountered. A few small pebbles were found in the clay, and at one point a thin bed of sandy clay was encountered. As usual, the complete record was not preserved.

A shaft sunk on the farm of F. H. Seers, five miles north of Fontanelle, is reported as passing into soft sandstone at a depth of 260 feet. About twenty feet of the sandstone was penetrated without any change in the nature of the materials being noted.

On the farm of Henry Rose, two miles north of Bridgewater, Missouri limestone was struck at a depth of 270 feet, while a shaft on the farm of Al. Bowers, a mile or two north of the Rose farm, passed into Dakota sandstone at a depth of 260 feet. Forty feet of "fine-grained sandstone" is also reported from a well bored by William Turner near Adair.

The only record of Dakota sandstone east of the divide is given by Simpson in Norton's report on the Underground Waters of Iowa. This is a well bored on the Whittum farm in section 19 of Lincoln township.

Enough has been said to indicate that the surface of the Missouri rock in the northwestern half of Adair county is dotted with scattered outliers of Dakota sandstone. Probably no part of the county is covered with a solid and continuous mass of Cretaceous rock. The variation in the depth at which rock is encountered indicates two things: the depth of the erosion to which the drift has been subjected, and the depth of erosion to which the underlying rocks were subjected before the coming of the ice-sheet.

The abandoned Eureka coal shaft, six miles south of Adair, passes entirely through drift and Missouri rock. The shaft is now partly filled, and is not in condition for examination, but it was described by Keyes (Iowa Geological Survey, Volume II) as follows, in the year 1894:

The shaft is 262 feet in depth, the coal varying from twenty to thirty-two inches in thickness. The roof is bituminous shale. The bottom of the shaft shows:

	Feet	
Clay shale (exposed)	2	
Coal	2	
Fire clay		2-3
Shale, dark (exposed)	1	1-3
Total	6	

The mine is worked on the long wall plan. There are a few unimportant clay seams, but no other breaks in the continuity of the bed. This is a new mine. The coal has been taken out only from about 150 to 200 feet to the east and west of the bottom of the shaft. It is reported that there are two other seams below the one now worked, one at a depth of about forty-five feet and the other at a depth of about fifty-five feet from the bottom of the shaft.

In June, 1892, a correspondent of the Greenfield Transcript wrote as follows:

The size of the shaft is 6x16 feet and is divided into three apartments. At the depth of over a hundred feet they found a cedar post. The dirt passed through was very hard and had to be dug with a pick. Thence through different kinds of clay and into soapstone. The caprock is four feet and nine inches thick. After passing that, came into two feet of black looking substance which contained coal blossom; passing on into slate, thence into a three foot vein of good coal. The shaft is 228 feet deep, and the coal is deposited 268 feet from the top of the ground.

The evidence of a forest bed, in the shape of a cedar log, is suggestive of Aftonian deposits. No Cretaceous rocks appear at this point. The coal in the shaft near Bridgewater is probably to be referred to the horizon of the Nodaway coal as described by Smith for the counties south and southwest of Adair, but the information is so scanty that no definite correlation is yet possible.

COMMENT ON CORRELATION AND STRUCTURE

JOHN L. TILTON

The blue-black shale which Gow mentions as being present in section 36 of Harrison township, Adair county, is Lawrence shale, between the Iatan limestone below and the Oread limestone above, in the Douglas division of the Missouri stage.

The isolated group of outcrops in the central part of Harrison township belongs to the Oread (Plattsmouth) substage, Douglas division of the Missouri stage. The outcrop described by Gow that is located in section 27 (northwest quarter of the northwest quarter) is an almost exact reproduction of the section at the brickyard south of Plattsmouth, Nebraska, and of the outcrop at Fox quarries, Cass county, Iowa, together with beds of limestone and associated shale found along the river from Fox quarries to Reno. The Oread limestone in Adair county is more shaly than that in Nebraska, but there is the same general distribution of fossil content in all three regions: Adair and Cass counties, Iowa, and eastern Nebraska. At the bridge in the southwest quarter of the southwest quarter of section 22, Harrison township, low water in the river is at the level of a lower portion of this limestone. Near the old mill in the next section northwest (section 22) the river crosses the eight feet of shale that appears in the lower third of the cliff in section 27, above which the next group of limestone appears in the river bank. The topmost, very fossiliferous beds of section 27 have been eroded away near the mill.

Four miles further up the river (northwest quarter of section 12, Grove township) the thick limestones in the hillsides apparently are the Cullom and Cedar Creek limestones, with accompanying shale, of the Nebraska section, the Lecompton limestone of the Missouri section.

The very small exposure of limestone in section 16, Jefferson township (southwest quarter of the southwest quarter), is judged to be one of the lowest beds of the Deer creek (Forbes) limestone. The reason why no more of this limestone appears up the river is because the limestone has been removed from the upthrow side of a normal fault* near at hand. Strata of the lowest part of the Kansas City division of the Missouri stage have been encountered beneath the drift at the Eureka shaft in the northwest part of the county (north center of section 4, Eureka township).

The difficulties in determining the relation of the strata in this part of the state have been due (a) to the presence of thick drift concealing all beds except in these isolated positions; (b) to the near proximity of Kansas City beds immediately north of the Stuart-Casey region† without recognition of a fault of about 284 feet throw between that district and Arbor Hill; (c) to the presence of a nearly complete section of the Kansas City division

*Note Gow's description of brecciated limestone.

†In the summer of 1920 the writer was convinced that the strata north of Stuart, mapped by Bain as of the Missouri stage, are not Missouri in age, but belong to the Des Moines stage and are located well down in that stage.

nine miles east of the county, with the thinned shale and limestone concealed by drift between that locality and Adair county. The thinning of these beds has not previously been recognized for this region.*

The relation of conditions in these adjacent regions will now be more fully stated.

Adjacent Regions

Nineteen miles a little north of west of the isolated outcrops of Missouri limestone in Harrison township is the location of an old mine in section 4 of Eureka township, Adair county, reported by Keyes and also by Gow, with shaft passing through the base of the Missouri stage into the Des Moines, reaching a seam of coal at a depth of 262 feet below the upland and apparently ending in coal eighty-six feet below the Bethany Falls (Earlham) of the Madison county section, and thirty feet below the Hertha limestone.†

Bain mapped the most western exposure of the Des Moines stage in Guthrie county, three miles north of Stuart, thirteen miles to the north of the isolated outcrops.

Twelve miles east of the outcrops and a little south the base of the Missouri stage passes beneath the bed of Middle river, while Cherryvale shale and DeKalb limestone are in the upland.

Such a relation to the west, north and east, in a region where the dip is slight, might lead to the expectation that the isolated outcrops of Harrison township belong near the base of the Missouri stage. When, however, the sections described by Gow are compared with sections near Earlham and Winterset it is found that the sections described by Gow do not fit into the sections found in those places. Unfortunately, neither individual fossils nor the entire assemblage of fossils named in Gow's lists aid in fixing precisely the position of the beds. All the fossils listed are found throughout the central portion of the Missouri stage in Missouri, and also throughout the central portion of the Missouri stage as far as known in Iowa.

Referring to adjacent regions to the southeast and to the southwest, the writer found in Clarke county, the next county to

*John L. Tilton, The Thurman Wilson Fault through Southwestern Iowa, and its Bearing: The Journal of Geology, Vol. XXVII, pp. 383-390, 1920.

†According to the note on page 298 this stratum of coal is farther down in the Des Moines stage.

the southeast, that an average dip of 9′ 26″, fourteen and a half feet per mile, was all that was necessary, even without a thinning of beds in the intervening region, to carry the Bethany Falls (Earlham) limestone, outcropping in the hillsides north of Osceola, down so that the Westerville limestone, which belongs considerably above the Bethany Falls limestone, is at the level of Grand river near the southwest corner of Clarke county. Between these two points the strata in Clarke county are completely concealed by the overlying drift; but there can be no southeast-northwest fault concealed there, for directly south in Decatur county Bain found no break in his section along Grand river from the base (Hertha) up to the last outcrop which he describes, which is that of the beds of Westerville limestone just mentioned.

Twenty-one miles to the southwest of the outcrops in Harrison township coal has been reported near Bridgewater, a few miles north of the area where G. L. Smith found that the coal mined was Nodaway coal, with which decision the results of the work in and near Cass county by the present writer are in accord. This coal, far up in the Missouri stage, is thus found only thirteen miles south of the old shaft above mentioned, in Eureka township, where coal was formerly obtained from the Des Moines stage—a stratigraphic difference of 743 feet, according to the Clarinda well record, which should be diminished by 70 feet to 673 feet because of thinning of strata as stated in the report on the "Geology of Cass County, Iowa." This is an average of 51.8 feet to the mile, that would require only an average dip of 33′ 44″ straight south, or of 1° 7′ 8″ southwest, in the supposed general direction of the dip.

HOW THE HORIZON AT BRIDGEWATER WAS ASCERTAINED

As no section east and west across southwestern Iowa can be made directly from exposures, without referring to data from elsewhere, recourse must be had to results of work along Missouri river. A number of years ago Bain correlated the Winterset and the Decatur county sections with the beds at Bethany Falls, Missouri, but unfortunately he mistook the limestone at the mills at Bethany Falls for his "Fragmental" limestone (Hertha). It was to test the criticism by F. C. Greene, and also to correlate the strata in Clarke county, that the present writer went with Greene to Bethany Falls, and later reported in a paper that some of the writers on Geology seem to have overlooked[2]. Hinds and Greene have since then completed their section across the Carboniferous of Missouri, reviewing Broadhead's section; and, while their work was progressing, G. L. Smith[3] connected the Carboniferous section of southwestern Iowa with Broadhead's section, including in his correlation the beds at Stennett, Montgomery county, Fox quarries[4], Cass county, and the coal at and near Briscoe[5], Adams county. At Briscoe the coal is about eighteen inches thick, at a depth of 121 feet from the hillside; Gow gives its thickness as twenty inches at Bridgewater at a depth of 140 feet, or about the same distance beneath the level of the upland as the coal at Briscoe. Limestone lies beneath the coal at both places. Since at the old shaft, fourteen miles north in Eureka township, the coal is 262 feet below the level of the upland, and the general dip is to the southwest in that region, that seam of coal should be far below the seam of coal found at Bridgewater, even if the shaft in Eureka township were not on the upthrow side of a fault plane between the two locations. Further, the only other seam of coal between the Hertha limestone and the Nodaway coal seam that could possibly claim attention from its relations, that is the seam four to six inches thick in the Ladore shale, beneath the Bethany Falls (Earlham) limestone, does not meet at all the conditions found south of Bridgewater and near Briscoe. Thus the argument from relations north of Bridgewater agrees with conclusions G. L. Smith reached in a study to the southwest toward Briscoe. Under these conditions it seems indisputable that the coal seam found near Bridgewater is the Nodaway coal seam.

A Fault Plane

Todd[6] first recognized the presence of a fault near Thurman and the Wilson quarries in Fremont county. Later Smith deter-

[2]John L. Tilton, "The Proper Use of the Geological Name, Bethany:" Proc. Iowa Acad. Sci., Vol. XX, p. 207, 1913.

[3]G. L. Smith, "Carboniferous Section of Southwestern Iowa:" Iowa Geological Survey, Vol. XIX, pp. 627, 628 and 654.

[4]The relation of the beds at Fox quarries was not worked out. It was misjudged, apparently because of the proximity of Fox quarries to Briscoe. A fault with a throw of 284.5 feet passes between these two points.

[5]Keyes thought the coal seam near Briscoe was "apparently the Nodaway coal seam." See Iowa Geological Survey, Vol. II, p. 440, 1894, (but Briscoe is there incorrectly located as in Cass county).

[6]J. E. Todd, "On the Folding of Carboniferous Strata in Southwestern Iowa:" Proc. Iowa Acad. Sci., Vol. I, Part 1, p. 61, 1887; also, "Some Variant Conclusions in Iowa Geology," Proc. Iowa Acad. Sci., Vol. XIII, p. 184, 1906.

mined the throw at that point to be three hundred feet[7], with uplift to the north, and suggested that: "A continuation of the line of displacement from Jones Point to the Wilson section would pass south of the exposure of the Forbes limestone at Malvern, Stennett and Grant, and would thus give an explanation of the appearance of the limestone at those places[8]." He also states concerning the extension of this fault line: "The fault near Lake Wabonsie has, probably, in its eastward extension, become an anticline[9]," etc.

The present writer finds that the fault does not become an anticline near Stennett. He finds it to be a normal fault passing between Briscoe and the Fox quarries, at which point the displacement is 284.5 feet, with the upthrow on the north[10]. If this throw continued to diminish northeastward at the same small rate it would continue northeastward beyond the limits of the state. On tracing relations across the county the fault is found to pass northwest of Bridgewater, and apparently northwest of section 21, Jefferson township. At the northeast corner of section 11, Grove township, not far from the fault plane, the dip of the limestone is found to be 1° 15′ N. 80° W., as if on the southeast side of the fault plane. The effect passes on toward the northeast for a distance beyond Arbor Hill, but the main displacement is farther north at a parallel fault in Guthrie county.

In the above let it be noted (a) that north and south along the east side of the county no displacement of strata exists; (b) that along the west side there is a displacement of 284.5 feet with upthrow on the north; and (c) that the plane of the fault passes diagonally across the county from north of the southwest corner to west of the northeast corner.

A FURTHER TEST

The above argument is complete, but a further discussion dependent on general dip may be acceptable. The exact level of the base of the Hertha limestone at the old shaft in Eureka township, and of the coal at Bridgewater, are not known, but the estimates obtainable are believed to be sufficiently close to bring out the general relation.

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[7]G. L. Smith, "Carboniferous Section of Southwestern Iowa:" Iowa Geol. Surv., Vol. XIX, p. 612, 1908.
[8]Idem, p. 649.
[9]Idem, p. 636.
[10]See report on the Geology of Cass County, this volume.

On the north side of the fault plane two points can be selected for the determination of the dip between them in a direction approximately parallel to the fault plane: On Turkey creek two miles north of Lewis, in section 1 of Cass township, Cass county, the thick bed of the Oread limestone is at 1,123 feet above sea level. In section 4 of Eureka township, Adair county, the bottom of the Missouri stage is estimated to be at 1,239 feet above sea level. The thickness of the strata between these two points, according to the record of the Clarinda diamond drill hole,[11] is 470 feet, which should be changed to 400 feet because of thinning of beds as stated in the Cass county report. To this should be added the 116 feet difference in elevation, making 516 feet to be accounted for in a distance of twenty-two miles, which difference must be accounted for by dip (modified by thinning of strata), by faulting and by unconformity. There is no recorded evidence of faulting or of marked unconformity in this part of the section, except as stated in this discussion, but the strata do become thinner toward the northeast. The difference of 23.45 feet per mile would correspond to an average dip of 15′ 16″ if referred to dip alone.

On the south side of the fault plane a determination of the dip may be made in a similar manner. From the base of the Nodaway coal seam at Briscoe to the base of the Hertha limestone, the record of the diamond drill hole at Clarinda gives a thickness of 656 feet, which should be lessened by 70 feet to 586 feet because of thinning out of strata as stated in the Cass county report. From this must be subtracted 82.5 feet, the difference in level between the Nodaway coal (1,014.5 feet above sea level) at Briscoe and the base of the Hertha limestone (932 feet above sea level) at the "Backbone." This difference of 503.5 feet must be accounted for in a distance of 42 miles between Briscoe and the "Backbone," nine miles east of Adair county. At present there is no recorded evidence of a fault plane running northwest-southeast through this region. There is, however, a thinning of strata toward the northeast, which, because of the proximity of the two regions on opposite sides of the fault plane, is here overlooked. The entire difference of 503.5 feet could be accounted for by an average dip of 12 feet per mile (7′ 49″) along the line from the "Backbone" to Briscoe, which is half that found in the same direction along the north side of the fault plane, with the difference in part, at least, due to thinning of strata.

It is not necessary to assume any considerable continuation of the Wilson fault north and south along the east side of the county past Harrison township, so far as thickness of strata is concerned. At Stuart the base of the Hertha limestone is taken to be at 880 feet above sea level. Ten miles south it is, according to the section from Briscoe to the "Backbone", at 802 feet above sea level, a fall of 7.8 feet per mile, or of 5′ 5″, which would give 15.6 feet per mile southwest. This accords fairly closely with the dip of 17 feet per mile southwest obtained from the fall in the strata in ten miles from 1,000 feet above sea level at Earlham to 915 feet above sea level at Stuart.[12]

North and south along the west side of the county, however, from the old shaft in Eureka township to the coal south of Bridgewater, a distance of thir-

[11]Smith, G. L., Idem, p. 618.

[12]H. F. Bain, "Geology of Guthrie County, Iowa:" Iowa Geological Survey, Vol. VII, p. 428.

teen miles, across the fault plane, there is, as above stated, a stratigraphical difference of 743 feet according to the Clarinda well record, which should be diminished by 70 feet to 673 feet because of thinning of strata. At this point (Bridgewater) the Nodaway coal seam is not far from 1,076 feet above sea level, and the base of the Hertha not far from 403 feet above sea level. To this should be added 163 feet for the difference in level between the Nodaway coal at Bridgewater and the base of the Hertha at Eureka shaft. The 836 feet if referred to dip alone would require an average dip of 64.3 feet per mile, or 41′ 52″, to the south. If from this an average dip to the southwest were computed it would be 1° 23′ 44″, an average even greater than the dip found to the northeast near the fault plane, in section 12, Grove township.

Thus north to south along the west side of the county the difference is 8.24 times the difference along the east side of the county, while east and west along the general direction of the fault plane the difference per mile on the south side, where the strata are thinned out more than on the north side, is about half that along the north side. The differences are clearly in harmony with the presence of the fault as worked out in Cass county, and without field evidence that suggests warping in this locality.

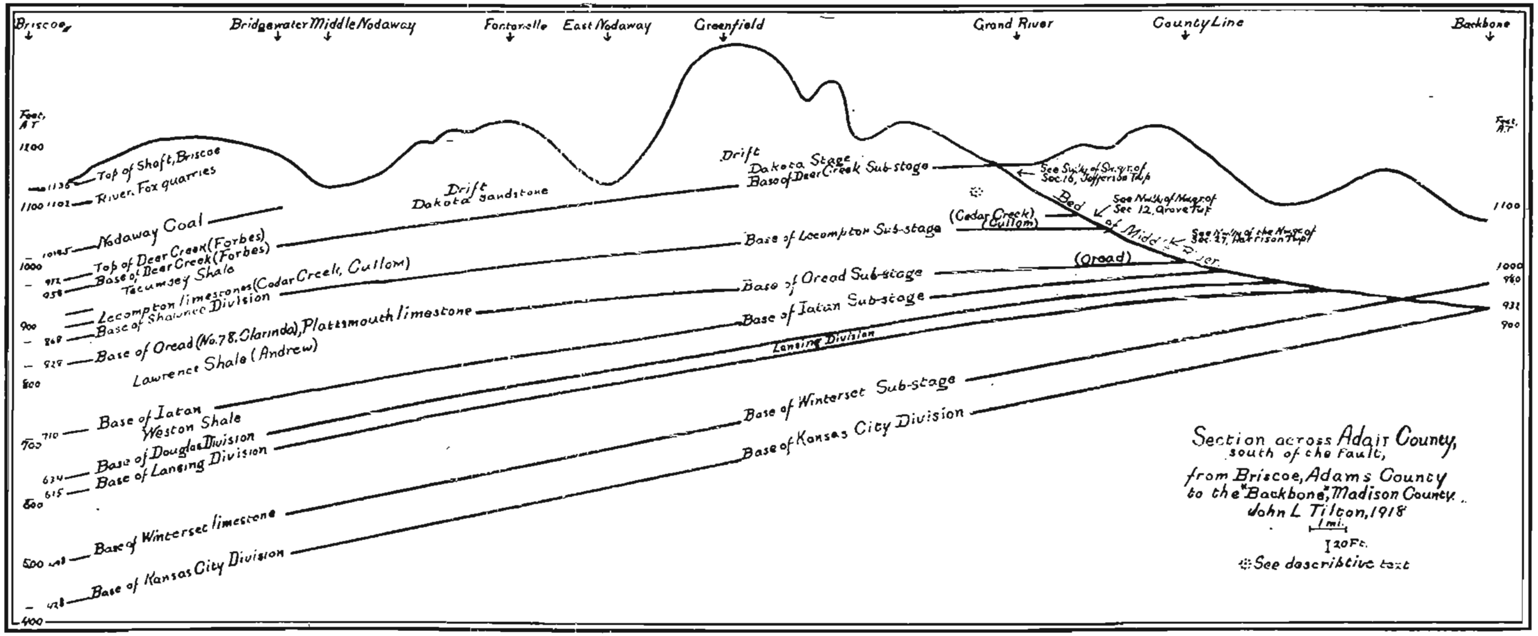
It is further noted that the dip measured in Grove township near the fault is, as stated above, northwest instead of southwest.

Location of the Beds

With an average dip of twelve feet per mile (0° 7′ 49″) on the south side of the fault plane for the entire distance of forty-two miles from the "Backbone" to Briscoe, the base of the Hertha limestone in Harrison township would be 132 feet below the level of Middle river at the "Backbone." If the slope of the river bed is 5.5 feet per mile, as was determined farther down the stream, although it may be more here, sixty feet must be added to the 132 feet, giving 192 feet. This number of feet above the base of the Hertha limestone is a stratum 519 feet from the surface in the Clarinda diamond drill hole. From this computation it is evident that the Stanton limestone is below the bed of the river where the limestone outcrops in the eastern part of Adair county, and that the limestones found in Adair county are a part of one of the important divisions not far above the Stanton.

The following facts also have a bearing on the question:

1st. The Kansas City division thins out from 165 feet thick at Clarinda to 125 feet at the "Backbone."



Section across Adair county, south of the fault, from Briscoe, Adams county, to the "Backbone," Madison county.

2d. "The thinning of the Lawrence shale is from south to north, as is the case of most of the other thick shale members[13]."

3d. There are apparently faunal breaks at the base of the Lansing, beneath the Oread, and in the Shawnee[14], with some evidence of erosional unconformity.

4th. The Deer creek limestone (Forbes) suffers a very pronounced diminution in thickness between Nebraska and Stennett.

5th. Between Briscoe and Bridgewater the Nodaway coal is essentially horizontal, so that at Bridgewater the seam is forty feet below what the average dip from the "Backbone" to Briscoe would lead one to expect to find it.

6th. There is no bed of limestone seen by the writer nor reported either by Gow or by others in the river valleys of Adair county west of Arbor Hill.

All six of these points agree, forcing the conclusion that the Missouri stage as a whole not only has disappeared by erosion at the exposed preglacial surface of the entire stage, but that the various members thin out rapidly to the northeast in this portion of the state.

The Iatan limestone lacks the persistency as a formation that marks the limestone in Harrison township, and the sequence of limestone and shale reported elsewhere for the Iatan does not agree with what is found in Harrison township. The Oread limestone is a resistant ledge, with divisions corresponding to what is here found, less the uppermost portion removed by erosion, and with fossil content agreeing in relative abundance—most pronounced in *Fusulina* beds.

It is therefore the judgment of the writer that these isolated outcrops in Harrison township of Adair county belong to the Oread and associated limestones. He also finds that, situated on the south side of the fault plane, they are the equivalent of the beds at Fox quarries, Lewis and Turkey creek, Cass county, situated on the north side of the fault plane. Other beds of the Missouri stage in which shale is the important element lie concealed beneath the thick deposits of drift along the divide between Arbor Hill and Bridgewater.

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[13]Hinds and Greene, "The Stratigraphy of the Pennsylvanian Series in Missouri:" Missouri Bureau of Geology and Mines, Vol. 13, 2d Series, p. 170.
[14]Idem. pp. 155, 169 and 183.

SECTION ACROSS ADAIR COUNTY

The section across the county east and west south of the fault plane is expressed in the accompanying diagram, which may be compared with a diagram of a section east and west across Cass county along a line north of the fault plane. It should be noted that the fault is a dip or slightly oblique normal fault, with offset of thirty-five and one-half miles, and a thinning of strata toward the northeast.

In order to express the relation of the beds that outcrop along Middle river in the eastern part of the county it has seemed desirable to represent the base of the Deer creek substage as it meets the bed of Middle river, which in a straight line is ten and three-fourths miles northwest of the base of the Oread substage where it outcrops in Harrison township. As the strata rise to the north this makes it appear as if the Tecumsey shale became thicker, when in reality all the strata become thinner to the northeast. To obtain the average component of dip in the direction indicated the dip illustrated should be divided by 88 1-3.

THE GLACIAL AND INTERGLACIAL DEPOSITS

JOHN L. TILTON

The glacial and interglacial deposits consist of the Nebraskan, or oldest drift, the Aftonian interglacial deposits, and the Kansan, or uppermost, drift. The lower portion of the loess may also be mentioned here, for the deposition of the loess probably began while the northeastern and northern parts of the state were occupied by ice sheets later than the Kansan, and continued in varying amounts up to the present.

The Nebraskan drift underlies the Kansan drift in parts of Adair county, but it is impossible from existing evidence to define its distribution exactly. From the few places where the stratified rock appears at the surface and from the many more locations where wells reach the stratified rocks without encountering it, it is evident that the Nebraskan drift is now absent from a portion of the county. That it was once present even in those places is evident from its present position in other parts of the county, from the evidence of weathering that the surface of that drift presents, and from evidence that the surface of that drift has been removed in places by stream erosion in the Aftonian interglacial interval that followed the deposition of the drift. Some of the Nebraskan drift lying in places exposed to erosion by the Kansan ice sheet undoubtedly was removed as that sheet spread over the country. The Nebraskan drift has also in post-Kansan times been removed somewhat in places by streams that have cut through the Kansan drift into the Nebraskan drift.

It has been shown recently by Kay that in many places in Iowa there has been developed on each of the older drifts, the Nebraskan, the Kansan, and the Illinoian, a sticky, tenacious clay, to which the name gumbotil has been given[15]. In Adair county the Nebraskan gumbotil has been found in many places underlying the Kansan drift, and the Kansan gumbotil is found consistently at or close to the surfaces of the remnants of the Kansan upland plain[16].

In the following localities the Nebraskan gumbotil, which separates the Nebraskan drift from the Kansan drift, is about eighty feet below the level of the upland or at a level of 1,136 feet above sea level, since the level of Stuart is given as 1,216 feet above sea level. The Nebraskan gumbotil is three to four feet thick in a few places where its thickness could be noted:

Lincoln township	Se qr of the Se ¼ of section 35
	Eastern portion of section 30
Grove township	Se qr of the Se ¼ of section 14
Harrison township	Sw qr of the Nw ¼ of section 24
	Ne qr of the Ne ¼ of section 30
Summerset township	Sw qr of the Sw ¼ of section 28
	Se qr of the Sw ¼ of section 29
	Ne qr of the Sw ¼ of section 16
Grand River township	Se qr of section 10
Washington township	Sw qr of the Se ¼ of section 29
Orient township	Se qr of the Se ¼ of section 3
	East center of section 9
	Sw qr of the Sw ¼ of section 29
Union township	Se qr of the Se ¼ of section 19.

There are numerous places where the roads cross the level of the Nebraskan gumbotil on the slopes of the hillside, so that the

[15]Kay, George F., Gumbotil, a New Term in Pleistocene Geology: Science, new series, Vol. XLIV, November 3, 1916.
[16]Kay, George F. Some Features of the Kansan Drift in Southern Iowa: Bull. Geol. Soc. of Amer., Vol. 27, pp. 115-117; also Iowa Geol. Surv., Vol. XXV, pp. 612-615.

gumbotil if there present merges with the black soil at the surface.

The tendency of the ravine bottoms to widen out at this same level was so conspicuous that it did not seem fortuitous, but seemed rather to be dependent upon the porosity of the gumbotil and the ease with which it was eroded, thus extending the flat and allowing the Kansan drift above it to be eroded further back. Some of these conspicuous flats are the following:

Walnut township	Southern part of section 32
Jefferson township	Section 8, and Sw portion of section 14
Prussia township	Se qr of the Se ¼ of section 26
	Centers of sections 9 and 10
Summerset township	Section 8
	Sw qr of section 20, and southern part of section 22
Richland township	West part of Se qr of section 21
	Se qr of Se ¼ of section 25
	South central part of sections 27 and 28
	Nw qr of section 28

It will be observed that none of the above locations are in the northwestern portion of the county, nor in the upland anywhere in the county. The Nebraskan gumbotil can be found only where stream valleys and ravines have been cut deep beneath the surface.

What the thickness of the Nebraskan drift, and what the character of it may be beneath the gumbotil can be ascertained only from well records, none of which, unfortunately, give us the necessary data, though two records, numbers 11 and 12, page 314, give depths of 208 and 240 feet respectively, which reach 128 and 160 feet below the level at which the upland phase of the Nebraskan drift, that is the Nebraskan gumbotil, was noted. It is possible that the deepest portions of such wells are really in Nebraskan drift which from meager evidence it is impossible to differentiate. It is also possible that such wells are in Kansan drift only. In this case some of the valleys eroded in the Nebraskan drift in Aftonian times and since then filled in by Kansan drift were from 128 to 160 feet deep, which is a considerably greater depth beneath the Nebraskan gumbotil plain than is yet reported in other counties.

The Aftonian interglacial deposits include such deposits of sand, gravel and related deposits as were laid down in the long interval of time that elapsed between the melting of the Nebraskan ice sheet and the advent of the Kansan ice. The material was obtained largely from erosion of the Nebraskan drift, and partly from erosion of such sandstone, limestone and shale of underlying formations as may have been exposed. Here also must be included the gumbotil developed from the Nebraskan drift. While the gumbotil itself is a part of the Nebraskan drift the surface of it marks the level of an extensive plain developed first as weathering proceeded and later trenched by stream action following uplift, or change that quickened the streams, through whose work the sand, gravel and clay were sorted and distributed to lower levels. Here also are included forest beds and peat developed in the latter part of the Aftonian times. Evidence of such accumulations in this county must be derived largely from well records, a number of which are included in the description that follows that of the Kansan drift. Evidence of interglacial conditions is especially noticeable in well records numbered 2 and 3, and in the general statement of well diggers.

The Kansan drift is the bowlder-bearing clay that can be seen exposed on the hillsides in all parts of the county. On it and related topographically to the upland plains is Kansan gumbotil. The gumbotil apparently is composed of the former surface deposits of the Kansan plain so changed by long continued weathering that the pebbles and bowlders have been almost completely lost by solution. The soluble portion has been carried away and the clayey portion has thus been relatively increased. By these processes the surface of the drift has been converted into gumbotil, with loss of the characteristics that may have originally marked the surface of the ground moraine.

It is the surface of this Kansan gumbotil or the overlying loesslike clay that forms the rich soil of the upland, from which surface much material which was formerly there has been washed to lower levels and in many cases transported completely away from the county. It is from the Kansan gumbotil that water seeps out upon the hillsides after rainy weather forming the springy ground there so noticeable. Pebbles and sand are sometimes found above this level upon the hillsides, but bowlders, never.

Beneath the gumbotil a yellowish red oxidized portion of the Kansan drift with numerous accompanying pebbles is a marked characteristic along roads and ravines at about forty feet below the general level of the upland. A count of the pebbles in the drift was made in Jackson township, southwest quarter of the southeast quarter of section 13, with the following result:

Red quartzite	30	Quartz schist	2
Dark quartzite	1	Hornblende schist	2
Light quartzite	13	Dark schist	1
Greenstone	30	Limestone, gray	3
Dark granite	1	Chert, gray	6
Light granite	4	Sandstone, reddish brown	1
Decomposed granite	1	Iron concretions from sandstone	1
Quartz	4		—
			100

A deeper phase of the same bowlder-bearing portion of the Kansan drift is dark blue in color, and even black. This phase is seen only in material taken from wells, and on the sides of ravines where water has cut back through the weathered portion of the drift. Drift of this character is to be seen immediately south of the wagon bridge over Middle river a mile east of Casey (Walnut township, northwest of the northwest quarter of section 1). Here in a cliff twenty-three feet high from low water level the exposure is as follows:

	Feet
Clay, brown	6
Sand	2
Clay, dark brown above to black below; containing pebbles up to six and eight inches in diameter	15

The following count of pebbles was made at this location:

Red quartzite	16	Quartz	5
Dark quartzite	2	Quartz schist	2
Gray quartzite	2	Sandstone (not native)	4
Light quartzite	3	Sandstone (native)	6
Greenstone	23	Iron concretions from sandstone	1
Dark granite	5	Black shale	1
Light granite	8	Chert	18
Decomposed granite	4		—
			100

The clay contained also pieces of spruce, and a streak of reddish yellow sand three inches thick, exposed for a horizontal distance of six feet. One of the greenstones was subangular and striated. The largest stone included in the count was six inches in diameter and was obtained from the black clay. As the pebbles in the clay were of the same type as those on the clay, the pebbles listed above were picked up indiscriminately.

In both the above counts the sandstone last named, the iron concretions, black shale, limestone and chert are such as may have been derived from such strata as are found in the county. The remainder of the stones came from distant regions.

WELL SECTIONS

JAMES E. GOW[17]

The thickness of the Kansan, and the general nature of the materials composing it, may best be indicated by the sections of a number of well shafts.

1. On the Conway farm, west of Macksburg in Madison county, but not far from the Adair county line, a well shaft was dug which passed through fifty feet of alluvium and Kansan drift. For the most part the latter consisted of a stiff blue clay, unstratified, and without bowlders, though containing a few small pebbles. Below this there was struck a bed of sandy clay in which was imbedded a log of hard wood, probably walnut, four feet in diameter.

2. On the same farm, at about the same depth, the auger entered a bed of rather soft, ill preserved peat. The peat seemed to consist principally of compacted grass and grass roots, and was roughly but not inaptly described by the well digger as a "fossil haystack." Above it lay a nodule of brown haematite the size of a goose egg.

3. On the farm of J. M. Wilson, in section 12, Union township, a well was dug with the following result:

		Feet
2.	Stiff joint clay, yellow near surface, blue beneath	49
3.	Black surface soil with much humus	1
1.	Black silt, with many small wood chips	3

The yellow and blue clay was entirely unstratified, contained a very few pebbles and small bowlders, and *in places* numerous lime concretions.

[17]The remainder of the report was written by Doctor Gow.

4. On what is known as the Ed. Baker farm, northwest of Macksburg, a well was dug, the auger passing through twenty feet of stiff joint clay, varying in color from yellow to blue-black. An impediment was then encountered in the shape of a mass of sticks and twigs lying criss-cross and very slightly compacted. Associated with these were pebbles and bog-iron nodules. The larger sticks were as large as a man's arm, or larger, and were much broken and apparently gnawed at the ends, but not decayed.

5. The well digger reports that on the Funk farm, northwest of Greenfield (Section 2, Summerset township), at a depth of twenty-three feet he was obliged to chop through a willow log six inches in diameter.

6. Some years since the writer watched the boring of a well on lot 3, block 36, original town of Greenfield. The auger passed through two feet of black surface soil, then entering yellow brown joint clay the upper three inches of which had a slightly reddish cast. It passed through fifty feet of stiff joint clay, varying in color from yellow-brown to dark blue-brown, absolutely unstratified, and containing no sand, gravel, or bowlders.

7. A second well on the same lot passed through thirty feet of stiff blue joint clay without pebbles, sand, or bowlders. The lower part of this was the so-called "stinking clay." The two wells are about a hundred yards apart.

8. In the northwest corner of section 7, Jefferson township, a well was sunk to the depth of about thirty feet. The first twenty feet passed through fine-grained black sand with an admixture of barely enough clay to bind it somewhat. The auger then entered stiff blue Kansan clay. The sand is doubtless post-Kansan, and was laid down as part of the old flood plain of Middle river.

9. In digging a well on the Sears farm, in Jackson township, the driller encountered a number of logs at a depth of thirty or forty feet. The overlying material is unstratified blue and yellow clay with many pebbles and small angular fragments of quartzite.

10. In a well on the farm of E. Stacey the auger penetrated to the depth of forty feet through stiff blue clay. At that depth a section of a good sized log of some coniferous wood was removed from the shaft. After digging an additional ten feet through gravelly clay, black Carboniferous shale was encountered. The water was reported to be unfit for use.

11. The city well at Greenfield is bored through 208 feet of stiff blue joint clay, very slightly sandy in places, unstratified, and containing a few small angular pebbles. This is four blocks distant from the Greenfield well already mentioned. The Kansan rests directly on Missouri limestone.

12. In the well on the Witham farm, already mentioned, the clay is reported as having a thickness of 240 feet and as resting directly on Missouri limestone. The clay is blue, unstratified, showing typical joint structure, and containing a very few small angular pebbles and bowlders.

13. About 1897 the writer watched the boring of a well in section 31, Jefferson township. The well was sunk to the depth of about thirty-five feet and the material consisted of a stiff blue clay, unstratified, and without pebbles below the first four feet, very few being present there. The material from this well was piled near the shaft and left there permanently. In 1911 it was examined by the writer. The clay still showed the joint texture but as a result of leaching it crumbled somewhat more readily than it had when first taken out, and the color had changed from dark blue to light brown-yellow.

14. Two wells were dug on section 26, Orient township, under the writer's immediate observation. The section of one is as follows:

		Feet
5.	Black soil	1
4.	Unstratified yellow-brown joint clay grading insensibly down into	3
3.	Unstratified stiff blue joint clay without pebbles or bowlders. This again grades insensibly into	8
2.	Blue joint clay, containing numerous angular pebbles and this in turn grades insensibly into the next	3
1.	Blue joint clay without pebbles or bowlders	15

The shaft of the second well is almost identical with the foregoing except that a very few angular pebbles were scattered through strata Nos. 1, 3, and 4. Stratum No. 2 shows no signs of stratification, but consists of perfectly typical Kansan clay.

In addition to collecting the foregoing data, the writer has made careful observations wherever the working of the roads has exposed good sections. The individual points at which observations of this sort have been made it is unnecessary to catalog, since the entire county has been quite thoroughly covered in this respect, and the results everywhere agree. The surface soil everywhere except where covered by alluvium or modified by the presence of abundant plant humus is a joint clay—that is, a clay that when crushed dry in the fingers becomes coarsely granular in texture. It is usually light in color, grading through the shades of brownish yellow and brown. The granular surface clay, when exposed in a fresh cut, at some localities shows lime nodules, and at others does not. Where the clay has been penetrated by plant roots the latter are in some cases surrounded by iron, and the soil at the lower limit of the portion penetrated by the grass roots at some places shows a reddish streak. It is nowhere fossiliferous. Pebbles, and small quartzite fragments as large as one's two fists are not uncommon, larger bowlders are occasionally present, and in very many instances the clay is—like the underlying blue clay—entirely without stone fragments of any sort whatever. Where pebbles and bowlders are present they are usually very angular. The largest bowlder the writer has seen was one about three feet in diameter on section 31, Jefferson township, and in Greenfield a number of quartzite bowlders two feet in diameter are used as corner stones and hitching posts, but stones of this size are extremely rare. This yellow joint clay grades down insensibly into the stiff blue clay beneath, and it is impossible ever to draw a definite line of separation between the two. In fact, when the stiff blue clay is exposed at the surface the action of the weather leaches it out to a yellow tint, it becomes somewhat more porous, and takes on all the characteristics of the surface clay as here described. In view of these facts the writer is driven to believe that they are in fact identical.

Loess is a deposit of fine dust, brought by wind from river valleys and dry upland. The surface is generally of a yellowish hue due to the hydrated oxide of iron which the loess contains, but the deposit is sometimes of a bluish cast. In Adair county only the yellowish loess is observed. Where this loess is present in conspicuous quantities it represents long continued action of the wind in transporting soil from other localities, especially from river valleys, and represents the excess of deposition over erosion by wind and water from Kansan times to the present. The most favorable place for deposition and accumulation of loess is at and near the crest of hills on the lee side of a valley where the upward winds from the valley eddy as they pass over the hill allowing the dust to settle in quiet air.

The best exposure of loess in Adair county is at the railroad cut in the town of Adair (northwest quarter of the northwest quarter of section 3). Here are at least six feet of loess with fossils and concretions capping the divide where a long sweep

FIG. 39. The railroad cut at Adair reveals a thick bed of loess in the upland where it is now largely concealed by grass. The long sweep of the wind up the valley of Turkey creek in Cass county has transported fine material from the lower to the higher ground and deposited it as a blanket over the adjacent upland to the east, where the deposits are conspicuous for several miles south of Adair. Beneath the loess is the Kansan gumbotil and below this is the Kansan drift with its pebbles, which is exposed in grading the streets in the city of Adair.

of the southwest wind up the valley of Turkey creek has allowed the accumulation of a deposit so located that erosion could not remove it. Southward along the hills east of Turkey creek loess is prominent in the upland soil for about three miles. (The creek flows southwest into Cass county.) What may have been deposited on the sides of ravines has not remained there. So, too, eastward from the valley of Turkey creek the loess on the upland becomes a less conspicuous factor in the upland soil, till, even five miles away, it is not recognizable as a distinct bed, though undoubtedly it is there to a minor extent as a part of the soil. Similarly, in the upland bordering the Nodaway, the light color of the subsoil is due to loess, but loess here is not so conspicuous as it is near Adair. Throughout the entire northeastern half of the county the weathered surface of the Kansan drift is what is converted into a soil, the loess being an inconspicuous portion. Here, in cuttings only two or three feet deep on the edge of the upland, loess is completely wanting and the sticky, dark Kansan gumbotil appears everywhere, while beneath it the pebble-bearing portion of the Kansan drift appears on the hillsides. Loess does not here mantle the hillsides like an undulating carpet.

To sum up: the lower Pleistocene of Adair county includes Nebraskan till, with its uppermost phase, gumbotil, and a sheet of gravels and silts, and old soils, peat and forest beds, representing the Aftonian interglacial period. The upper Pleistocene is the bowlder clay so conspicuous along the hillsides, representing the Kansan drift, and the lower part of the loess in the northwest part of the county, representing post-Kansan glacial and interglacial deposits. The cases of Aftonian deposits mentioned here in detail are but a few of many that might be found. So general is this condition that well diggers tell the writer that below a depth of thirty-five or forty feet they "expect to strike logs" and the Aftonian gravel is well recognized among local well diggers as a water-bearing stratum[18]. Above the Aftonian lies the Kansan drift, of variable thickness depending upon the two factors of pre-Kansan erosion and post-Kansan erosion, but

[18]Mr. Jesse Hines, a veteran well digger residing in Greenfield and well known to the writer for many years, writes thus: "We find pieces of wood in this county *anywhere* when we go down through blue or black clay." Many other well diggers bear witness to the correctness of this statement.

perhaps 270 feet at its maximum. This is a heterogeneous mass of clays, sands, gravels and bowlders, the various materials being arranged in no discoverable order. They nowhere show signs of stratification, nor do they at different points in the county sustain a uniform relation to each other. The materials lie as they were left by the ice, and are, as one would expect, absolutely heterogeneous. Large bowlders are rare, while smaller fragments are not uncommon, the prevailing stone being Sioux quartzite. Sands and gravels are not very common. The typical material is stiff blue joint clay, which on exposure to the weather becomes lighter in color except where stained by iron or darkened by the products of vegetable decay. The blue clay varies in density. Where it is very dense it is when once wet, impermeable by water from above, and is known as hardpan. The hardpan grades insensibly into the softer clay above and below. It sustains no constant relation to the other materials, and may be found at any depth.

Post-Pleistocene Deposits

Typical alluvium as found in Adair county is when dry a very dark gray-brown, when wet it becomes black. It is usually more or less distinctly stratified. Occasionally sand and alluvium are found interstratified, the former of course representing an old bar, the latter being laid down on top of the bar after it had become a part of the overflow plain, through the deepening and shifting of the stream's course. The flood plain is usually broader on the north and east sides of the valley than on the south and west. In the former case it slopes gently back to the hills bordering the valley, in the latter case it usually forms a more acute angle with the hills at their base. The hills to the south and west have a steeper gradient than have those to the north and east. The latter slope southwesterly and face the noonday and afternoon sun. The former are shaded during much of the day, and consequently hold the frost longer in the spring and are not so subject to erosion. This variation in the contours of the two sides of a valley is constant throughout the county for all the larger streams. The best sheltered flood plains are on the south side of the valleys, and it is there that the timber is densest and there the moisture-loving and shade-loving plants flourish most luxuriantly.

An interesting deposit of stratified gravels and peat is found on the Burrell farm, two miles southwest of Greenfield. At the extreme edge of the flood plain of a small tributary of the East Nodaway, a gravel pit has been sunk to the depth of eight feet. On the side toward the hill the gravel is distinctly stratified with much cross-bedding. On the opposite side (i. e. next the flood plain) the section shows a more uniformly horizontal stratification without cross-bedding, the material being the same coarse gravel mixed with many nodules and cysts of bog iron, the whole bound together by layer after layer of coarse dark colored peat. The peat is very recent, as is evidenced by the fact that the topmost layer forms the present ground surface and shows the hummocks characteristic of the slough grass growing here before the bottom was sowed to blue-grass. The peat consists merely of layer after layer of solidified or semisolidified grass roots to the thickness of about five feet. Many of the tinier roots are more or less intact and are surrounded by red tubules of bog-iron. The hollow bog-iron cysts so common at this point are frequently filled with a matted tangle of grass roots. The cysts differ in diameter from that of a hazel nut to ten or twelve inches. The pebbles making up the gravel exposed at this point are extremely waterworn, *more so than are those usually found in the beds of streams cutting through the Kansan drift.* Their rounded condition, and the fact that quartzite fragments are not present, would suggest an Aftonian origin. The writer suspects that this gravel deposit was originally an Aftonian bowlder, ploughed up by the Kansan ice sheet in its advance, and buried in the Kansan till. Subsequent erosion cut the valley, and in doing so cut through one side of the bowlder. Owing to a local imperfection in the post-Kansan drainage system, however, the material was not carried down into the Nodaway, but was caught in a small bog at the foot of the hill and there redeposited with horizontal stratification. Much coarse grass was growing in the bog, and the peat thus formed was interstratified with the gravel washed down from the hillside. Hematite cysts and nodules would necessarily form under these conditions. The area of the peat may be traced in the alluvial bottom by the poor growth of the blue-grass, and the fact that it is of a much darker color than is the surrounding grass. The little peat-bog is only a few rods in diameter. It is interesting to note that this tiny and inconspicuous peat bed was discovered by White and is noted by him in his Geology of Iowa. He did not, of course, discover the gravels, as they were not uncovered until 1910.

Another peat bed is known to the writer (Mr. Gow). This one is in the northeast corner of Walnut and the northwest corner of Jefferson townships. This is a part of the flood plain of Middle river, and was originally covered with hummocks of coarse slough grass. It was an area of imperfect drainage, about thirty rods in diameter, having been originally doubtless an oxbow lake and having been filled up by successive crops of grass. Years ago this was turned into a pasture, and the blue-grass turf finally covered it. A well sunk in the turf to the depth of three feet gave an inexhaustible supply of extremely clear water. In wet seasons the place showed a tendency to revert to its boggy condition, owing to the fact that the cattle trampled out the turf, and it was decided to drain the bog into Middle river. The ditch was dug to a depth of five feet, through a rather coarse but densely compacted dark brown peat. Doubtless many peat bogs of this sort might be found along the alluvial plains of the larger streams.

Loess is still in process of deposition, though it may be not so rapidly as formerly, except in dry seasons, for the winds that now sweep from the southwest up the river valleys find the source of supply largely protected by vegetation. Conditions in the past, especially when ice occupied the northeastern portion of the state, may not have favored such a growth of vegetation. The interglacial conditions apparently compared favorably with the changing conditions of the present.

PALEONTOLOGY

The shells of modern land snails are frequently found in the alluvium of flood plains and terraces. No systematic investigation of these has yet been made, and the subject must be reserved for a future paper.

The joint clay which makes up the greater part of the Kansan drift sheet is entirely nonfossiliferous. Many species of land molluscs dwell on the surface of the drift, and are buried by caving banks or become covered by the humus which forms a veneer over the surface, but careful search has failed to reveal any imbedded in the body of the drift. The leached portion of the drift sheet, which has been sometimes mistakenly described as "loess," is nonfossiliferous equally with the deeper and more compact clay.

Owing to the extremely limited opportunities for observation nothing is known as to the fossiliferous character of the Dakota deposits in Adair county. No fossils are reported from the few shafts which penetrate this formation.

The uppermost limestone contains the following species:

Productus nebrascensis
P. punctatus
Athyris subtilita

The massive ledges found below this level reveal the following fauna:

Productus nebrascensis
P. cora
P. costatus
P. punctatus
P. longispinus
Spirifer cameratus
Composita subtilita
Fenestella sp.
Rhombopora lepidodendroides
Allorisma terminale
Derbya crassa
Fistulipora nodulifera
Fusulina cylindrica

The blue shale associated with the foregoing limestone is particularly rich in *Chonetes verneuilianus*.

The shale at Port Union contains a rich and distinctive fauna, of which only the following can here be given:

Aviculopecten neglectus
Aviculopecten sp.
Myalina subquadrata

Owing to the extremely soft and brittle character of the shale at Port Union the securing of perfect fossil remains from it is very difficult, but the shale is extremely fossiliferous and will well repay future investigation on the part of paleontologists. In the Keating breccia were found remains of *Composita subtilita*, and an unidentified *Productus*.

ECONOMIC GEOLOGY

In an earlier day much limestone was quarried from the uppermost beds and the thin ledges of massive limestone below, but the cheapening of cement construction has driven the limestone out of use. For a limestone, the uppermost bed resists the action of rain and frost excellently. Many foundations, and one stone house about forty years old bear witness to its enduring qualities. For purposes of construction, the lower beds are, of course, worthless. The massive limestone will be marketable for macadam and concrete construction as soon as the Port Union country shall be opened up by the advent of a railroad, but the lower beds cannot be used even for this purpose, since they contain too great an admixture of carbonaceous clay. The shales at Port Union, and the other blue shales cropping out farther down Middle river are of smooth, even consistency, without grit, and with the limestone should make a cement of good quality. This industry also awaits the coming of a railroad to make it profitable.

The brick industry in Adair county goes back to the very early history of the county. At a very early day there were brickyards at Fontanelle, Adair, and Casey. About thirty years ago there was a brickyard just west of Greenfield, north of the old Fontanelle road which is now Main street, and at the same time the Day brickyard was in operation a short distance east of Fontanelle in the Nodaway bottom. In all these cases the brick was molded by hand, and was of rather inferior quality as measured by the standard of today, being rough and soft. About fifteen years ago a brickyard was established in Greenfield by Mr. J. W. Darby, and for a decade an excellent quality of brick and tile was manufactured at that point. The material used in the early manufacture of brick in the county was the black alluvium of "sloughs" and stream bottoms, since it was then believed that the joint clay was useless for this purpose. In fact, the latter cannot be used successfully where the method of molding by hand is in vogue, since it will check in drying and experience has shown that most of the brick are ruined. It often has the added disadvantage of containing many small pebbles, which of course make its use in brickmaking impossible. The material used by Mr. Darby was a deposit of drift, or joint clay, lying just east of the railway station in Greenfield. At this point the drift is practically free from small pebbles. One large bowlder was uncovered in the diggings, and in a search of an hour covering the exposure the writer found three very tiny flint pebbles. The brick and tile were moulded by machinery, and it was found that there was but little checking and very few were spoiled in the burning. Mr. Darby maintained a permanent equipment of one large brick kiln and three tile kilns, the product being taken as soon as made, and the demand usually exceeding the supply. The establishment finally passed into other hands, and the business having become involved was discontinued in a few years. The machinery was bought by Mr. C. H. Cass of Bridgewater.

Mr. Cass is a contractor and bricklayer who maintains a yard at Bridgewater and manufactures his own materials for the brick buildings constructed by him. Consequently the yard is in operation but a part of the time. The material is ordinary Kansan drift clay, which in the vicinity of Bridgewater is commonly very free from pebbles and sand, and burns into an excellent brick. Mr. Cass has the added advantage of cheap fuel, since wood is to be obtained in the immediate neighborhood. His brick is made both by the machine and the hand-moulding process, and he also manufactures drain tile which is disposed of in the local market. But little effort has been made to work up an outside trade.

The brick and tile industry in Adair county offers good possibilities. The Creston brick and tile works, using identically the same material to be had at Greenfield, Fontanelle, and Bridgewater, have operated profitably for many years and put out an excellent product. The railway facilities are not so good in the Adair county towns along the Chicago, Burlington and Quincy Railway as at Creston, but at least one good yard could supply all the home trade for the southern half of the county and make the importation of an outside product unnecessary. The trade of the northern half of the county is to a large extent supplied by the output of the Stuart Brick & Tile Company, located just across the line in Guthrie county.

Changes Incident to Human Occupation

Open pastures in all parts of the county show much recent erosion. Gullies have been cut to a depth of a few inches to fifteen or twenty feet, and are gradually backing up from the lowlands toward the higher ground. This process is so general, and is so recent in all observed cases, as to lead to the suspicion that the region may have undergone recent rejuvenation. After careful examination, however, the writer has been led to reject the rejuvenation theory. It is noticeable that the process of gully cutting takes place only in those places where the wild grass has been replaced by tame grass. Blue grass pastures are especially subject to dissection of this sort, while the process is absolutely unknown in those places where the native slough grass still carpets the soil. It must, of course, be remembered that the slough grass is not limited to bogs and marshes, but is the normal ground covering in all shallow sloughs[19] and draws, even where the latter lie close to the crest of the divide. Originally, therefore, every place that would, by reason of its lower level, be the natural starting point for the development of a gully, was covered by the slough grass. This grass grows in hummocks, which lie usually so close together that one may step from one to the other. It roots very deep (three to six feet in cases investigated by the writer) and the root system forms a dense spongy mass that absorbs and holds water readily. The decay of the culms and

[19]This word is here used in its popular sense as meaning a shallow, prairie depression sloping down to a stream valley. It is the writer's observation that this use of the word is practically universal in the common speech of the United States. When so used the word is pronounced "sloo." Usage as general as is this should not be ignored by the makers of dictionaries.

the older roots forms a very absorbent humus, and because of the dense root mass this humus does not wash away, but remains and so increases the absorbent capacity. The grass grows very thick, to a height of three to four feet, producing a dense shade, and thus reducing evaporation. The roots are not limited to the hummocks or "stools" but penetrate between and the whole slough thus becomes a great tough sponge for the retention of moisture. Under these conditions rapid erosion is an impossibility.

When the slough grass has been replaced by blue grass, most of these conditions are reversed. The blue grass makes, it is true, a dense ground cover, but it does not root deeply, and it does not produce a heavy humus. Especially is the latter true in the case of pastures where the grass is continually eaten off short. Once erosion is started at one point it proceeds with great rapidity. The soil beneath the turf (and the latter is but a few inches in thickness) is quickly washed out, the water excavates beneath the edge of the overhanging turf, and the latter soon begins to break off by its own weight and to fall into the little gully thus forming. Each rain storm deepens the gully a little, and backs it up a few feet, until finally the greater part of a valuable pasture may be dissected by a series of several wide deep gullies and many square rods of pasturage destroyed. In the wasteful farming of the past, farmers and agricultural teachers of Iowa have alike failed to estimate at its full value the damage to the agriculture of Iowa wrought by this process. In the more economical farming of the future, effective means will have to be taken to check it.

The cultivation of the soil has, of course, greatly increased the factors of creep and sheet-water erosion, denuding the higher ground of much of its humus, and increasing the thickness of alluvium on the lower lands. To a certain extent, of course, this is unavoidable, but true economy would suggest that the steeper hillsides should not be ploughed, but should be kept in permanent meadow or pasture. The annual run-off has also been greatly modified by cultivation. Under primitive conditions the water of the spring rains was caught by every slough and held through the season, gradually seeping out, as the summer went on, to feed the smaller streams. The whole land surface was covered by this network of reservoirs which, by reason of the conditions of shade, humus, spongy consistency and depth of root-mass, etc., made an excellent series of feeders for the streams. Under present conditions the run-off is much more rapid in the spring, and this is likely to be succeeded by a condition of semiaridity during July and August. It is no unusual thing for Middle river and the East Nodaway to cease flowing during August, the water being reduced to a few shallow pools. In the summer of 1911, the writer walked for half a mile down the bed of Middle river and not only found no water, but in that distance found the sand for the most part perfectly dry and dustlike. Above and below this half-mile stretch were stagnant pools, and there may, of course, have been a little seepage through the lower part of the sand, but there could not have been much. Such is the condition in a year of drought. Conditions of this sort were unknown in the early days before the breaking up of the prairie and the extirpation of the native grass.

The cutting of much of the timber has had a marked effect on erosion and topography. It is true that much good land has been added to the cultivable area. On the other hand, much land has been cleared that ought to have been left in timber. The clearing of the steeper hillsides has led to the washing away of the humus with which they were once carpeted. This having once occurred, the grass becomes thin, gullies begin to develop, and soon the entire slope is dissected by deep V-shaped valleys, and is perfectly bare of vegetation. If after clearing the attempt is made to put a slope of this sort under the plow, the process of erosion, of course, is hastened. In any case land which was originally productive becomes waste, and then cannot be farmed, nor can it be reforested without tremendous expense. True conservation demands that the rougher land be kept in timber.

The destruction of the brush and smaller forest vegetation has led to much destructive erosion on the steeper slopes. A blue grass surface, covered with sparse timber is readily cut into gullies in the same way as are open pastures though not at the same rate. In clearing ground the brush should be left on the steeper slopes. With the increasing value of timber, and the advanced price of land, the problem of woodland conservation should no longer be ignored.

NATURAL HISTORY

In its broadest sense, a geological report may include observations not simply on the soil and mineral resources, and the historical geology of the region in question, but also on the plant and animal life indigenous to it. The native mammalian fauna of Adair county has, of course, been largely exterminated. The writer has made no study of the mammalian fauna, and in leaving it for another will merely suggest that the mammals of the county ought to have been catalogued at a much earlier day, and that no time should now be lost in securing as complete a list as possible of the mammalian inhabitants of this part of the state. With entomological questions the writer is unfamiliar, and this work must be left for others. The ornithology of this section, as of the entire state, is already in competent hands, and will be embodied in separate reports to be issued by the Survey. The botany of the county lies within the special province of knowledge with which the writer of this article claims some acquaintance, and his observations thereon will accordingly be included as part of this report.

Botany of Adair County

The relation of botany to geological conditions is always a close one, since the nature of the plant covering and the distribution of plant species depends very largely upon the character of the mantle rock. Conversely, the nature of the vegetation may profoundly modify the ground conditions—and this in many ways, as through the prevention or hastening of erosion, the retention of moisture through shading of the ground surface, the addition of humus to the soil, the change in consistency of the soil through the influence of roots, through chemical changes, etc., etc. This being the case, the geologist is chiefly interested in those phases of botany that relate themselves to such changes as those just mentioned, and he and the botanist meet on common ground in the field of ecology. It is from the ecological standpoint accordingly that an attempt will be made to treat the botany of the region now under discussion.

The flora of the county comprises a number of fairly distinct types, and these types conform in a general way to the three conditions of moisture, shade, and soil. As the soil is very uniform over the entire area, the chief conditions with which we have to deal are those of moisture and shade. In general these types may be classified as follows:

Prairie	Upland prairie flora Xerophytic to mesophytic	High gravel points—Xerophytic. High exposed south and west slopes—partly xerophytic. North and east slopes—Xerophytic to mesophytic.
	Slough[20] flora	Slight depression in high prairie—Mesophytic. And intermediate stages down to wet bogs on lower levels—Hydrophytic.
	Prairie stream flora	Hydrophytic flora, bordered by thin fringe of mesophytic flora.
	Unforested alluvial bottoms	Mesophytic on higher ground. Hydrophytic in bogs and oxbows and near streams.
Native forest	Steep bluff flora, usually on south or west bank of larger streams—Mesophytic	
	Ravine flora, found low in gullies cut in river bluffs, and at base of bluffs. Mesophytic to hydrophytic. This includes much the same species as the next.	
	Shaded alluvial bottoms. Mesophytic to hydrophytic.	

The final paper that Doctor Gow evidently intended to prepare on the flora of Adair county was never completed, but his preliminary papers on the subject are of such value that they are reproduced in full.

[20]This word is here used in the sense in which it is universally used locally in Iowa as meaning a shallow depression in the prairie, gradually deepening until it develops into the value of a tributary brook or rivulet. It is never here used in the dictionary sense as meaning a quagmire, nor is this meaning sanctioned by American usage.

FOREST TREES OF ADAIR COUNTY[21]

In order to understand the forestry conditions of Adair county, a short description of the lay of the land and the nature of the soil is first necessary. The county lies along the crest of the "grand divide," between the Mississippi and the Missouri, so that a line drawn along the crest of the ridge traverses it diagonally from northwest to southeast. The land is undulating enough to secure an easy natural drainage, but not so undulating as to be difficult of cultivation, except in a few isolated localities. The soil is a rich, black loam, varying in thickness from a few inches to ten or fifteen feet and underlain by a stiff, yellow clay. Here and there, the larger streams may be found flowing over beds of limestone, but as a rule they flow either through the black surface soil or the yellow clay below it. Of these streams, North river and Middle river enter the Des Moines, while Grand river and the Nodaway flow into the Missouri. Although commonly called rivers, none of them attain to sufficient size, in Adair county, to deserve the name, but all become streams of considerable size before losing their identity in the Missouri or the Des Moines. The rivers along whose course is found the heaviest timber are Middle river and the west branch of the Middle Nodaway, and it is on these streams that the greatest variety of species have been found and most of the observations have been made. The prairie in Adair county is practically bare. The only trees or bushes ever found upon it in any abundance are the hazel and bur oak, and these have been largely grubbed out and destroyed. The wild plum, wild cherry and American crab, may occasionally be found on the high prairie, but they very seldom, if ever, occur there unless protected by other low timber, and as the bur oak and hazel are destroyed, they vanish also. So it is along the streams that the student of forestry must seek his information.

Even a cursory examination of these streams is sufficient to show that, with few exceptions, the southern or western bank is steep and rough, while the northern or eastern bank is smooth and rises with a gentle slope. Along most of the course of Mid-

[21]Gow, James E., Forest Trees of Adair County; Iowa Acad. Sci., Vol. VI, pp. 56-63, 1898.

dle river, through the county, the southwestern bank consists of steep clay bluffs densely wooded and rising abruptly from the water, while the northeastern bank slopes up very gradually from the water—making a wide level valley or bottom, which is usually either destitute of trees, or less heavily wooded than are the bluffs of the opposite bank. The same condition may be noticed quite generally with regard to the smaller streams. In driving along the road it is noticeable that the steepest hills face the north or east, and the gentler inclines the south or west. The reason for this must be that the erosion has been greater on the north than on the south bank, owing to the fact that the former receives the full rays of the spring sun, while the southern bluff lies in shadow most of the day. This, of course, would cause the snow and ice upon the northern slope to melt very quickly, making considerable erosion, while upon the southern bank it would melt much more slowly and hence cause much less erosion. Where the course of a stream is southward it is the left bank which shows the greater signs of erosion, because it is exposed to the burning rays of the afternoon sun, while the right bank is in shadow during the hottest part of the day. The effect of this process upon the distribution of timber is evident. The steep bluff-land upon the southern or western bank of a stream is usually heavily wooded, while the flat "bottom" upon the northern or eastern side is often very sparsely covered with trees and sometimes quite bare. Before the advent of civilization the southern bluffs often held the moisture of the winter snows and spring rains until after the season of prairie fires, thus giving the trees sprouting upon their surface a chance to grow, and, when the trees had grown large enough, they further protected themselves from fire, the surrounding grass being killed out. But the northern bank, which had to face the rays of the spring sun, was well dried by the time the grass on the prairie was dry enough to burn, and so the trees growing upon its surface were destroyed. This is the process which must have taken place during many years before the day when the plow of the first white settler cut the soil of western Iowa. Its effects are still noticeable, but not so noticeable as they must have been at an earlier day. To-day, practically all of the trees in Adair county are of second growth. There are left only a few isolated specimens of the so-called first-growth timber. Since the days when the prairie fires ceased, seedlings have taken root in the fertile flats which form the northern and eastern banks of our streams, and have grown into trees of goodly size, and in some places the southern bluffs have been shorn of their trees. Still, in a general way, the primitive condition is still noticeable; the timber on the southern bluff is usually larger and thicker than that on the northern bottom. It is noticeable too, on the prairie wherever enough of the original brush has been left to indicate anything at all. The hazel and bur oak will grow on a southern or western slope, but they are not generally found in such a situation. Usually they seek the northeastern side of a hill, and there they flourish luxuriantly.

As has been said, there is very little of the first-growth timber remaining in Adair county. The first settlers of the county found along the streams a thick growth of large, well developed trees. Since then almost all of these trees have been removed, until there remains very little timber which was well grown at the time of the first settlement of the county, fórty years ago. In its place has appeared a growth of smaller trees, which were saplings when the older trees were destroyed, or have grown from the seed since that time. Here and there may be seen a relic of the first growth—some giant of the forest who towers high above all the trees about him—but, as a rule, the forest of to-day is made up of younger and smaller trees than those which composed the forests of forty years ago.

The area, however, of the timber land along the streams remains about what it was at an earlier day. It may possibly be a trifle less, but only a trifle. The second growth covers substantially the same area that was covered by the first growth. The chief denudation of the country has come about, not through the destruction of the larger trees which grow along the rivers, but through the removal of the bur oak, hazel, and other prairie species. Before the settlement of the county—if we may trust the accounts of the earliest settlers—a large part of the prairie was covered with brush. To-day the greater part of the brush is gone and the land upon which it grew is under cultivation. The absence of the brush from the prairie tends to increase erosion and decrease the conservation of moisture in the soil, but its destruction was inevitable because necessary to the successful carrying on of agriculture; and, as conditions grow harder and the land becomes more densely populated and more closely farmed, the destruction of that which is left will become necessary and inevitable. But as the prairie brush is destroyed greater care than ever should be taken to preserve the large and really valuable timber along the rivers, and to extend its area if possible. The people of Adair county have not carelessly destroyed their forests as have the people of many portions of the country. They have preserved them, but it cannot be said that they have preserved them understandingly. The second growth has come in so thick in many places as to choke itself. Valuable walnut, ash or hickory trees are often prevented from making a good growth by the thickets of maple, elm or elder in which they grow, and, too often, when the needs of the farmer force him to cut firewood for himself, he takes all the trees from a certain area, instead of cutting out only those which can best be spared and leaving the remainder. A little popular education on the subject of forestry might remedy these difficulties and teach our farmers to take greater interest in their forests and better care of them.

During the past twenty-five or thirty years the extent of artificial groves in Adair county has grown from nothing at all to many acres. Almost every farm house now has a yard full of trees and a wind-break to the north, and hedges of maple, willow and osage orange line many of the roads. Unfortunately, the best species for the purpose are seldom used in these groves. Instead of planting walnut, ash or white oak, our farmers usually plant the soft maple, on account of its rapid growth, and the result is that no sooner do the trees arrive at a respectable size than the winds play havoc with them. The box elder is much used, more on lawns, however, than in groves, and although rather soft it is a good tree and a very pretty one when properly trimmed. The willow figures occasionally in groves, but more frequently in hedges on low lands, where the maple is also sometimes used. Groves of walnut or of ash are occasionally met with, but are not common. The cottonwood is used but rarely and the oak never, so far as we know. While these artificial groves are of little value in conserving moisture, preventing erosion and preserving true forest conditions, they are useful in breaking the force of the winter winds, and they exert more or less of a civilizing influence by adding to the beauty of the monotonous prairie landscape and the comfort of life on the farm.

In Adair county a few species of trees, which are common elsewhere in Iowa, are conspicuous for their absence. The butternut, sycamore and hard maple are found in Madison county, along the course of the Middle river, but we have been unable to discover that a single specimen has ever been found growing wild on this side of the line. The Missouri hickory grows along the Nodaway, it is said, north of the state line, but does not extend this far north. The pawpaw is found occasionally in southern Iowa, but has not been found in Adair county. The fact of a few birch trees having been observed, some twenty years ago, near the town of Casey, on the north line of the county, led to a search through that locality, but no birches were found and none have been found in any part of the county. Both the butternut and birch are reported as being common along the course of the North Raccoon river in Guthrie county.

Following is a list of the species of forest trees found growing in Adair county. The nomenclature of Wood has been followed throughout:

Ulmus americana L. White elm. Common on banks of streams and in valleys, sometimes growing a little way up the sides of bluffs and occasionally found on upland. Attains its greatest size on low ground. Well distributed throughout the county. Frequently planted as a shade tree.

Ulmus fulva L. Red elm. Slippery elm. Found only on low land. Common. A smaller species than the preceding.

Ulmus racemosa Thomas. Rock elm. A rare species which we have not found within the county. Has been reported by an early settler, well acquainted with the native timber, as growing in scattered locations along the west branch of the Middle Nodaway.

Quercus macrocarpa Michx. Bur oak. Scrub oak. This species is very common and occurs most frequently on the sides and summits of river bluffs and on the high prairie, where it is a gnarled, stunted, shrubby tree, varying in height from ten to twenty feet. Occasionally, however, it may be found growing in rich river bottoms, where it becomes much straighter, resembling the white oak in its habit of growth and attaining a height of thirty or forty feet. It is the most abundant species of oak and one of the most abundant trees in Adair county. On the prairie it and the hazel appear to be inseparable companions. The bur oak is almost the only tree which safely resisted the prairie fires and grew in abundance on the open prairie, before the advent of civilization. Clumps of it are found scattered over the prairie at intervals—remnants, evidently, of the more abundant growth which once covered the country.

Quercus rubra L. Red oak. A handsome, straight tree, found in tolerable abundance on the bluffs near the larger streams and occasionally on bottom land or in thickets of bur oak on the high prairie.

Quercus alba L. White oak. Not uncommon. Found along the larger streams—seldom, if ever, on prairie. Prefers rough, clay bluffs.

Quercus coccinea var. *tinctoria* Wang. Black oak. Not so abundant as the red oak and occupies the same habitat. Does not attain the size of either of the preceding species.

Negundo aceroides Moench. Box elder. This is probably the most common of all the trees native to Adair county. It is found along all the streams wherever there is any timber at all and is often planted on lawns and in groves on the prairie, where it flourishes.

Acer rubrum L. Red maple. Soft maple. Swamp maple. Quite common. Grows luxuriantly on the banks of streams and in all low, moist places. Very frequently planted in groves and on lawns, where its soft wood is often broken by high winds which it is unable to resist without the protection of larger timber.

Carya alba N. Shell-bark hickory. Common along the larger streams where it grows well up on the bluffs, and occasionally in the bottoms.

Carya glabra Torr. Pig nut. A somewhat smaller and coarser species than the preceding. Usually found on lower land. The two species are about equally common.

Juglans nigra L. Walnut. Common along the larger streams, where it grows luxuriantly and attains a good height. Never seen on the prairie, except when planted there, which is not often the case. The walnut was much more abundant a quarter of a century ago than it is today, although it is still a very common tree. Owing to the value of the wood it has probably suffered more at the hands of woodmen than has any other tree found in Adair county.

Tilia americana L. Basswood. Linden. Quite common in all river bottoms. Seldom seen elsewhere.

Populus canadensis Desf. Cottonwood. Not rare. May be found in occasional clumps in all low, moist situations. Is occasionally planted in groves or hedges.

Celtis occidentalis L. Hackberry. Not rare. Found only in timber along the larger streams, always on low land. Is occasionally transplanted and makes a very handsome lawn tree.

Aesculus flava Ait. Buckeye. A tolerably common species along Middle river and the Nodaway, but never found on Grand river.

Gleditschia triacanthos L. Honey locust. Not common. Is found in scattered groups along both the Nodaway and Middle rivers.

Prunus serotina Ehr. Wild cherry. Tolerably common along the roads and on all waste land.

Prunus americana L. American plum. Wild plum. Very common on low lands. About equally abundant in the larger timber and along the small prairie streams where it and the wild crab are often the only species of trees. Occurs occasionally on the uplands in company with hazel, bur oak and sumac.

Ostyra virginica Willd. Ironwood. Not uncommon along the Nodaway, and may be found on Middle river, but not abundantly.

Crataegus coccinea L. Hawthorn. White thorn. Red haw. Common on low land, usually in larger timber.

Crataegus tomentosa L. Black haw. Not very common. Found in greater abundance on the west than on the east side of the county.

Pyrus coronaria L. Crab apple. Very common on all low land, whether open or covered by larger timber.

Cornus paniculata L'Her. Dogwood. Common in thickets, both in valleys and on the higher land.

Rhus glabra L. Sumac. Common in thickets along the side and crest of river bluffs and on the high prairie. Found usually with hazel and bur oak.

Sambucus canadensis L. Elderberry. Common in thickets on all waste, rich land. Prefers the bottoms.

Prunus virginiana L. Chokecherry. Fairly common on all low land. Usually found in thickets of other timber.

Corylus americana Walt. Hazel. Very common on all rough, rolling land, especially near the larger streams. Very seldom found on low land. Originally a great part of the prairie was covered with hazel, but most of it has been removed. A good deal yet remains, however, and all along the larger streams it is very abundant.

Salix nigra Marshall. Willow. Tolerably common on all low, moist ground.

Vitis aestivalis L. Wild grape. Common in all timber.

Lonicera parviflora Lam. Not common. Found occasionally in heavy thickets.

PRELIMINARY LIST OF THE FLOWERING PLANTS OF ADAIR COUNTY[22]

The collections on which this report is based were made chiefly during the summer of the year 1900, some of the work, however, having been done some years earlier. It is the hope of the author that he may in the course of time be able to supply a complete account of the flora of the county, one which will be exhaustive to the last detail. Heretofore such an undertaking has not been possible for him. The work has been done in the intervals of other work and has taken into account chiefly the more common

[22]Gow, James E., Preliminary list of the Flowering Plants of Adair County; Iowa Acad. Sci., Vol. VIII, pp. 152-159, 1900.

species. It is here presented as preliminary to the more complete report which, it is hoped, will follow it. The grasses and sedges have been purposely reserved for a separate report.

The nomenclature used is that of the sixth edition of Gray's Botany. While more recent systems may have good claims to superiority, the nomenclature of Gray is more generally known than any other, and is better understood by the majority of amateur botanists.

RANUNCULACEAE

Clematis virginiana L. Not rare

Anemone cylindrica Gray. Very common[23]

A. virginiana L. Not rare

Thalictrum purpurascens L.

Ranunculus acris. Very abundant in low grounds.

R. abortivus L.

Isopyrum biternatum T. and G.

Aquilegia canadensis L.

Delphinium azureum Ait. Low grounds. Common.

D. exaltatum Ait. Very rare. One specimen in the author's collection is certainly of this species.

Delphinium tricorne Michx. Very common in low grounds.

BERBERIDACEAE

Berberis vulgaris L. Escaped from cultivation.

PAPAVERACEAE

Sanguinaria canadensis L. Common in woodlands.

FUMARIACEAE

Dicentra cucullaria DC. Very common in woods.

Corydalis aurea Willd. Not uncommon.

CRUCIFERAE

Capsella bursa-pastoris (L) Moench.

Lepidium virginicum L.

Sisymbrium officinale (L) Scop.

Brassica nigra (L) Koch.

B. sinapistrum Boiss.

Arabis Canadensis L.

Cardamine hirsuta L.

Nasturtium armoracia (L) Fries.

N. officinale R. Br.

Raphanus sativus L. Escaped from cultivation.

[23]In the case of the more common prairie species no attempt is here made to describe the habitat, or abundance of the species, except in cases where Adair county shows features which are novel and unusual. Most of the species are common and generally known. As a rule woodland species are noted in the text.

CAPPARIDACEAE

Polanisia trachysperma T. and G.

VIOLACEAE

Viola pedata L.
V. blanda Willd. Not common.
V. cucullata Ait.
V. pubescens Ait.

CARYOPHYLLACEAE

Silene stellata Ait.
S. nocturna L.

PORTULACACEAE

Portulaca oleracea L.
Claytonia virginica L. Common in woodlands.

HYPERICACEAE

Hypericum ascyron L. Common.

MALVACEAE

Malva rotundifolia L.
Abutilon avicennae Gaertn. Escaped from cultivation, or introduced in grain seed.

TILIACEAE

Tilia americana L.

LINACEAE

Linum usitatissimum. Escaped from cultivation.
L. sulcatum Riddell. Not very common.

GERANIACEAE

Geranium maculatum L.
Oxalis violacea L.
O. stricta L.

RUTACEAE

Xanthoxylum americanum Mill. Not common. Found on steep bluffs along the course of Middle river.

CELASTRACEAE

Celastrus scandens L.

VITACEAE

Vitis riparia Michx.
Ampelopsis quinquefolia Mx. Common in timber.

SAPINDACEAE

Aesculus glabra Willd.
Acer dasycarpum Ehrh.
Negundo aceroides Moench.

ANACARDIACEAE

Rhus glabra L.
R. toxicodendron L. Rare, in dense timber.

LEGUMINOSAE

Baptisia leucantha T. and G.
B. leucophea Nutt.
Lupinus perennis L. Probably fugitive from gardens.
Trifolium pratense L.
T. repens L.
T. hybridum L.
Melilotus alba Lam. Quite common, only in the western half of the county, where the roadsides are covered with it.
Medicago sativa L.
Amorpha canescens Nutt.
Petalostemon violaceus Michx.
P. candidus Michx.
Tephrosia virginiana Pers.
Astragalus caryocarpus Ker.
A. cooperi Gray. Not common.
Desmodium acuminatum DC. Common on Middle river near northern boundary of county.
D. rigidum DC.
Lespedeza capitata Michx.
Amphicarpaea monoica Nutt. Tolerably common in woods.
Cassia chamaecrista L. Very abundant.
Gleditschia triancanthos L. Rare.

ROSACEAE

Prunus americana Marsh.
P. serotina Ehrh.
Prunus virginiana L.
Geum virginianum L.
Rubus villosus Ait. Escaped from cultivation.
Fragaria vesca L. Escaped from cultivation.
F. virginiana Mill.
Potentilla norvegica L.
P. arguta Pursh.
P. paradoxa.
P. canadensis L. Common in lowlands.
Agrimonia eupatoria L. Woodlands.
A. parviflora Ait. Woods.
Crataegus coccinea L.
C. tomentosa L.
Rosa arkansana Porter.
Pyrus coronaria L.

SAXIFRAGACEAE

Ribes gracile Michx. Common in woodlands, and cultivated.

LYTHRACEAE

Lythrum alatum Pursh. Not very common.

ONAGRACEAE

Gaura biennis L.
Oenothera biennis L.
Circaea lutetiana L. Not common.

CUCURBITACEAE

Echinocystis lobata Torr. & Gray.

UMBELLIFERAE

Heracleum lanatum Mx. Low prairie. Common.
Thaspium barbinode Nutt. Banks of streams.
Sium cicutaefolium Gmelin. Common on lowlands.
Zizia aurea Koch. Common on lowlands.
Cicuta maculata L. Common on lowlands.
Osmorrhiza brevistylis DC. Not uncommon on higher land than preceding.
O. longistylis DC. Same habitat as preceding.
Eryngium yuccaefolium Mx.

CORNACEAE

Cornus paniculata L'Her. Low thickets. Only tolerably common.

CAPRIFOLIACEAE

Sambucus canadensis L.
Lonicera glauca Hill. (?)

COMPOSITAE

Vernonia fasciculata Mx.
Eupatorium ageratoides L. Rather common in woods.
Liatris scariosa Willd.
L. pychnostachya Mx.
Solidago missouriensis Nutt.
S. speciosa var. *angustata*.
S. rigida L.
S. lanceolata L.
Aster multiflorus Ait.
Aster laevis L.
Erigeron strigosus Muhl.
Silphium laciniatum L.
S. integrifolium Mx.
S. perfoliatum L.
Ambrosia trifida L.
A. artemisiaefolia L.

A. *psilostachya* DC. Less common than the two preceding species.

Xanthium canadense Mill.

Heliopsis scabra Dunal.

Echinacea angustifolia DC.

Rudbeckia subtomentosa Pursh.

Lepachys pinnata T. & G.

Helianthus annuus L.

H. grosse-serratus Marteus.

Bidens frondosa L.

Dysodia chrysanthemoides Lag.

Chrysanthemum leucantheumum L. Abundant in pastures, in scattered localities throughout the county. A very troublesome weed.

Tanacetum vulgare L.

Senecio aureus L.

Cacalia tuberosa Nutt.

Arctium lappa L.

Cnicus arvensis Hoffm. Common only in isolated localities but spreading.

Taraxacum officinale Weber.

Lactuca scariola L. Very abundant as a weed in gardens, as are also the two following species.

L. canadensis L.

Sonchus asper Vill.

LOBELIACEAE.

Lobelia spicata Lam.

L. syphilitica L.

CAMPANULACEAE.

Campanula americana L.

PRIMULACEAE

Steironema ciliatum Raf. (*Lysimachia ciliata.*)

OLEACEAE

Fraxinus americana L.

F. rigidis Mx.

Asclepias tuberosa L.

A. incarnata L.

A. cornuti Dec.

A. verticillata L.

Acerates longifolia Ell.

GENTIANACEAE

Gentiana alba Muhl.

G. saponaria L.

POLEMONIACEAE

Phlox pilosa L.

HYDROPHYLLACEAE

Hydrophyllum virginicum L. Woodlands.

Ellisia nyctelea L. Not very common.

Borraginaceae

Lithospermum canescens Lehm.

Convolvulaceae

Convolvulus sepium L.
Cuscuta glomerata Choisy. Not common.

Solanaceae

Solanum nigrum L.
S. carolinense L.
S. rostratum Dunal.
Physalis lanceolata Mx.
Datura stramonium L.
D. tatula L.

Scrophulariaceae

Verbascum thapsus L.
Veronica virginica L.
Catalpa speciosa Warder. Escaped from cultivation.

Verbenaceae

Verbena stricta Vent.
V. urticaefolia L.
V. bracteosa Mx.

Labiatae

Pycnanthemum lanceolatum Pursh. Not common. Woodlands.
Mentha canadensis L. Low prairies—common.
Monarda fistulosa L.
Nepeta cataria L.
N. glechoma Benth.
Scutellaria lateriflora L. Woods.
Brunella vulgaris L. Woodlands. Common.
Stachys palustris L. Woodlands. Common.

Plantaginaceae

Plantago major L.

Nyctaginaceae

Oxybaphus hirsutus Sweet.
O. angustifolius Sweet. (?)

Illecebraceae

Anychia dichotoma Mx. Woods. Not very common.

Amarantaceae

Amarantus retroflexus L.

Chenopodiaceae

Chenopodium album L.

Polygonaceae

Rumex crispus L. Common everywhere.

R. verticillatus L. Tolerably common.

Polygonum aviculare L.

P. ramosissimum Mx.

P. incarnatum Watson. Sloughs. Only tolerably common.

P. persicaria L.

P. orientale L. Escaped from gardens.

Fagopyrum esculentum Moench. Cultivated species run wild.

Euphorbiaceae

Euphorbia corollata L.

E. maculata L.

E. preslii Guss.

Acalypha virginica var. *gracileus* Mueller. Not common.

Urticaceae

Ulmus americana L.

U. pubescens Walt. (*U. fulva* Mx.)

Ulmus racemosa Thomas. Reported from the west side of the county, along the course of the Nodaway river, but very doubtful.

Celtis occidentalis L.

Cannabis sativa L. Escaped from cultivation, or adventitious.

Humulus lupulus L. Occasionally fugitive from cultivation in brush and low woody thickets.

Urtica gracilis Ait.

Pilea pumila Gray. Common in all woods.

Juglandaceae

Juglans nigra L.[24]

Carya alba Nutt.

C. amara Nutt.

Cupuliferae[25]

Corylus americana Walt.

Ostrya virginica Willd.

Quercus macrocarpa Mx. High prairie and bluffs along river.

Q. rubra L.

Q. alba L.

Q. coccinea Wang. All four species common along larger streams.

Salicaceae

Salix amygdaloides And.

S. alba L.

S. nigra Marsh.

S. cordata Muhl. Not common. Discovered on Middle river near Madison county line.

Populus monilifera Ait.

[24]*Juglans cinerea* occurs in Madison county, but has not been found in Adair county. The sycamore tree has also been found to the east of the line separating the two counties, but never to the west of it.

[25]The birch occurs in Guthrie county but has not been discovered in Adair.

ORCHIDACEAE

Spiranthes gracilis Bigelow. Very rare. Collected by Mr. J. G. Culver on the road between Greenfield and Orient.

Cypripedium candidum Willd. Very rare.

Habenaria leucophea Gray. Once very common. Now almost extinct.

IRIDACEAE

Sisyrinchium angustifolium Mill.

AMARYLLIDACEAE

Hypoxis erecta L.

LILIACEAE

Allium canadense Kalm. Abundant in two or three restricted localities.

Polygonatum biflorum Ell. Low woodlands or brush.

Asparagus officinalis L. Escaped from gardens.

Uvularia grandiflora Smith. Woodlands. Not very common.

Erythronium americanum Ker. Woods.

Lilium philadelphicum L.

Trillium nivale Riddell. Woods.

Melanthium virginicum L.

Smilacena racemosa Desf. Woods.

MAYACEAE

Tradescantia virginica L.

TYPHACEAE

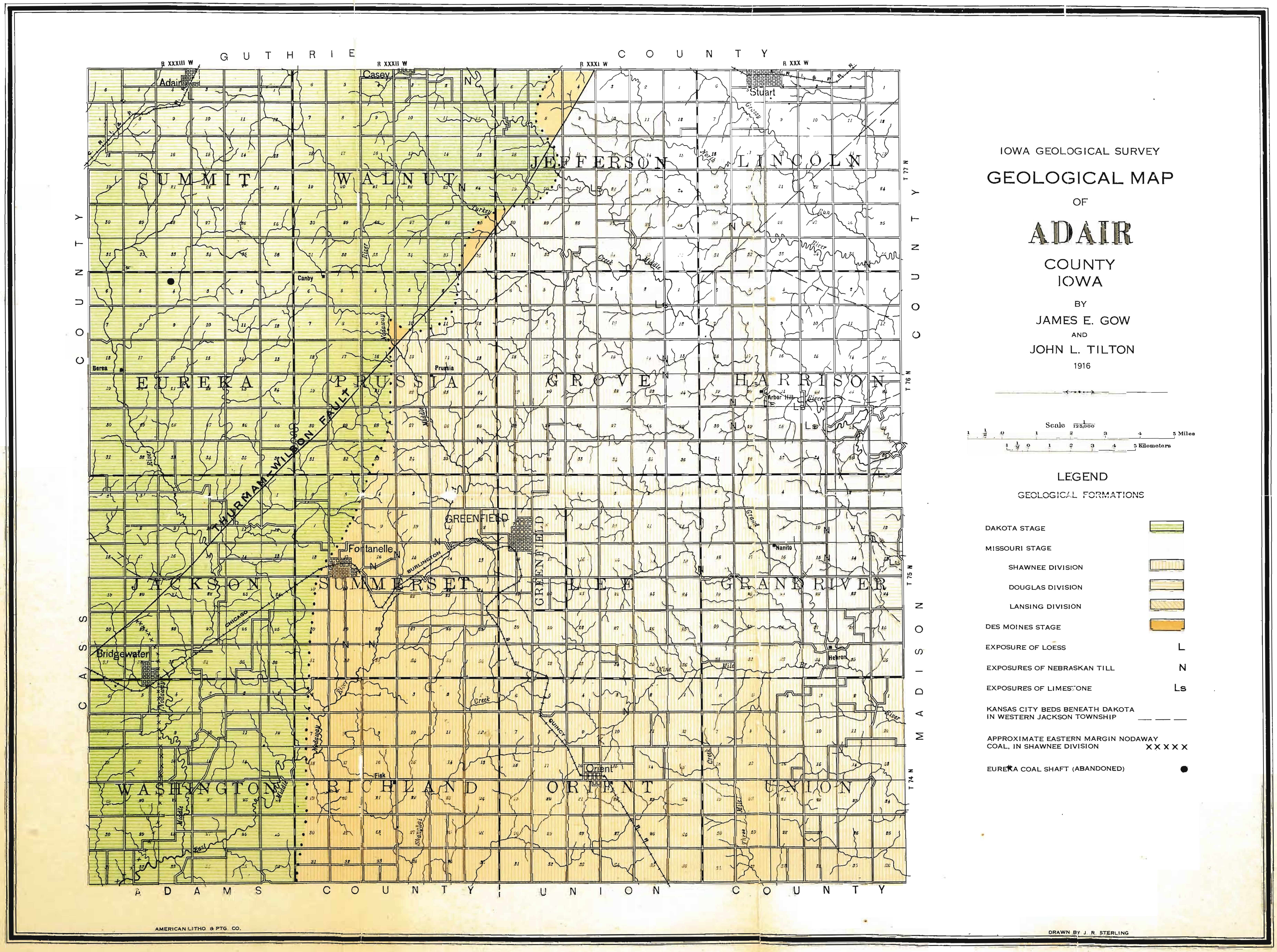
Typha latifolia L.

ARACEAE

Arisaema triphyllum Tou.

ALISMACEAE

Sagittaria variabilis Eng.


IOWA GEOLOGICAL SURVEY
GEOLOGICAL MAP
OF
ADAIR
COUNTY
IOWA
BY
JAMES E. GOW
AND
JOHN L. TILTON
1916
Scale $\frac{1}{125,000}$
5 Miles
5 Kilometers
LEGEND
GEOLOGICAL FORMATIONS
DAKOTA STAGE
MISSOURI STAGE
SHAWNEE DIVISION
DOUGLAS DIVISION
LANSING DIVISION
DES MOINES STAGE
EXPOSURE OF LOESS L
EXPOSURES OF NEBRASKAN TILL N
EXPOSURES OF LIMESTONE Ls
KANSAS CITY BEDS BENEATH DAKOTA IN WESTERN JACKSON TOWNSHIP
APPROXIMATE EASTERN MARGIN NODAWAY COAL, IN SHAWNEE DIVISION XXXXX
EUREKA COAL SHAFT (ABANDONED)
GUTHRIE COUNTY
CASS COUNTY
MADISON COUNTY
ADAMS COUNTY
UNION COUNTY
R XXXIII W
R XXXII W
R XXXI W
R XXX W
T 77 N
T 76 N
T 75 N
T 74 N
SUMMIT
WALNUT
JEFFERSON
LINCOLN
EUREKA
PRUSSIA
GROVE
HARRISON
JACKSON
SUMMERSET
LEE
GRAND RIVER
WASHINGTON
RICHLAND
ORIENT
UNION
GREENFIELD
Adair
Casey
Stuart
Canby
Berea
Prussia
Arbor Hill
Fontanelle
Nanito
Bridgewater
Hebron
Fisk
Orient
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QUINCY
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SOME LARGE BOWLDERS IN THE KANSAN DRIFT OF SOUTHERN IOWA

BY

rederick

GEORGE F. KAY

SOME LARGE BOWLDERS IN THE KANSAN DRIFT OF SOUTHERN IOWA

Many times the fact has been emphasized that the number of large bowlders on the surface of the Kansan drift is small when compared with the number on the surface of the Iowan drift. In fact, as has been pointed out by Alden and Leighton[1], there was at one time among some geologists the general impression that if large bowlders of coarse, feldspathic granite were found associated with a drift, that drift was presumably the Iowan and should be so mapped. However, many years ago large bowlders

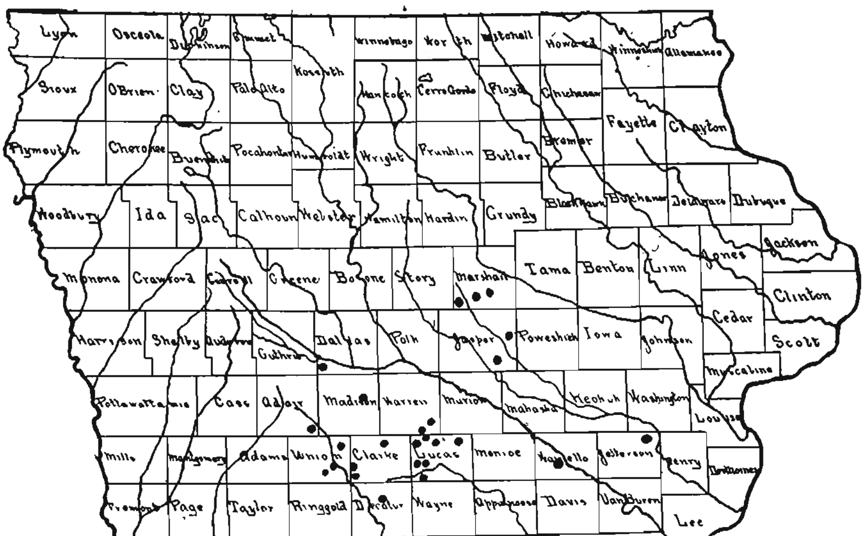


FIG. 40.—Map showing distribution of some large bowlders in Kansan drift in southern Iowa.

[1]Iowa Geological Survey, Vol. XXVI, p. 126.

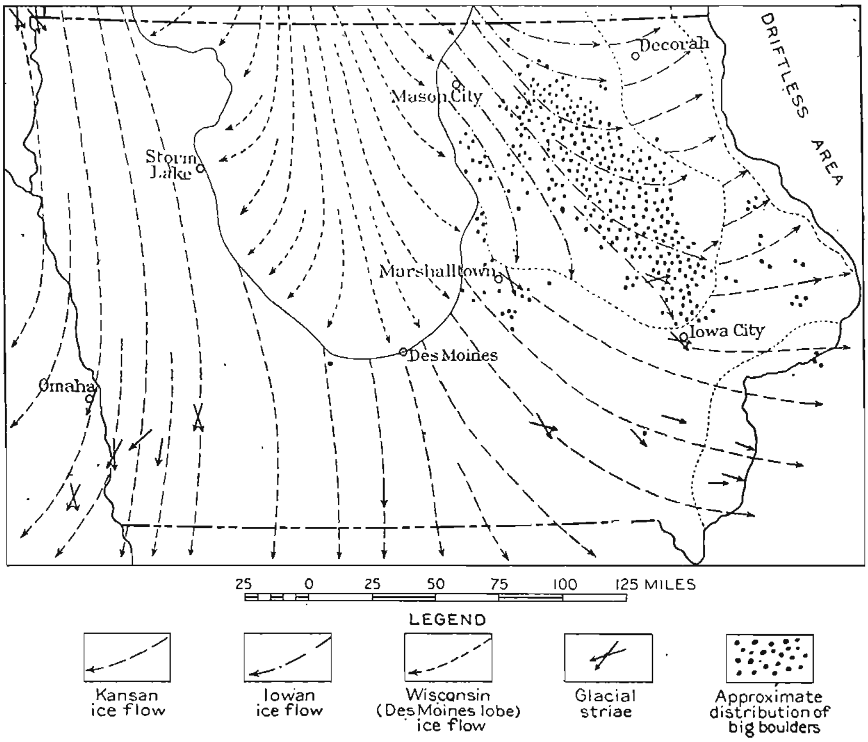


FIG. 41.—Diagram showing the distribution of big granite bowlders as related to the distribution of the ice sheets in Iowa.

which are within the area of Kansan drift and many miles from any well recognized area of Iowan drift were described in reports of the Iowa Geological Survey and in other publications.

Recent studies of the Kansan drift of southern Iowa have revealed the presence of more large bowlders than had been anticipated, and no doubt if an attempt were made to locate all bowlders of large size the number now known could be increased considerably. It seems well at this time to make record of the locations and sizes of large bowlders in the Kansan drift area for, one by one, they will be destroyed, some by the farmers in better preparing the farms for cultivation, and some for use in foundations of buildings and for abutments of bridges. A few are being removed to parks and other places to serve as memorials of important events in the history of the state. In figure 40, there are represented only some of the largest bowlders, some of which have been described in former publications; some are described here for the first time. Figure 41, when compared with figure 40, shows graphically in a general way the relative numbers of bowlders in the Iowan and Kansan areas.

In the Kansan drift of southern Iowa the largest bowlder known to the writer is in the northwest quarter of section 15, Otter Creek township, Lucas county. It is 25 feet long, 20 feet wide, and is exposed for 16 feet above the surface, figure 42. In this connection it may be of interest to state that the largest bowlder known in the Iowan drift area is in the northwest quarter of the southwest quarter of section 22, Riverton township, in Floyd county. Its dimensions are 50 feet by 40 feet by $11\frac{1}{2}$ feet above ground. A smaller piece which is beside it, and which is apparently a fragment of the larger, measures 17 feet by 7 feet by $1\frac{1}{2}$ feet.

The writer has seen no large granite bowlders in the southwestern part of the state. It is worthy of mention, however,

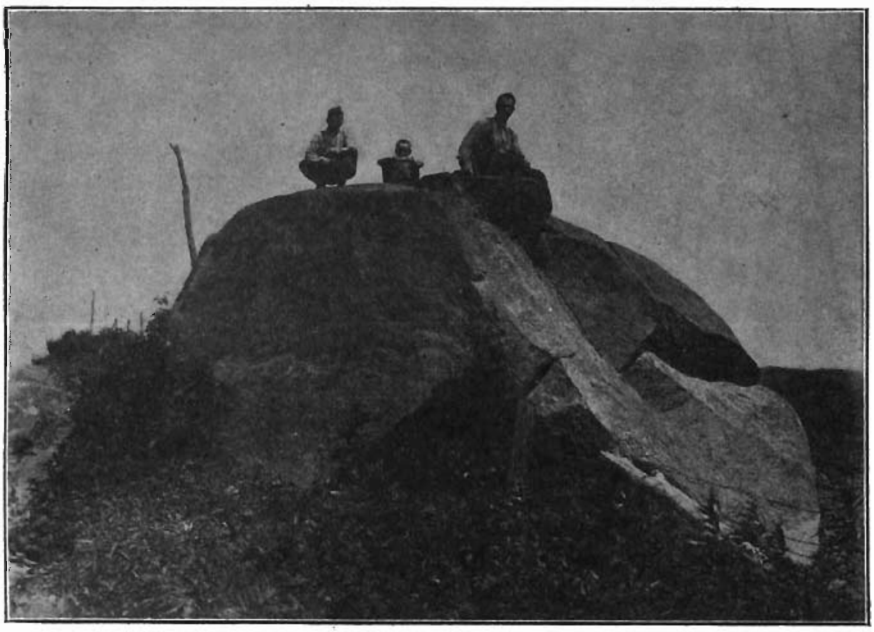


FIG. 42.—Large granite bowlder in the northwest quarter of section 15, Otter Creek township, Lucas county.

that Mr. F. H. Reed, a farmer living a few miles northeast of Yorktown, furnished information to the effect that in section 15, Morton township, Page county, there used to be a granite bowlder on the McCormick farm close to Lone Rock school, which school received its name from the presence of the bowlder. It was 20 feet long, 20 feet wide, and 5 feet high. Mr. Reed stated also that a bowlder with dimensions of 6 feet by 8 feet by 3 feet

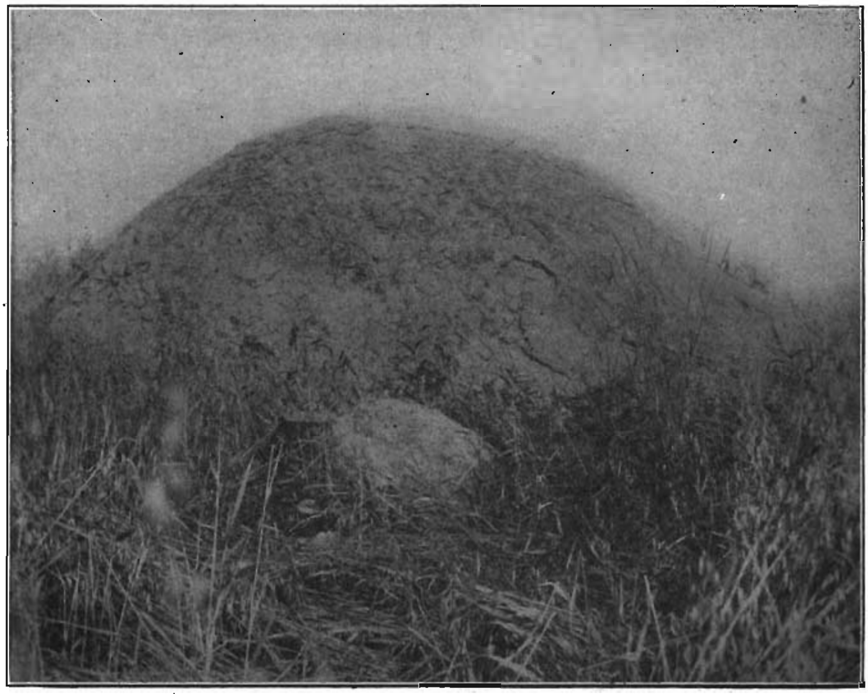
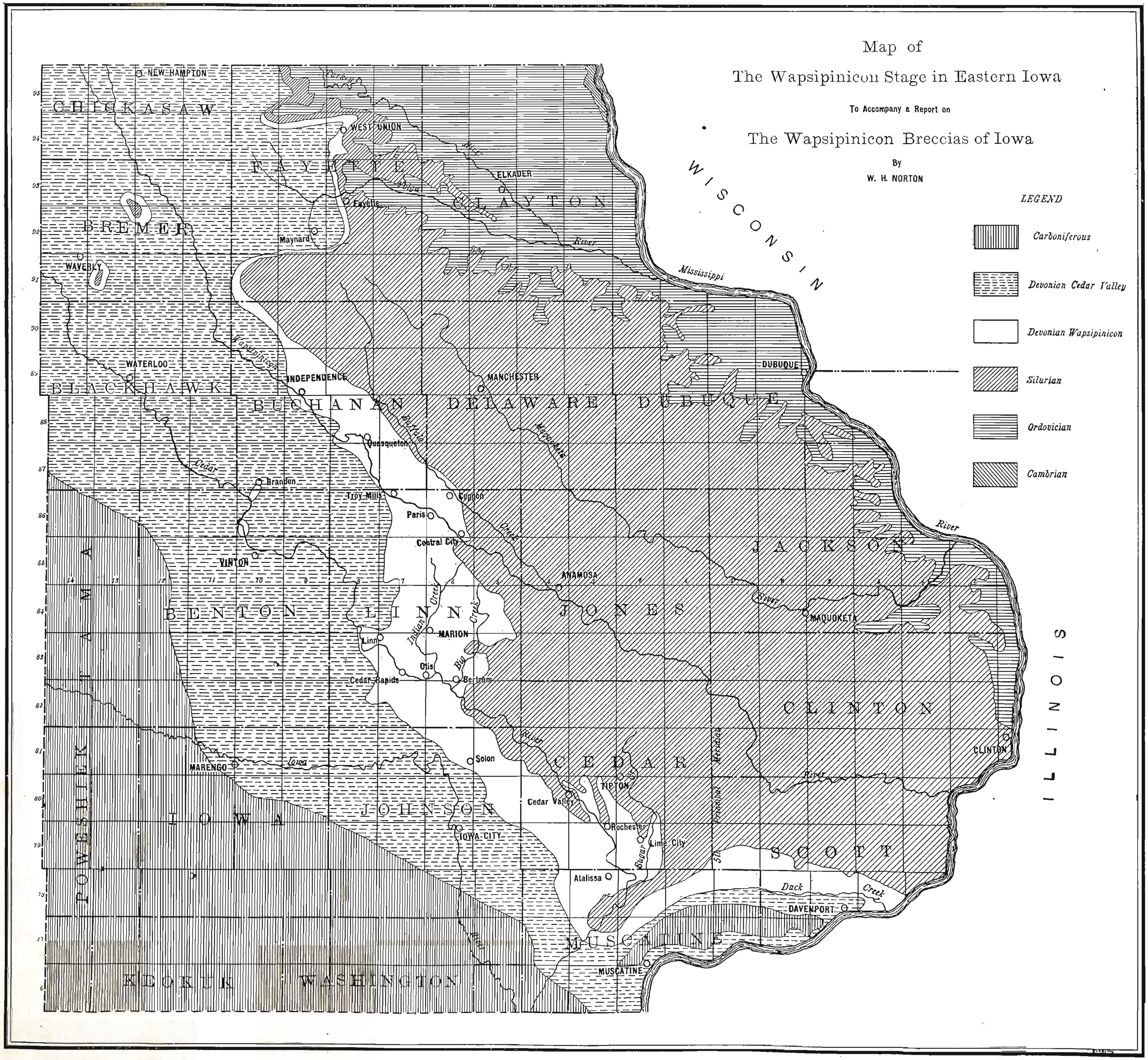


FIG. 43.—Large granite bowlder in the southeast quarter of section 13, Liberty township, Lucas county.

had been blasted from the northeast quarter of section 34, Morton township, Page county. In the park at College Springs there is now a bowlder of Sioux quartzite with dimensions 6 feet by 4 feet by 3 feet. In this part of the state the loess in many places is sufficiently thick to cover from view such large bowlders as may lie on the Kansan drift.


Map of
The Wapsipinicon Stage in Eastern Iowa
To Accompany a Report on
The Wapsipinicon Breccias of Iowa
By
W. H. NORTON
LEGEND
Carboniferous
Devonian Cedar Valley
Devonian Wapsipinicon
Silurian
Ordovician
Cambrian
WISCONSIN
ILLINOIS
CHICKASAW
FAYETTE
CLAYTON
BREMER
BLACKHAWK
BUCHANAN
DELAWARE
DUBUQUE
JACKSON
TAMA
BENTON
LINN
JONES
CLINTON
CEDAR
SCOTT
POWESHIEK
IOWA
JOHNSON
MUSCATINE
KEOKUK
WASHINGTON
NEW HAMPTON
WEST UNION
ELKADER
Fayette
Maynard
WAVERLY
WATERLOO
INDEPENDENCE
MANCHESTER
DUBUQUE
Quasqueton
Brandon
Troy Mills
Coggon
Paris
Central City
VINTON
ANAMOSA
MAQUOKETA
Linn
MARION
Otis
Cedar Rapids
Bertram
Solon
MARENGO
Cedar Valley
TIPTON
Rochester
Lime City
IOWA CITY
Atalissa
DAVENPORT
CLINTON
MUSCATINE
Mississippi
River
Wapsipinicon
Cedar
Iowa
Buffalo
Maquoketa
Indian Creek
Big Creek
Duck Creek
Sugar
5th Principal Meridian

There is given below a brief description of some of the large bowlders in Kansan drift in southern Iowa. Attention is called to the publications in which previous reference has been made to some of these bowlders.

It will be observed that nearly all of the large bowlders are granite; a few are quartzite.

FIG. 44.—Large granite bowlder in the northeast quarter of the northwest quarter of section 33, New Hope township, Union county.

County	Location in County	Kind of Rock	Size	Reference
Henry	Not given	Reddish gray granite	10 ft. across	Ia. Geol. Sur. Vol. XII, p. 290, 1902.
Jefferson	¼ mi. east of the N. W. corner of Sec. 15, Walnut twp.	Porphyritic granite	17'x12'x7'	Ia. Geol. Sur. Vol. XII, p. 427, 1902.
Wapello	S. W. ¼ of S. E. ¼ of Sec. 32, Center twp.	Fine-grained granite	12'x6'x5'	Ia. Geol. Sur. Vol. XII, p. 472, 1902.
Jasper	East of Turner on Rock Island Ry., Sec. 27, Rock Creek twp.	Coarse granite	13'x8'x4' 6"	
	South of east-west road in northern part of Sec. 11, Elk Creek twp.	Granite	15'x4'x3'	
Marshall	S. E. ¼ of S. W. ¼, Sec. 8, Eden twp.	Granite	19'x17'x4'	
	S. E. ¼, Sec. 4, Logan twp.	Granite	10'x4'x6'	
	S. W. ¼ Timber Creek twp.	Granite	5'x8'x3'	Ia. Geol Sur. Vol. XXVI, p. 127.
Lucas	N. W. ¼ of S. W. ¼, Sec. 32, Whitebreast twp.	Granite	8'x7'x6'	
	West side of road between Secs. 31, Benton twp., and 36, Warren twp.,	Granite	10'x9'x6'	
	N. W. ¼ of Sec. 15, Otter Creek twp.	Granite	25'x20'x16'	See figure 42.
	S. E. ¼ of Sec. 13, Liberty twp.	Granite	12'x9'x7'	See figure 43.
	N. W. ¼ of Sec. 36, Jackson twp.	Granite	9'x6'x3'	
	Middle of Sec. 17, Pleasant twp.	Granite	23'x15'x10'	
	N. W. part of Sec. 5, Liberty twp.	Granite	5'x5'x2'	
Warren	S. E. ¼ of Sec. 31, Whitebreast twp.	Coarse granite	Three parts: 12'x12'x4' 6" 6'x4'x2' 6'x1'x1'	
	S. E. ¼ Sec. 16, Whitebreast twp.	Coarse granite	Three parts: 12'x11'x4' 8'x2'x3' 5'x3'x3'	
Decatur	N. E. ¼ of S. E. ¼ Sec. 17, Center twp.; now in park at Leon	Granite	6'x6'x4'	

Clarke	Just south of C. B. & Q. Ry., and close to west boundary, Sec. 19, Troy twp.	Granite	8'x7'x2'. Also three detached slabs.	
	N. W. ¼ of N. E. ¼ Sec. 30, Doyle twp.	Quartzite	12'x11'x5'	
	S. W. ¼ of N. W. ¼ Sec. 18, Fremont twp.	Reddish granite	17'x14' 10"x8'	Ia. Geol. Surv. Vol. XXVII, p. 143.
Madison	1 mi. north of Patterson	Sioux quartzite	10'x6'x5'	Ia. Geol. Surv. Vol. VII, p. 521, 1896.
Dallas	Sec. 18, Union twp.	Red granite	25' long and half as wide	Ia. Geol. Surv. Vol. VII, p. 85, 1896.
Union	N. E. ¼ of N. W. ¼ Sec. 33, New Hope twp.	Granite	12'x9'x4'	See figure 44.
	N. W. ¼ of S. W. ¼ Sec. 29, Jones twp.	Granite	Three parts: 20'x9'x6'; 9'x4'x2'; 8'x4'x2'	
	Beside C. G. W. R. R. tracks. Few hundred yards north of Shepard, Union twp.	Quartzite	6'x3'x2'	
	Another near here		6'x4'x2'	
Adair	N. W. ¼ of Sec. 26, Union twp.	Granite	12'x9'x4' 6"	

WAPSIPINICON BRECCIAS OF IOWA

BY

W. H. NORTON

CONTENTS

THE WAPSIPINICON BRECCIAS OF IOWA

INTRODUCTION

It has long been known that one of the most extensive breccias of the United States is that of the lower stage of the Devonian in Iowa, the Wapsipinicon. Breccia beds involving one or more of its terranes occur along the line of strike from Muscatine county on the southeast to Fayette county on the northwest, a distance of about two hundred miles. Owing to the thickness of the strata affected and their gentle dip to the southwest, the belt of breccia is of considerable width and embraces an area which may be roughly estimated at a thousand square miles. The brecciation is therefore regional, and its causes must be equally widespread in their operation.

These beds of broken rock have been objects of observation and study since Owen in 1850 noted the brecciation of the lowest Devonian strata exposed in the valley of Cedar river, in Cedar county. McGee in 1891 devoted one or two pages of "The Pleistocene History of Northeastern Iowa" to lucid description and suggestive interpretation of the breccia as seen typically at Fayette. The writers of the reports on areal geology of the Iowa Geological Survey whose work lay in the counties in which these breccias occur have given to them more than cursory attention. Yet although these observations have continued for more than half a century the brecciation of the Iowa Devonian has remained an outstanding problem in Iowa geology for which no full and convincing solution has been given.

The processes by which rocks are broken up and reassembled into beds of breccia are many, and they do not always leave in their product clear evidence of the method of its manufacture.

In long studied areas, such as Europe and eastern North America, breccias are not uncommon, and the literature regarding them is extensive. Yet example after example might be cited of breccias which have received the most diverse of explanations and as to whose cause no unanimity of judgment has yet been reached. The solution of the Iowa problem requires the holding in mind of a genetic classification of breccias with the diagnostics of each variety, and furthermore it requires a comprehensive and minute study of the phenomena in the field. The fragments must be traced back to their sources. The strata from which they have been derived must be found, if possible, in an undisturbed condition, and assigned to their proper stratigraphic places. The matrix in which the fragments are imbedded must be scrutinized in order to find any possible traces of its origin. Nothing is too small, and nothing too large, for investigation if only it may throw light on the processes by which the strata were broken up and reassembled in these breccias.

For an exposition of the various types of breccias, the reader is referred to the author's paper on *The Classification of Breccias*, Journal of Geology, vol. XXV, pp. 160-194, 1917. The following outlines of this classification may be found convenient.

Classification by Physical Characters

Endostratic breccia: one bedded in a distinct stratum.

Crackle breccia: one showing only incipient brecciation, with little or no displacement of fragments.

Mosaic breccia: one whose fragments are largely but not wholly disjointed and displaced.

Rubble breccia: one whose fragments do not match along initial planes of rupture, and are close set.

Pudding breccia, breccia of sporadic fragments: one whose fragments are imbedded in a preponderant matrix.

Classification by Origin; Fragmentation and Assemblage

I. SUBAERIAL BRECCIAS; ASSEMBLED IN OPEN AIR.

Residual breccia: the angular debris of the waste mantle.
Talus breccia: the accumulation of waste at the foot of cliffs.
Rock glacier breccia: the material of rock glaciers, rock streams, or talus glaciers.
Landslide breccia: the material of rock falls and rock slides.
Bajada breccia: assembled in the debris slopes (*baiada*) of the rims of desert basins.
Glacial breccia: morainic deposits of glaciers.
Volcanic breccia: due to volcanic action and including
  Flow breccia: in which angular fragments are included in lava flows.
  Tuff breccia: made up of fragmental products of volcanic eruptions.

II. SUBAQUEOUS BRECCIAS; ACCUMULATED UNDER WATER

Breccias of subaerial fragmentation.
Subaqueous talus breccia.
Subaqueous landslide breccia.
Raft breccia, deposits from rafts of icebergs or icefloes, trees, or sea weed.
Desiccation breccia: fragmentation due to drying of surficial sediments of flood plains, playa lake beds and mud flats along shores.
Volcanic subaqueous breccia.
Shoal breccia: both disruption and assemblage due to the action of waves and tides on shoals.
Reef breccia: composed of the fragments of coral reefs or of other reefs of organic origin, including
  Reef-rock breccia: formed by the direct upbuilding of the reef rock.
  Island-rock breccia: composed of fragments of the reef heaped by waves into coral islands.
  Talus reef breccia: composed of fragments of the reef accumulated below wave base.

Beach breccia: composed of more or less angular material of bowlder or pebble beaches.

Glide breccia: in which brecciation is due to gravitational movement of subaqueous deposits. The precipitory causes of these glides may be *overload, earthquake shock, deformation or undercut.*

III. ENDOLITHIC BRECCIAS, FORMED WITHIN THE LITHOSPHERE.

Tectonic breccia: due to crustal movements produced by lateral or vertical pressure or by tension.

Fault breccia: fragmentation due to friction or shearing stresses along a fault plane.

Fold breccia: fragmentation due to stresses producing folds.

Crush breccia: fragmentation due to stresses without mass deformation.

Expansion breccia: caused by increase of bulk of the brecciating rock or of associated layers due to hydration or recrystallization.

Founder breccia: due to the removal by solution of inferior terranes leaving the unsupported superincumbent beds to break down into breccia. *Cavern breccia,* composed of detached masses fallen from the roofs and sides of caverns, is a variety.

HISTORY OF EARLIER INVESTIGATIONS

The position of the breccias along the line of contact of the Devonian and the Silurian indicates that it is the lower strata of the Iowa Devonian which are affected. The stratigraphic position of these lower strata, and indeed of the entire body of the Devonian in Iowa, has long been a matter of question especially in its equivalencies with other fields. A resumé of the investigations of the Iowa Devonian may thus be useful so far as they relate to the brecciated terranes.

As early as 1850 Owen correlated the Iowa Devonian with the Hamilton and the Upper Helderberg of New York.[1] He noted white, brecciated, close-textured limestone resting on the Niag-

[1]Owen, D. D., Geol. Surv. of Wisc., Iowa, and Minn. Chap. III.

aran along Sugar creek below the present site of Lime City in Cedar county and considered it an extension of the beds of the Rock Island rapids. He concluded that the Devonian rocks of the Cedar river valley consist chiefly of close-textured, white and gray limestones, in some places brecciated, or of argillaceous limestones. The former are of no great thickness, probably not exceeding seventy feet.

Hall,[2] in 1858, following the classification of Owen, recognized the Upper Helderberg at Davenport and on the road from that city to LeClaire at the level of the bottom land, referring probably to the outcrops of Otis limestone on Crow and Pigeon creeks. He states that "on Duck creek the same limestone appears in great force" and finds that at Davenport "the lowest beds are often concretionary and sometimes iron stained and brecciated."

White[3] correlated the entire Devonian terrane in Iowa with the New York Hamilton. He mentions different lithological variations such as magnesian limestone and calcareous shales, but states that "so far as has yet been ascertained none of these lithological variations characterize any particular horizon of this formation over any large portion of the area occupied by it, but the concretionary or partially brecciated bluish gray common limestone is its prevailing lithological characteristic."

In 1878 Calvin[4] announced the discovery at Independence, in a shaft sunk in search for coal, of a dark shale with a brachiopod fauna of twelve Devonian species. He suggests a tripartite division of the Iowa Devonian: in descending order, the Rockford shales, the central limestones, and the Independence shales. All of these he refers to the Hamilton epoch.

The local geologists of Davenport have recognized the individuality of the beds classified by Hall on lithologic grounds as Upper Helderberg and Hamilton. In 1877 Rev. W. H. Barris[5] distinguished the Upper Helderberg from the Hamilton by its fauna and mentions two lithologic types of the former limestone,

[2]Hall, Geol. of Iowa; Vol. I, p. 82.
[3]White, C. A., Geol. of Iowa. 1870, p. 185.
[4]Calvin, Samuel, Bull, U. S. Geol. and Geog. Surv. Terr., Vol. IV. pp. 725-730, Washington, 1878.
[5]Local Geology of Davenport and Vicinity: Proc. Dav. Acad. of Nat. Sciences, Vol. 2, p. 261.

a fossiliferous upper bed and lower concretionary unfossiliferous beds "closely approaching the character of chert." In 1879 he described new fossils from the Upper Helderberg[6].

In 1885 Mr. A. S. Tiffany[7] noted various exposures of the "Upper Helderberg" near Davenport and the brecciation of several beds. He also published a list of 246 species of fossils collected from this formation in the vicinity of Davenport!

In 1891 Calvin[8] observed that the Independence shales are not the lowest of the Iowa Devonian but are preceded by brecciated limestones exposed at Troy Mills. He classified the exposed Devonian strata of the county—so far as these have been since referred to the Wapsipinicon—as follows:

4. *Spirifer pennatus* beds.
3. *Gyroceras* beds, characterized by a large *Gyroceras* and robust forms of *Gypidula comis*.
2. The Independence shales.
1. Brecciated limestone.

As to No. 1 he states, "No fossils have been seen as yet in these beds at Independence, but at Troy Mills in Linn county they contain many brachiopods which are characteristic of the lower part of the Iowa Devonian."

In 1891 McGee[9] followed the tripartite division of Calvin and named the central calcareous terrane the Cedar Valley limestone. He described and illustrated the breccia beds at Fayette.[10] He noted the exhibition of this structure over an immense area in nine counties, and adds that "brecciation appears to be practically co-extensive with the Cedar Valley terrane." He briefly sketched a hypothesis of expansion of Paleozoic sediments by rise of isogeotherms and a consequent horizontal expansion and creep of Devonian sediments down the prevailing seaward slope. Thus the Devonian strata were "thrown into anticlinal and synclinal folds concentric with the shore, or elsewhere were crushed and broken into fragments along planes of least strength." Regarding crumpling and brecciation as coeval with deposition,

[6]Ibid, pp. 284-288.
[7]Geology of Scott County, Iowa, and Rock Island County, Illinois: Davenport, 1885.
[8]Calvin S., Additional Notes on the Devonian Rocks of Buchanan County, Iowa: Am. Geol., Vol. 8, pp. 142-145.
[9]McGee, W J, Pleistocene History of Northeastern Iowa: 11th Ann. Rept. U. S. G. S., pp. 314-323.
[10]Of McGee's excellent and typical illustrations Pl. XXV and Fig. 15 are of rubble breccia of the horizon of the Otis calcilutites, and Fig. 16 is a mosaic breccia from the thinly laminated Otis just beneath.

McGee dates both at about the close of the period of Cedar Valley deposition[11].

The writer does not find that McGee himself used the term Fayette breccia, which rather unfortunately came later into somewhat general use. McGee did not regard the breccia as a formation, but as a structure characteristic of different horizons in a formation—the Cedar Valley limestone—over a wide extent of country. His closest approach to any formal name is to speak of it as the "Devonian breccia" or the "Devonian limestone breccia."

In 1893 Norton[12] found beneath the Independence shales an extensive Devonian formation which he designated as the Otis. He discriminated four stages or zones of brecciation as follows:

4. A zone involving the *Acervularia davidsoni, Phillipsastrea billingsi* and *Spirifer pennatus* horizons.

3. A zone distinguished by the brecciation of a limestone bed called the fossiliferous Upper Helderberg at Davenport, the *Gyroceras* beds of Calvin. For this limestone the name *Upper Davenport* is suggested.

2. A zone defined by the large number of calcilutite fragments, identical with the lower unfossiliferous "Upper Helderberg" limestone at Davenport and here named the Lower Davenport.

1. A zone in which the Independence contributes largely both to matrix and to fragments.

The Davenport limestones are thus separated from the Cedar Valley. At the same time it is pointed out that they lie above the Independence, and that the Otis carries as its characteristic fossil a Hamilton and Chemung brachiopod. Hence the Davenport limestones can no longer be regarded as Upper Helderberg.

In 1895 Norton[13] described the four zones of the brecciated beds in much detail and found two magnesian terranes below the Otis and above the Anamosa beds of the Niagaran—the Coggon and the Bertram—both of which were included in the Silurian, although the inclusion of the Coggon was only provisional. He proposed the term Wapsipinicon as the designation of a stage composed of the Upper Davenport limestone and the Devonian substages underneath it. The appropriateness of this term is due to the exposure of the entire terrane along the banks of Wapsipinicon river which traverses over a large part

[11]Ibid, pp. 323, 338, 351.
[12]Norton, W. H., Notes on the Lower Strata of the Devonian Series in Iowa: Proc. Iowa Acad. Sci., Vol. I, Pt. IV, pp. 22-24.
[13]Geology of Linn County, Iowa Geol. Surv., Vol. IV.

of its course the Devonian area of outcrop east of the valley of the Cedar. Since this date, the Iowa Geological Survey, and the United States Geological Survey in its publications relating to Iowa, recognize the division of the major part of the Iowa Devonian into the two stages named after the parallel rivers which traverse the belt of outcrop of the system.

In 1897 Calvin[14] found the exposures of breccia in Johnson county to correspond with the zones of Norton and classified the *Spirifer pennatus* beds with the Wapsipinicon.

In 1897 Barris[15] withdrew the reference of the Davenport limestones to the Upper Helderberg or Corniferous. He abandoned the attempt to correlate the Iowa Devonian with the New York section and quoted with apparent approval the classification by McGee of all the limestones of the Iowa Devonian in a single terrane, the Cedar Valley. At the same time he designated the fossiliferous "Upper Helderberg" at Davenport as the "Phragmoceras beds" and listed their characteristic fossils to the number of twenty-four.

In the same year Udden[16] discriminated from the Cedar Valley limestones about Rock Island an inferior terrane which he identified as the *Gyroceras* beds of Calvin and Barris and the Upper Davenport of Norton. Number 1 of his section includes a lower fossiliferous part which "appears to be the same as Prof. W. H. Norton's Otis beds. The greater part of these beds have by the latter author been called the Lower Davenport beds." The thickness assigned to No. 1 is seventy feet, the exact thickness assigned by Owen in 1850 to the "lower close-textured white and gray limestones sometimes brecciated" of the Iowa Devonian.

In 1898 Calvin[17] published the Geology of Buchanan county. He classified the Devonian rocks of the county as belonging to the Middle Devonian, but stated with emphasis that the western Devonian can not be correlated except in a broad and very general way with the Devonian of the east. Under the Wapsipinicon stage he classified the Fayette breccia as follows:

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[14] Calvin, S., Geology of Johnson County: Iowa Geol. Surv., Vol. VII, p. 59.

[15] Barris, W. H., Our Local Geology. Reprint from Proc. Dav. Acad. of Nat. Sci., Vol. VII.

[16] Udden, J. A., A Brief Description of the Section of Devonian Rocks exposed in the Vicinity of Rock Island, Illinois, Etc.: Journal of the Cincinnati Soc. of Nat. Hist., Vol. 19, pp. 93-95.

[17] Iowa Geol. Surv., Vol. VIII.

4. *Spirifer pennatus* beds, shattered.
3. Barren beds, similar in lithological characters and physical condition to the *S. pennatus* beds.
2. *Gyroceras* beds, in displaced and tumbled fragments.
1. The true brecciated beds, composed in the main of small angular fragments mostly unfossiliferous, many of the fragments fine-grained and dark drab in color.

The Independence shales are now found to lie beneath this breccia and the Otis is not exposed.

A graphic description is given[18] of the chaotic breccia of the river's bed at Independence, and consideration of the cause of this brecciation is waived by a phrase—"the general destructive process, whatever it may have been, which reduced a large number of limestone layers to the brecciated condition." Calvin distinctly states, however, that above the "*Gyroceras* beds" "the phenomena of slickensides are indicative of the tremendous crushing and shearing strains to which the rocks of this horizon have been subjected."

In 1899 Norton[19] found all the members of the Wapsipinicon present in Scott county and described the brecciation of the Davenport limestones. He defended the theory of crush under lateral pressure as the only theory tenable. He found *Phillipsastrea billingsi* in the Upper Davenport beds and again drew the upper limit of the Wapsipinicon at their summit on the ground of the faunal change at that horizon as was emphasized by Barris, but adds "If it appears that the difference in the fauna has been exaggerated the upper limit of the Wapsipinicon may well be redrawn." This remark refers to Calvin's inclusion in the Wapsipinicon of the *Spirifer pennatus* beds, which in Scott county are found in shaly limestone above the Upper Davenport.

In the same year Udden[20] in his geology of Muscatine county states: "Of the members of the Wapsipinicon stage, the Fayette breccia is alone exposed in this county and that in only a few places. There appears to be no well defined line of demarcation between it and the Cedar Valley above. This may be due to a lack of good outcrops."

[18]Ibid, pp. 224, 225, 226.
[19]Geology of Scott County: Iowa Geol. Surv., Vol. IX.
[20]Udden, J. A., Iowa Geol. Surv., Vol. IX, p. 268.

Udden's description of the partly brecciated beds of the Wapsipinicon as fine-grained, compact, very pure limestone, and especially their stratigraphic place in the section seem to indicate the exact equivalency with the Lower Davenport of the county adjoining on the north. These partly brecciated beds are overlain by the *Phillipsastrea* beds. As described by Udden, the position, the lithological character, the thickness, and the presence of the coral mentioned, along with *Acervularia davidsoni,* agree entirely with the Upper Davenport of Scott county. *Spirifer pennatus* occurs toward the summit of the *Phillipsastrea* beds, while in Scott county it is found above the Upper Davenport, taking the *Phillipsastrea* horizon as a datum plane. Calvin in a footnote to Udden's general section states that the partly brecciated limestones beneath the *Phillipsastrea* beds are the stratigraphical equivalent of the *Spirifer pennatus* beds. It will be recalled that in Buchanan county Calvin found immediately beneath the *S. pennatus* beds barren beds similar to them in lithological character and physical condition.

In 1901, in the Geology of Cedar County[21] Norton transferred the Coggon from the Silurian and made it the basal member of the Wapsipinicon, on account of the fossils found in it at Cedar Valley and at other points. The position of the *Spirifer pennatus* beds was left uncertain, whether with the Upper Davenport or with the Cedar Valley.

In 1902 Calvin[22] described the lowest Devonian strata of Howard county as resting directly upon the Maquoketa shales and stated that they belong to the Upper Davenport, "below which, before reaching the base of the Devonian in Linn and Scott counties there are the divisions of the Wapsipinicon stage which have been described as the Lower Davenport, Independence, Otis and Coggon."

In 1905 Savage[23] divided the Wapsipinicon of Benton county into the Fayette and the Coggon. The Fayette brecciated beds include the *Spirifer pennatus* beds, the *Gyroceras* beds, and probably the Lower Davenport. It is stated that "the cause and

[21] Iowa Geol. Surv., Vol. XI.
[22] Calvin, S., Geol. of Howard County: Iowa Geol. Surv., Vol. XIII, p. 50.
[23] Savage, T. E., Geology of Benton County: Iowa Geol. Surv., Vol. XV.

the process by which these brecciated beds were formed are alike somewhat obscure.'' After quoting Norton's theory of crumpling under lateral pressure as given in the Scott county report, Savage adds: ''The facts which are revealed in most of these beds in Benton county are in harmony with such a mode of rock fracture.'' He also suggests that ''certain phases of the Lower Davenport breccia seem difficult of explanation by assuming crushing as the mode of formation, and seem to indicate a talus origin.''

In the same year Savage[24] in his table of formations divides the Wapsipinicon of Fayette county into the Upper Davenport and the Lower Davenport. The basal member of the Devonian series in the county is also stated in the text to have close resemblances to the Otis limestone. ''The *Spirifer pennatus* horizon cannot be perfectly differentiated from that of the *Gyroceras* beds which precede it'' and the Cedar Valley stage is held to begin with undisturbed layers a short distance below the *Acervularia profunda* and *Newberria johannis* zone.

In 1906 Norton found in Bremer county breccia of the first and second zones. The lowest fossiliferous beds contain *Spirifer pennatus* as well as *Schizophoria macfarlanei* and *Gypidula comis*.

In 1912 Ekblaw[25] found that ''the Rock Island county Devonian limestones are a continuation eastward of the Wapsipinicon and Cedar Valley stages of Iowa.'' He also discriminated the equivalents of the Lower and Upper Davenport divisions of the Wapsipinicon stage.

In resumé, all workers in the field since the earliest reconnaissances of Owen and Hall have recognized the lithological distinctness of the Wapsipinicon from the Cedar Valley, and its prevailing brecciation has been made by some a ground for demarcation. The fauna of the Wapsipinicon has been found distinctive in the subdivisions of the Otis and the Independence. It was long held that the fauna of the Upper Davenport was sufficiently individual to warrant its reférence to the Upper Helderberg, a reference now universally abandoned. While the

[24]Savage, T. E., Geology of Fayette County: Iowa Geol. Surv., Vol. XV.
[25]Ekblaw, W. E., Correlation of the Devonian System of the Rock Island Region: Trans. Ill. Acad. Sci., 1912.

Wapsipinicon has been everywhere recognized as a stage of the Iowa Devonian, there has been less unanimity in the divisions of it into substages, and there is still doubt as to whether the upper limit of it should be drawn at the summit of the *Spirifer pennatus* beds, which by Calvin were included in the Upper Davenport, or at their base. The question is wholly one of paleontology, and while the data so far gathered do not appear to have been sufficient for its complete solution, enough is known to show that the difficulty lies in the fact that species held to be diagnostic do not appear at the same horizons or with the same associates in all parts of the field.

THE DIVISIONS OF THE WAPSIPINICON STAGE

The Wapsipinicon of Iowa has been subdivided on very simple and for the most part faunal lines. The Upper Davenport, the Independence and the Otis are demarked because of their distinctive fauna. With the uppermost of these formations are associated barren beds of calcilutites[25a] and other types of limestone. They directly underlie the Upper Davenport at all points of contact where the beds are seen in place, as at Davenport and Vinton. Their affinities are with it rather than with the argillaceous Independence underneath. Yet the extension in northeastern Iowa is so wide, their lithologic characters are so distinct from those of the beds above them and below that for convenience they have been given a name, the Lower Davenport, which expresses both their individuality and their close affinity with the beds above.

Thickness—The total thickness of these terranes comprises a very considerable part of the entire thickness of the Devonian of Iowa. The amazing estimate of Tiffany[26] of 390 feet for the "Upper Helderberg" at Davenport, based on artesian well sections was corrected by Norton[27] from the same data to 115 feet and from much fuller data Norton[28] later placed the base of

[25a]*Calcilutite*, a calcareous rock of lutaceous (Lat. *lutum*, mud) structure, composed of lime particles of mudlike fineness of grain. Lithographic limestone is an example. See Grabau, Principles of Stratigraphy, p. 285. New York, 1913.

[26]Tiffany, A. S., Am. Geol., Vol. 3, p. 117, 1889.

[27]Norton, W. H., Iowa Geol. Surv., Vol. III, p. 202, 1893.

[28]Norton, W. H., Underground Water Resources of Iowa: U. S. G. S., Water Supply Paper 293, p. 494.

the Devonian at Davenport at 475 feet above sea level, giving a thickness to the Wapsipinicon at this point of about one hundred feet.

At Kenwood the thickness of the Independence is about thirty feet. The Otis at Cedar Rapids reaches a thickness of fifty feet above water level in the river and incomplete well data indicate that it is about eighty feet lower before the dolomites of the Niagaran are reached. Half of this dimension may be occupied by the Bertram beds, hitherto referred to the Silurian, but whose position is more probably with the Devonian. In Linn county the total thickness of the Wapsipinicon including the Bertram beds may easily reach 150 feet.

In the quarries and railway cut north of Vinton a section of the Wapsipinicon extending from the barren beds of the *Spirifer pennatus* beds well down in the Otis measures about sixty feet. In the artesian well at Vinton, Niagaran dolomite was reached at 135 feet, and the curb of the well is somewhat below the *Spirifer pennatus* beds.

At Waterloo the city artesians reach the Niagaran dolomite at a depth of 158 feet. In city well No. 1 no samples were saved for a depth of seventy feet. From this down to the Niagaran dolomite the drillings include a number of Wapsipinicon types of rock such as brown calcilutite, brecciated limestone, mottled buff limestone, gray sandstone and limestone arenaceous with bits of flint. The well curb is somewhat below the base of the *Acervularia profunda* beds, which occur in the Waterloo quarries[29].

To the north the Wapsipinicon abruptly thins. The Niagaran emerges in southern Bremer county, and at Waverly the city artesian reached the Niagaran dolomite at a depth of seventy feet. The well curb here is at the horizon of the *Spirifer pennatus* beds.

At Fayette the entire thickness of the Wapsipinicon measures forty-seven feet from its base resting upon the Niagaran to the summit of the *Gypidula comis—Hypothyridina cuboides* (*Hypothyris intermedia*) ledge (p. 458).

[29]Arey, M. F., Geology of Black Hawk County: Iowa Geol. Surv., Vol. XVI, p. 421.

It is now necessary to describe the physical characteristics of the different terranes of the Wapsipinicon as they are exhibited in typical exposures where they are little disturbed. We shall thus be better prepared to identify the fragments of their beds in the chaotic breccia in which they elsewhere have been commingled.

The Bertram Beds

It has been seen that the lowest beds which can be assigned to the Devonian with certitude are the Otis limestones. Between the fossiliferous beds of the Coggon phase of the Otis and the uppermost Niagaran, and showing well defined contacts with each, are unfossiliferous magnesian limestones of so peculiar a character that they have been distinguished as the Bertram beds[30]. These beds were assigned to the Silurian along with the Coggon beds of the Otis, because of their dolomitic nature. Fossils found in the Coggon afterwards proved it to be simply the magnesian basal portion of the Otis. And while the true place of the Bertram beds must be uncertain until fossils are found in it or a distinct unconformity is seen above it or below, it is related to the Wapsipinicon in texture and in brecciation, and may now be provisionally classed with that formation. These beds occur, so far as known, only in Linn county and outcrop along the zone of contact between the Silurian and the Devonian. They extend from the town of Bertram up the valley of Big creek and appear again at various points in the valley of Indian creek to the west. Sections on the former creek show a thickness of nearly or quite fifty feet.

The limestone is commonly heavily bedded. Numerous sections record layers one, two and even five and eight feet in thickness. Courses are constant although rough surfaced. The dip of the beds is low, not exceeding four or five degrees. In color the rock resembles many beds of the Wapsipinicon limestones. It is a light drab, weathering to whitish. The rock is hard and breaks with an uneven fracture. In texture it again resembles the Wapsipinicon limestones in that it is a calcilu-

[30]Norton, W. H., Geology of Linn County: Iowa Geol. Surv., Vol. IV, pp. 135-138.

tite, made of impalpable calcareo-magnesian silt, and showing no traces of granular or crystalline structure.

The rock in places is finely laminated, the harder laminæ standing in relief on weathered surfaces. The laminæ undulate, thicken to low lenses or feather out. In this feature, again, it resembles the Cedar Rapids phase of the Otis. Vesicularity is not uncommon, and minute vesicles stained yellow by oxidation indicate lines of lamination in otherwise massive layers. Weathered surfaces are usually smooth, but in some cases are pitted and rough with fantastic slender projections in low relief. In the original description of the Bertram limestone there are given several sections showing the contact with both the Otis and the Niagaran which demonstrate the individuality of this terrane.

Chemical analyses show a not unusual amount of magnesium carbonate:

ANALYSES OF BERTRAM DOLOMITES

	BIG CREEK Per Cent	SPRINGVILLE Per Cent	INDIAN CREEK Per Cent	BERTRAM Per Cent
SiO_2	1.37	00.33	00.72	00.90
Fe_2O_3	00.58	00.56	00.60	00.90
CaO	30.77	30.99	30.66	31.11
MgO	20.61	21.05	21.03	20.36
CO_2	46.84	47.50	47.22	46.72
	100.17	100.43	100.23	99.99

The Otis Limestone

This formation takes its name from the railway junction of Otis, east of Cedar Rapids, where it is very typically displayed in both its magnesian and non-magnesian phases and where it is in immediate contact with the Independence. The former facies is termed for convenience the Cedar Rapids phase and the latter the Coggon. A facies somewhat distinct from either is found at Vinton. A fourth distinct type, a basal conglomerate resting upon the Silurian, is termed the Westfield phase.

THE COGGON PHASE OF THE OTIS

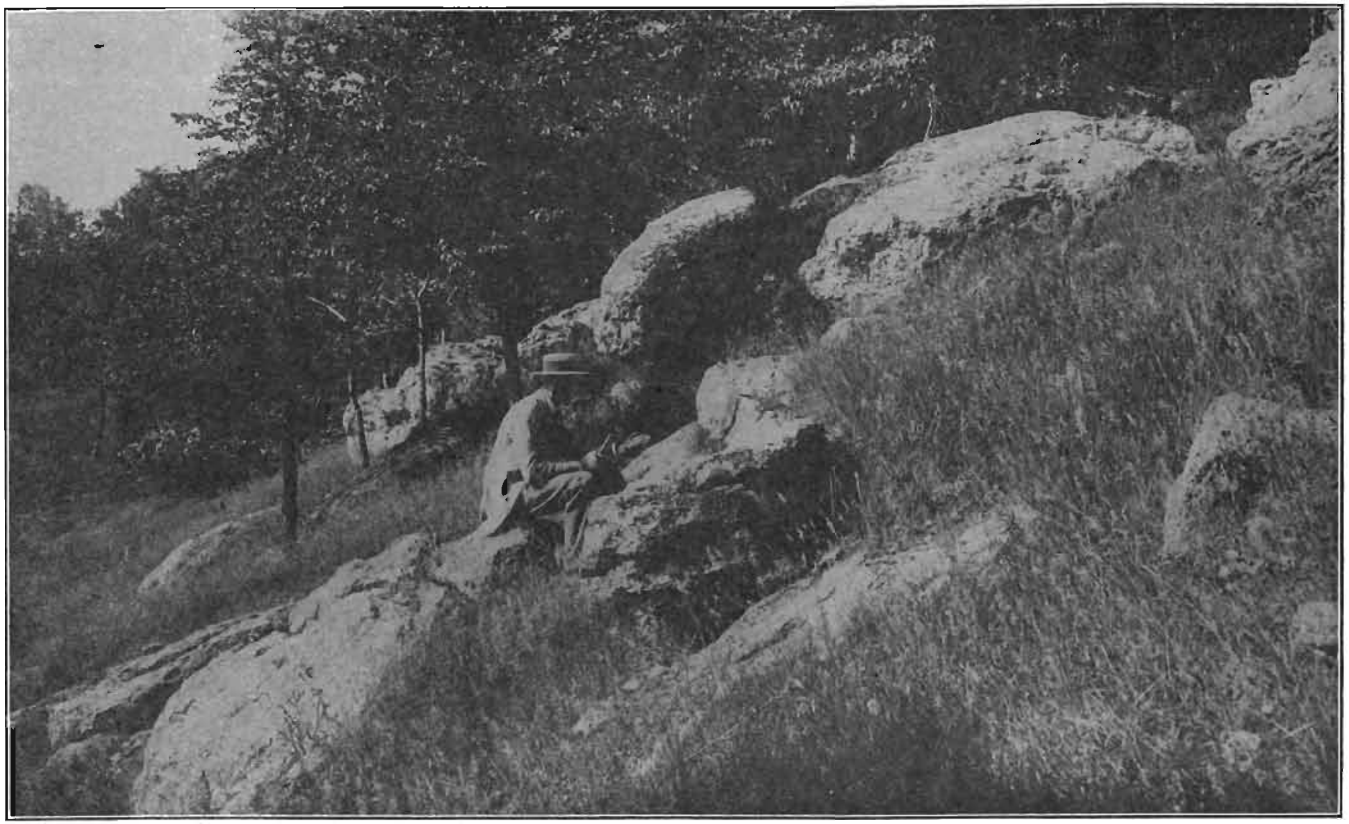
The type exposure of this bed of magnesian limestone is at Coggon, a town of northern Linn county, at the crossing of Buffalo river by the Illinois Central railway, where Ashby's quarry affords a section of it about fourteen feet thick (p. 496).

The Coggon facies is a soft magnesian limestone finely crystalline-granular, or in some places earthy, varying in color from light cream-yellow to rather dark buff. The rock is in many cases highly vesicular with dusty cavities and with moulds of fossils. In places it resembles the upper phase of the Otis in carrying dark flint nodules, which may unite to form narrow continuous bands. It is evenly and rather heavily bedded and with little or no lamination. Under the hammer it frequently emits a bituminous odor. No traces of brecciation or of shattering have been observed. The following analyses indicate the range in chemical composition:

BEALER'S QUARRY, CEDAR VALLEY		LIME CITY QUARRIES	
$CaCO_3$	58.2	$CaCO_3$	54.44
$MgCO_3$	39.5	$MgCO_3$	44.67
Fe_2O_3 and Al_2O_3	0.9	Fe, Al and Mn	00.84
SiO_2	1.2	SiO_2 and insoluble residue	00.13

The Coggon phase occurs in Scott and Cedar counties and in Linn in exposures on all the three rivers which traverse it. In Buchanan county the Devonian section does not reach its horizon and the same may be true in Benton county. In Bremer and Fayette counties this phase of the Otis is absent. In Linn county the Coggon phase rests in several interesting contacts upon the Bertram beds and in the northern part of the county upon the Hopkinton limestone of the Niagaran. In Cedar county the contact is with the Gower. Where the Coggon overlies the LeClaire beds of the Gower the contact is unconformable but no unconformity has been observed where the contact is with the Anamosa beds.

Fossils.—In Linn and Cedar counties *Spirifer subumbonus* is common and in some localities gregarious in the form of moulds and rarely of casts. At several localities the specimens are larger than those of the Cedar Rapids phase at the summit



Bowlders of weathering of Bertram limestone on Big creek, two and one-fourth miles north of Bertram, Linn county, showing massiveness of rock. All the rock is finely brecciated.

of the Otis. At the Cedar Valley quarries the Coggon phase contains *Spirifer subumbonus* in plentiful numbers. Here were collected several trilobite pygidia which were referred to Dr. John M. Clarke, who considered them to belong to "a species not far removed from *Dalmanites erina,* which occurs sparsely in the Onondaga limestone of both New York and Ohio. So far as the specimens indicate the species has little affinity to typical Silurian forms and its relation to the species cited indicates the Devonic."[31]

A cheek of a small *Proetus,* an unidentified *Conocardium* and a little spiral gastropod also were found here.

THE WESTFIELD PHASE

At Fayette, at the Westfield bridge, there rests upon the fossiliferous Niagaran about eight feet of magnesian limestone or dolomite in heavy beds distinguished by bands arenaceous with rounded grains of fine quartz sand and angular bits of white chert (p. 458). The same arenaceous bed is seen in Bremer county southeast of Waverly in similar relation to the Niagaran and fragments of it are included in breccia at Janesville of the same county (p. 472).

These beds have the essential relations of a basal conglomerate. In both Fayette and Bremer counties they are succeeded by nonmagnesian limestones of the Cedar Rapids phase of the Otis.

THE VINTON PHASE

The basal layers of the Otis exposed in the quarries north of Vinton along Cedar river probably are somewhat higher in the terrane than the Coggon phase. In all these quarries the stone is remarkably homogeneous. It is a buff finely laminated magnesian limestone lying in even and rather heavy horizontal beds.

Chemical analysis shows it to be somewhat less magnesian than the Coggon phase, and it effervesces promptly and briskly in cold dilute HCl (figure 45).

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[31]Private letter to the author.

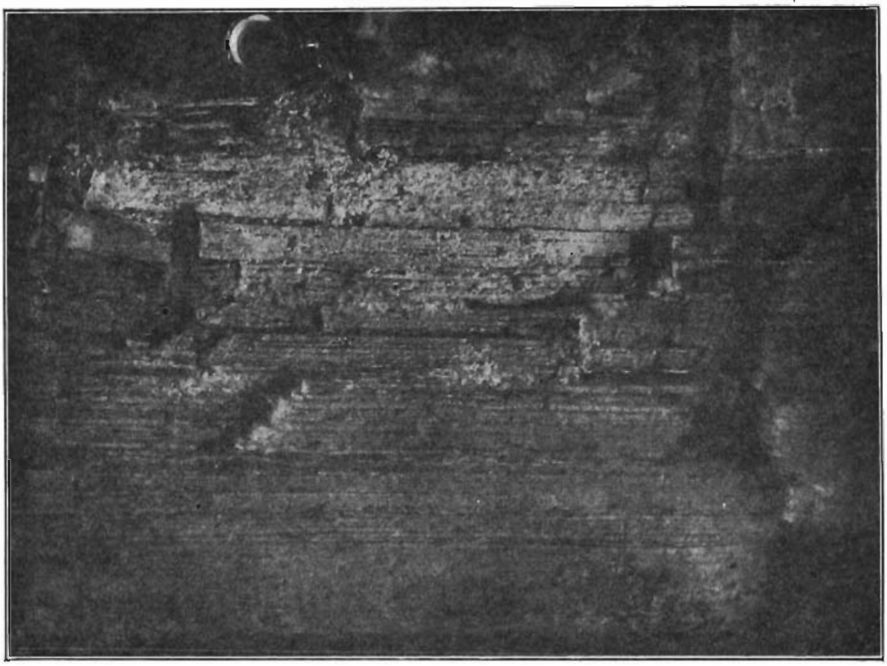


FIG. 45.—Laminated Otis magnesian beds in Kearn's quarry north of Vinton, Benton county.

ANALYSIS OF SAMPLE FROM DEGN'S QUARRY, VINTON.

Calcium carbonate	66.12
Magnesium carbonate	30.54
Silica	1.05
Iron	2.71

THE CEDAR RAPIDS PHASE

This phase includes the wide variety of lithologic types, usually but slightly magnesian, seen in the upper thirty feet of the Otis in the quarries at Cedar Rapids and at numerous other exposures at the summit of the terrane. A very common type is a hard brittle calcilutite of conchoidal irregular or splintery fracture, brown or drab in color, but weathering to lighter shades. Saccharoidal brown limestones, and some of pink and whitish color, are seen. Masses of brown crystalline rock which break with rhomboidal calcite cleavages are characteristic of this horizon.

A large part of the rock is laminated with coherent laminæ of alternating lighter and darker shades. Dark hair-line laminæ seen on vertical faces of the beds are the edges of brownish or blackish argillaceous films. In Fayette county the rock at this horizon weathers to thin ringing plates quite uniform in thickness. Here in places the brown film laminæ may be as close set as eighteen to the inch. At Cedar Rapids many of the layers thicken and thin irregularly, especially where lamination is absent. Many of the surfaces are rugose as if corroded and are covered with a blackish argillaceous and carbonaceous crust.

Flint, blackish in color, occurs in interlaminar lenticular small masses, and in mottlings which have a more or less marked vertical arrangement. Thus in a small quarry about one-half mile west of Otis black flint occurs in irregular columns and vertical leaves. Fantastic mottlings of flint and limestone also occur similar in their irregular outlines to those of the mottled brown and buff limestones also characteristic of the upper beds of the Otis of this phase.

Fossils.—In the Cedar Rapids phase *Spirifer subumbonus* is gregarious and the specimens are admirably preserved. Often the valves are found not only in unbroken condition, they are also undetached. This brachiopod ranges from Scott county through Cedar into northern Linn county along the Wapsipinicon, but to the north of this river it has not been observed.

A minute spiral foraminifer (?) is found at several localities: on Felton creek, Cedar Rapids, where it forms the entire upper layer of low dome-shaped masses immediately beneath the Independence (section B, p. 520); at Young's quarry on Indian creek, south of Marion (northwest quarter of the northwest quarter of section 12, township 83 north, range VII west); and in road cuttings in College township, Linn county, along the road leading southeast from Cedar Rapids.

CHEMICAL ANALYSES	I	II	III
$CaCO_3$	69.71	87.76	86.87
$MgCO_3$	26.16	5.66	10.02
SiO_2 and insoluble residue	0.85	.....	....
Organic matter	....	1.25	0.47
Fe, Mn and Al	1.75	....	....
Iron (Fe)	....	3.52	0.99
Silica (SiO_2)	....	2.18	1.99

I. Brown fossiliferous limestone, Otis.
II. Dark layers in Chicago & North Western Railway Quarry, Cedar Rapids.
III. Dark crystalline limestone, Ellis Park Quarry, Cedar Rapids.

LENTICULAR STRUCTURES

Especially in the uppermost beds, near or at the contact with the Independence shales, lenticular structures are characteristic of the Otis. At the Cedar Rapids outcrops these occur on a large scale, and some of them reach a horizontal diameter of nine or even twelve feet and a thickness of three to five feet. The quarrymen know this stratum as "the bowlder bed" and the lenses much resemble great elliptical bowlders of weathering both in their rounded form and in their corroded surfaces. In these quarries, which are worked only for crushed stone, the lenses are difficult to deal with. Dynamite exploded in drill holes reaching nearly to the level of the quarry floor throws down the quarry face from top to bottom, and shatters the strati-

FIG. 46.—A lens eight feet long in the upper beds of the Otis limestone, Ellis Park quarry, Cedar Rapids, Linn county.

FIG. 47.—A lens in the upper beds of the Otis limestone, split vertically. Ellis Park quarry, Cedar Rapids, Linn county.

fied rock into fragments ready for the crusher or easily broken up by "dobying," i. e. by exploding dynamite upon the surface of the rock beneath a cap of wet clay. But the bowlder-like lenses are thrown down intact and can be broken up only by the use of explosives in drilled holes.

Composition.—The lenses are generally composed in the greater part of massive brown macrocrystalline rock which may be shot through with rhombic calcite cleavages. In many cases the stone is mottled. A brown crystalline rock may be mottled especially toward the top with buff earthy limestone of fine grain. In one instance the foreign material is blackish and earthy. The mottled areas as a rule present irregularly curved and interlocking boundary surfaces, but in some instances the rock appears fragmental and the different colored areas are bounded by straight lines. In some instances the darker body rock is a drab calcilutite, carrying *Spirifer subumbonus,* while the lighter mottlings are of an earthy gray softer limestone.

Structure.—The lenses are commonly massive, but occasionally structure lines appear. A horizontal parting may pass through the center of the lens, while convex lines appear above, and concave lines below, parallel with the surfaces of the lens.

The Overlying Beds.—In some cases these arch over the lens, but in others at the sides they feather out up the slope or overlap. In some instances they bend down steeply—in one case at 55°—to the base of the lens where they abruptly become horizontal. These layers are seamed in places with radial cracks filled with calcite and in one instance are brecciated at the base.

The Underlying Beds.—The layers immediately beneath the larger lenses bend down parallel with the under surfaces, but thin somewhat toward the center of the synclines. Again, they "underlap"; the curving surface of the lens cutting the layers farther and farther back from the base of the lens upwards. Smaller lenses in places rest on layers which are themselves thin lenticular masses and which feather out in a distance of ten feet or less. At Ellis Park quarry, Cedar Rapids, a number of the lenses rest on massive drab calcilutite whose upper surface follows their basal curves but which within a few inches merges beneath into laminated rock whose laminæ are horizontal or slightly undulating. This calcilutite, like the lens rock, carries *Spirifer subumbonus.*

The upper surface of a lens, like the surfaces of many layers of the Otis at this horizon, is rugose and covered with films or thin selvages of black unctuous clay. In one lens at the Ellis Park quarry which occurs where the rocks have apparently broken down, the upper inch or so consists of a selvage of close-set perpendicular calcite crystals. The lower surface is in places stylolitic and blackish films of clay part it from the layer underneath.

Origin.—The characteristics just mentioned disfavor various theories of origin which might be considered, such as buckling produced by lateral pressure, and local accretion by wave heap, or the growth of colonial organisms. On the other hand, a con-

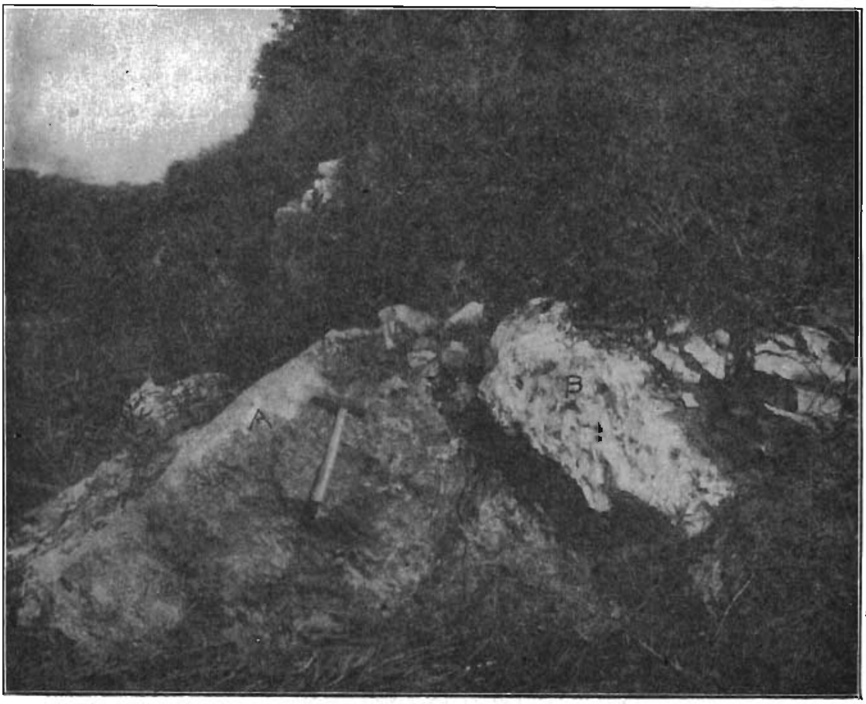


FIG. 48.—A lens in the upper layer of the Otis limestone in the quarry of the Chicago and North Western Railway Company at Cedar Rapids, Linn county. A, dark brown macrocrystalline massive limestone. B, Calcite.

cretionary origin is favored by the lenticular shape of these rock bodies, by their crystalline structure, by the dome and cup arrangement of the inclosing layers. Displacement or more probably the growth of the mass, produces underlap and overlap of the abutting layers, and the lateral thrust of the mass gives them steep slopes, and crackles and brecciates them. The entire terrane, however, has suffered slight deformation and in this way the dip of beds abutting on the unyielding lens would be accentuated. In the case of a lens in the Chicago and North Western Railway quarry at Cedar Rapids, the overarching beds seem to have buckled on one side leaving a cavity a foot in radial thickness filled now with white calcite and separated from the brown lens rock by a black clayey selvage (figures 48 and 49). Radial pressure exerted by the growing lens is seen also in the stylolitic structures mentioned.

MOTTLED LIMESTONES

At or near the upper surface the Otis limestone is in numerous instances fantastically mottled. At Snouffer's quarry the upper two feet of the lenticular layer shows light buff earthy areas within the dark brown saccharoidal limestone, which have a marked vertical arrangement (figure 50). The areas of differently colored rock meet on irregularly and minutely curved surfaces. In places small imbedded fragments of the buff rock are bounded by straight lines. The buff areas are at some places replaced by gray rock, but both buff and gray are like a soft argillaceous limestone or calcareous shale, and effervesce briskly in cold dilute HCl, like the brown saccharoidal rock which forms the mass of the stratum. Occasionally the gray rock is granular-crystalline.

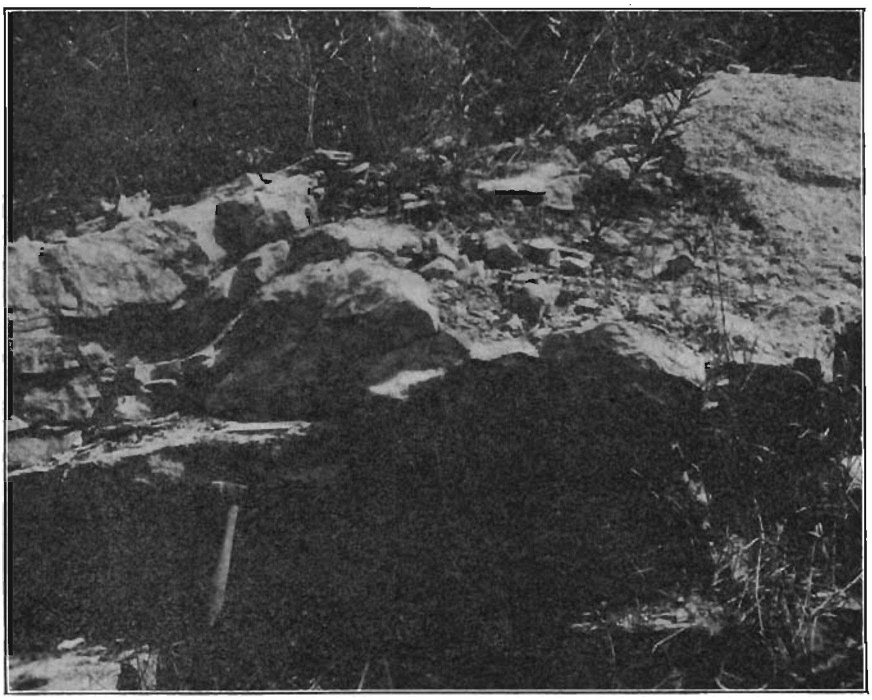


FIG. 49.—Lens in upper layers of Otis limestone in the quarry of the Chicago and North Western Railway Company at Cedar Rapids, Linn county. The layer immediately above the hammer is lenticular and feathers out to the right. The mound to the right is the lens, A, of figure 48.

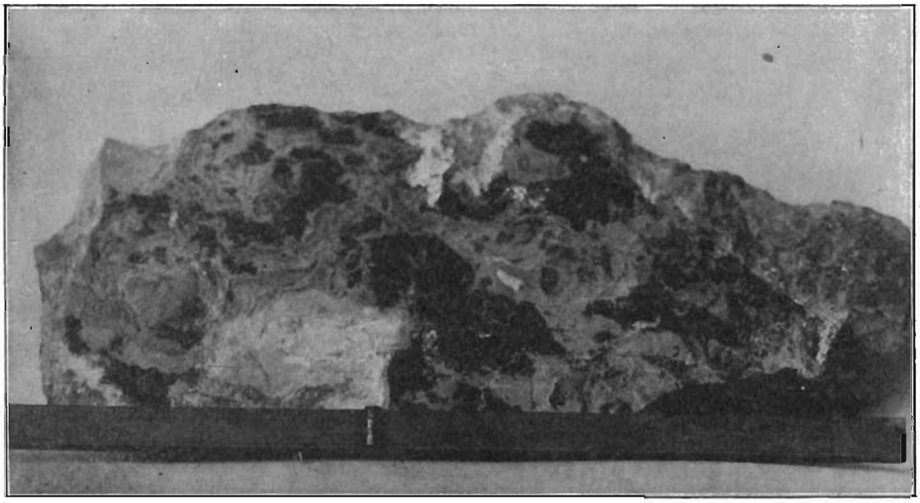


FIG. 50.—Vertically mottled limestone (polished). Upper bed of Otis limestone in Snouffer's quarry, Cedar Rapids, Linn county.

At the cut of the Chicago, Rock Island and Pacific Railway about two miles southeast of Cedar Rapids, the mottlings of the Otis at precisely the same horizon resemble buff stains on the weathered edges of the beds left by a trickling liquid. Weathering has etched out exceedingly fine lines of lamination in the earthy buff limestone. These lines are commonly concave and are crumpled slightly where they abut on the vertical edges where they meet the brown saccharoidal rock. The buff earthy rock at one point appears as an irregular band an inch and more wide inclined at an angle of 30° above a parallel parting in the lens in which it is included. The band is finely laminated and the undulating laminæ run parallel with the edges of the band. In places laminæ of the brown crystalline rock are inclosed in the laminæ of the buff earthy rock.

The same contemporaneous deposition of the two sorts of rock is seen at the quarries of the Chicago and North Western Railway where a lamina of the buff earthy type is embedded in the brown macrocrystalline rock near the top of a lens.

GEOGRAPHIC CONDITIONS OF DEPOSIT OF THE OTIS LIMESTONE

The Otis is a zone of transition in several respects. Within its limits a change was effected from heavily magnesian limestone resembling those of the Silurian to limestone almost or quite as free from carbonate of magnesia as are the limestones now in process of formation in coral seas. The even layers and homogeneous rock of the Coggon phase record quiet waters and undisturbed sedimentation, while the irregular beds of the Cedar Rapids phase present a picture of shallowing seas and shifting currents. A change also is in process ushering in the argillaceous sedimentation of the Independence. Clayey partings accumulate in the hollows of the irregular beds of limestone. Carbonaceous material also is present, contributed by decaying plants, we may assume, and in the approaching Independence conditions growing still more favorable will permit the formation of thin seams of coal. Reefs formed of minute foraminiferal (?) organisms approach the surface. Calcareous mud is thrown down in large quantities forming heavy beds. It is not improbable that considerable parts of the upper Otis limestones were precipitated as chemical deposits and that calcareous oozes on the floor of lagoons were saturated with sea water in which calcium carbonate was greatly concentrated. As a result intercrystallization went on. In massive limestones calcite crystals developed their characteristic surfaces and cleavages throughout the rock. And just as calcite crystals developing in sandstone do not extrude the sand, so here the forming calcite leaves all impurities within the crystalline mass. The sea water saturated with calcium carbonate acted also within the upper beds of the Otis as ground water similarly saturated often acts—it produced huge concretionary lenses.

The mottlings which affect the bed immediately beneath the Independence might be referred to irregular extrusion of clayey matter by growing calcite crystals but this does not seem here to be a convincing explanation. As we have seen, the more argillaceous material is in some cases deposited as laminæ imbedded in the more calcareous, and as fill in rude tubules traversing the more calcareous material vertically. As the Otis closed clayey sediments evidently were washed in over these areas in increasing quantity and mingled with the uppermost limy oozes of the Otis. The vertical arrangement of the more clayey sediments would be explained if the limy ooze were laid about the vertical stems of aquatic vegetation. On incomplete solidification moulds of these stems would be formed and the irregular tubes left by their decay would be filled by the clayey sediments now invading the area. In settling these fillings would give the concave tabulæ-like laminæ sometimes seen. The rugose corroded surfaces of the beds common at this horizon confirm the inference of shallowing lagoons.

The Independence

Fossiliferous shale.—The discovery of the Independence is thus related by Calvin:[32] "A dark shale had been exposed in working out the layers in the bottom of one of the limestone quarries near Independence. The quarrymen penetrated the shale to a considerable depth in the hope of finding coal. The shale varies somewhat lithologically, but where it presents its most characteristic features it is argillaceous, fine-grained, and highly charged with bituminous matter."

Devonian black shale and coal were reached somewhat earlier in Linn county at the same horizon apparently, in a well sunk near the village of Lafayette. In the summer of 1877 a miner's shaft was put down through four feet of soil and eighty-one feet of rock. The coal seam when reached was found to be a quarter of an inch thick and the work was abandoned after the expenditure of several thousand dollars. The waste heap about the shaft yielded specimens of brecciated limestone and the horizon of the coal and shale—which can not possibly be that of the Carboniferous outliers found in the county—is clearly that of the Independence, although no traces of gray fossiliferous shale were found about the shaft.

The Independence was reached at some date earlier than 1893 in a well sunk west of Walker (northeast quarter of the southeast quarter of section 8, township 86 north, range VII west).

[32]On some Dark Shale Recently Discovered at Independence: Bull. U. S. Geol. Surv., Vol. 4, No. 3, p. 725, Washington, 1878.

A blue shale was pierced at a depth of about one hundred feet, and the sand pump brought up a characteristic fossil of the Independence, *Douvillina arcuata*. Crystals of pyrite were attached to the shell and it was filled with soft blue clay when submitted to the writer.

The first natural outcrop of the fossiliferous Independence to be found lies in the midst of the brecciated beds displayed in the old cut of the Chicago, Milwaukee and St. Paul Railway west of Linn, a junction station four miles north of Cedar Rapids. The shale was brought to light some years after the cut was made by a mud flow which occurred in a short steep narrow ravine leading down to the tracks in the north cut toward the upper end (Plate V). The flow consisted of gray plastic shale and carried abundant fossils (*Douvillina variabilis, Stropheodonta quadrata* and *Rhynchonella ambigua*) of the same species as those collected at the type locality of the formation—the shaft put down for coal at Independence. The shale here lies immediately beneath the drift at a height about equal to that of the summit of the breccia on either side of the ravine along the cut. The presence of the shale at this level seems due to an anticlinal structure in the breccia which brings it to the summit of the section. The weakness of the shale allows the formation of the gully which no doubt from time to time has been enlarged by similar mud flows toward the river. The slide is now overgrown with grass and brush wood.

The most important outcrops of the fossiliferous Independence are found near Brandon in Buchanan and Benton counties. They were discovered by Mr. Merrill A. Stainbrook, a student in the State University of Iowa, and reported to Professor A. O. Thomas. Exposure No. 1, the first to be discovered, was visited by Thomas and at his request later by the writer. Exposures No. 2 and 3 were studied by Thomas and Norton together and the following descriptions of them are based on the joint observation and accordant opinion of both. Thomas describes Exposure No. 1 as follows:[33]

"The shale occurs in a sharp bend or reentrant on the right bank of the creek in the northwest quarter of section 26 about a mile

[3]The Independence Shale near Brandon, Iowa: Ia. Acad. of Science, Vol. XXVI, 1919.

Mud flow of Independence shale, Linn section, Linn county. A wall built to confine it is now overflowed.

northeast of the town of Brandon. Undercutting by the stream at this point has exposed from one to six feet of the shale for a distance of fifty to sixty feet. By digging back the sod at the top of the shale it was found to extend about five feet higher up the bank, making a total thickness above the water of at least eleven feet. The immediate bank of the stream at this point is about twenty feet high, while back from this the surface rises gradually to a height of about sixty feet. The outcrop is flanked by exposures of limestones; on the downstream side the shale and limestone are separated by about three feet of weathered shale and blocks and fragments of limestone. For some twenty yards below this point the limestone is arched up into a low anticline and is considerably broken and jointed. This limestone contains Cedar Valley fossils characteristic of the lower part of that terrane. On the upstream side for a short distance the bank of the stream is low and quite sodded over. Still farther upstream the low limestone ledges are more weathered than in the anticline below and contain Cedar Valley fossils similar to those found back of the cemetery a half mile or more down stream.

The shale is dark bluish, plastic, and weathers yellow with reddish streaks. It shows no bedding, but there are small blocks which show faint lamination and in some cases smoothed and slickensided faces. Irregular blocks of harder, tougher and more calcareous shale occur and there are also small nodules of pyrite and angular blocks of hard limestone. Fossils are fairly abundant and typical; to some of them cling crystals of pyrite as is the case with the fossils collected by Calvin and Deering at Independence. In the bend of the little stream and almost in contact with the shale is a large block of Lower Davenport limestone showing the brecciation and other unmistakable features of that formation. The block is angular, is three by five feet in dimensions, and is larger than any handled by the stream in flood. No exposures of the Lower Davenport are known either up or down the valley. We must conclude that the block is intimately associated with the shale and is of the same derivation as the smaller limestone pieces incorporated in the shale.''

Exposure No. 2.—This outcrop is located a few rods down valley from Exposure No. 1, on the left bank of Lime creek, near the south line of the northwest quarter of section 26. Here the low limestone ledge which rises from the edge of the water is interrupted by a grassy bank for a distance of about four rods. At several points within this distance exposures of the shale occur near the level of the creek, but all are obscure and unimportant except one at the north end, where a short little gully is used as a cattle track to the water. This outcrop is six or seven feet high, and somewhat more in breadth, extends from water level to about the height of the limestone ledge adjacent, and both shale and limestone are overlain by drift. The shale carries the characteristic fossils of the Independence. It is a stiff gray plastic clay without stratification and is distinctly brecciated. Among the fragments is an angular block a foot in diameter of a harder, more calcareous, unfossiliferous stratified yellow shale. There are also fairly numerous included fragments of limestone, sharply angular and set at any angle, some soft, buff and argillaceous, some hard, light reddish brown, fine-grained, marked with wavy coherent laminæ of one millimeter and less in thickness and of the facies seen in the Otis beds at Cedar Rapids, and at other localities. The general appearance of this exposure is that of the shaly breccia in the quarries up valley from the railway cut north of Vinton, (page 489) but in these quarries the shale is unfossiliferous. The Vinton brecciated shale lies immediately upon the magnesian lower beds of the Otis limestone and its fragments are largely those of the Otis calcilutites which normally lie above the magnesian beds. The shale of exposure No. 2 at Brandon also carries fragments apparently derived from the upper Otis. but the shale here occurs at the horizon of the Cedar Valley limestones, which close in upon it in flat-lying beds on either side. The limestone ledge descends sharply toward the shale and the surface of the slope is covered with four to six inches of dark brown and blackish plastic clay. The shale and limestone are separated by an interval of about three feet—a cattle track, and it was not determined whether the dark brown clay just mentioned is selvage, geest, or weathered shale. The limestone wall against which the shale presumably lies trends northwest along the few feet exposed and makes an acute angle with the bank of the creek.

As in the case of exposure No. 1 the shale comes down to the water's edge and is not seen to rest on any limestone floor. But at the north end, some twelve feet in front of the main outcrop the limestone of the north wall forms the bed of the creek.

A short distance up valley from exposure No. 1, occurs a shale on the right bank north of the bridge, on the south line of section 26, similar in its lithologic facies, but destitute of fossils. Here the limestone wall of the creek is interrupted for about three rods, and at one point about seven feet above the water and at the level of the upper beds of the limestone there is exposed one or two feet of plastic gray clay. The upper contiguous layers of limestone carry the coarse-ribbed *Atrypa reticularis* of bed No. 4 of Savage's general section of the Cedar Valley while the lower layers are of rough surfaced limestone with many joints of crinoid stems. The limestone here dips from 5° to 8° south. The shale thus lies in a cavity of some sort in the limestone. The sides of the cavity incline valley-wise downward and inward, but no floor of rock in place is found to prove that the cavity is not a pipe through which the shale has been pressed upward.

An interesting outcrop showing the deformation to which the rocks of this area have been subjected is found south of the bridge above mentioned on the west bank of the creek. The spur scarped by the creek and a tributary ravine shows on the north side buff Cedar Valley limestone, with the large *Orthis impressa* and coarse-ribbed *Atrypa,* extending down creek for twenty yards. Here it gives place seventeen feet above the stream to a light drab calcilutite in large crackled blocks. The actual contact is not seen, but the Cedar Valley limestone adjacent is broken into blocks four to five feet in diameter tilted toward the contact plane. The calcilutite ledges show massive layers a foot thick and also in places thin calcareous plates. No rock appears between the calcilutite and the creek. Down stream the calcilutite gives place to the buff Cedar Valley limestone dipping south-southwest at about 10°, at bottom a coral reef with huge heads of *Favosites* and *Acervularia davidsoni.* The calcilutite appears to be the equivalent of that seen on the summit of the hill to the south. Here ledges of crackled calcilutite aggregating about eight feet in thickness are exposed about thirty-five feet above the outcrop of the Independence shale, exposure No. 1, which occurs at the base of the hill and some rods to the east.

Exposure No. 3.—This outcrop, two miles south and nearly one mile west of Brandon, on the left bank of Cedar river, is in Benton county near the northwest corner of section 9, township 86 north, range X west. Here almost from the water's edge rises a perpendicular cliff of Cedar Valley limestone fifty feet high, whose various fossiliferous horizons are described in detail by Savage.[34] About four rods from its north end this cliff is cut by a shallow reëntrant at whose base occurs the outcrop of the fossiliferous Independence shale. The exposed thickness of the shale is about four feet and it lies some six feet above the river, from which it is parted by a narrow beach and talus of large limestone blocks. No rock is seen in place either beneath the shale or above it.

The entrance to the recess is about thirty feet wide. On either side the rock walls, determined by joint planes, rise almost vertical, while the strata lie horizontal and undisturbed. The recess widens within by lateral sapping. From the entrance a talus slope climbs steeply up to the summit of the cliff, where for a few feet the continuity of the strata is concealed or perhaps interrupted. A slight convexity in the shore line opposite the entrance is due evidently to a larger accumulation of talus at this point.

The basal section of the cliff is described by Savage[35] as follows: "1. Bed of light-gray limestone, somewhat shattered and brecciated, containing the following fossils, *Stropheodonta demissa, Orthis iowensis, Atrypa reticularis, A. aspera* var. *occidentalis, Spirifer pennatus,* and a species of Gomphoceras; exposed to the water's edge three feet." Savage further states that the above bed "represents the gray brecciated limestone near the upper part of the *Spirifer pennatus* beds" and notes the absence of *Gypidula comis* which is characteristic of this zone. This bed of somewhat shattered and brecciated rocks

[34]Geology of Benton County: Iowa Geol. Surv., Vol. XV, pp. 180-184.
[35]Ibid, p. 181.

rises gently—at one point rather sharply—toward the north. At the north end the cliff ends abruptly in an overhanging joint face, a slickensided normal fault of small throw. At the base the fault is bounded on the north, the upthrow side, by a mass of limestone twelve feet long along a line parallel with the fault, whose thin layers dip 60° S. 20° W. toward the fault plane. This limestone, mottled buff and drab, earthy-crystalline in structure and with some layers dark drab and macrocrystalline, is of a facies to be found both in the Otis and in the argillaceous limestones which lie above it. Upstream from this fault no cliffs occur but as far as the ravine south of Long's quarry brecciated rock masses outcrop on the hillside from water level to a height of about twenty-five feet. Some of the fragments are several feet in diameter and they are set at all angles. Some are gray crackled massive calcilutites, some are calcilutites of fine lamination, some are fossiliferous gray and buff limestones containing *Spirifer parryanus*.

Stratigraphic position and equivalency of the fossiliferous Independence Shales.—The meagre outcrops of the fossiliferous Independence shale now accessible do not make entirely certain its true place in the column of the Devonian rocks of Iowa. At none of these outcrops is the shale either covered or seen to be underlain by Devonian rock. No formation except the drift is found above it, and no section cuts below its base. Such conditions permit us to consider several hypotheses.

1. The close alliance of the fauna of the Independence with that of the Lime creek shales suggests that the two may be identical and that the exposures of the fossiliferous Independence are in reality sections of the Lime Creek shales where they fill unconformably old erosion channels cut in the earlier Devonian terranes. Thus they may be paralleled by the unconformities of the State Quarry beds and the Sweetland Creek shale. But recent more thorough studies of the faunas of the Lime Creek and the Independence show that they are not the same. It is pointed out by Thomas[36] that "The fossils of the Independence when they are critically studied are quite distinct from those of the Lime Creek." After mentioning several "striking ab-

[36]The Independence Shale near Brandon, Iowa: Iowa Acad. Sci., Vol. XXVI, 1919.

sences and differences'' Thomas concludes, ''the instances cited are sufficient to confirm the usual opinion that the Lime Creek fauna is a greatly expanded and recurrent descendant of the Independence.''

2. We may also entertain the hypothesis that the fossiliferous Independence is unconformable with the Wapsipinicon and Cedar Valley limestones but represents a formation, distinct from the Lime Creek shales, nowhere found conformably in place in the Iowa section. No special objection to this hypothesis inheres in the fact that it is found only at its unconformities, for this is true also of the Sweetland Creek and State Quarry formations. If the contacts of the fossiliferous Independence are true unconformities this hypothesis must be accepted. But if the contacts can be otherwise explained there is left no evidence in its support.

3. The contacts of the fossiliferous Independence with the Wapsipinicon and Cedar Valley limestones may be explained by deformation. On this hypothesis the horizon of the Independence is to be looked for below and not above the beds with which it is in contact. Under the stresses which have caused extensive brecciation over the area of outcrop of the Wapsipinicon the plastic fossiliferous shales have been squeezed up into the midst of higher Devonian terranes.

An interesting parallel is to be found in the breccias on Mackinac Island where the red and green shales, which in general lie somewhat below lake level, forming in places the wave-cut rock bench, are not only upwarped under anticlines of the Monroe limestone, but are also squeezed up in amorphous masses into the midst of the breccia into which that limestone has been so thoroughly broken.

It will be noted that at each of the exposures of the fossiliferous Independence shales brecciation or deformation is strongly in evidence. At the Linn Junction section (p. 388) the shale is fossiliferous and lies in the midst of a breccia in which blocks of the Upper Davenport predominate. While the outcrop shows nothing inconsistent with the theory that the shales occupy unconformably an erosion valley cut in the breccia, on the other hand it shows nothing opposed to the theory that under the severe stresses to which the terranes have been subjected the shale has been thrust up amid the fragments of broken limestone beds which normally overlie it.

In the vicinity of Brandon Calvin noted "the unusual peculiarities" of the Devonian beds. Speaking of the ledges along Lime creek south of the town he says:[37] "The beds are folded, buckled, and displaced on a scale sufficient to produce a complex series of alternations of lithological and paleontological characters at the same level along the hillside. At one point, for example, there are beds carrying *Spirifer pennatus*. At the same level a few yards away there is a portion of the coral reef with *Acervularia, Ptychophyllum, Favosites,* and other characteristic corals. Farther on are yellow shales corresponding to No. 8 of the Littleton section and carrying the coarse ribbed *Atrypa* and other fossils which everywhere distinguish this horizon. Some of the displacement may be due to faulting on a small scale, but the residual material resulting from extensive weathering conceals the beds over most of the hillside."

The above description applies in every detail to the course of Lime creek northeast of Brandon along which are the exposures of the fossiliferous Independence. In addition the crackled calcilutite found about fifty feet above the creek at exposure No. 1 of the shale, is seen at about the level of the upper part of the shale a few rods upstream and is within a short distance replaced horizontally by the yellow beds of the Littleton section No. 8. The shale of exposure No. 1 abuts at the south upon an anticline of Cedar Valley limestone broken at the crest and with a dip of 10° and 15° upon the limbs. The shale at this point is also itself brecciated. No foreign material is found in it, but scattered everywhere through it are angular blocks and fragments of harder shale set at all angles, and the mass nowhere shows any trace of bedding planes. At this point the stream has eaten back so far into the exposure that it is quite improbable that this brecciated structure is due to slump.

At exposure No. 2 the abutting limestones lie horizontal and show no evidence of deformation. The shale, however, is here not only brecciated; it also includes sharply angular fragments

[37]Geology of Buchanan County: Iowa Geol. Surv., Vol. VIII, p. 238.

of hard limestone of Otis types. The hypothesis that the shales are a late Devonian undisturbed deposit in a channel cut by erosion in the Cedar Valley limestone is thus precluded. Nor is it easy to conceive that the brecciation of the shale is due to stresses which affected it after its deposition unconformably in its present relations.

At exposure No. 3 the walls of the recess at whose base the shale occurs show little or no trace of disturbance. Yet, as we have seen, the basal bed of limestone contiguous to the shale is brecciated and shattered to some degree, and a few yards to the north a slickensided fault occurs, beyond which the brecciated masses rise to about twenty-five feet above the river.

In these exposures where the shale is covered only by the drift or by residual soils, or lies at the bottom of a deep recess or chasm in a cliff, it may well be that the shale is largely responsible for the gully, valley, or recess in which it now occurs. A mass of plastic clay upthrust into the midst of limestone beds makes a point of weakness whenever the terrane is cut through by stream erosion. It forms a yielding foundation to the limestones which rest upon it. Thus by sapping, a gully or ravine on the hillside, or a chasm on a cliff, develops, at whose base the shale may fortunately be found, or far more probably will be covered from sight by rock-debris. In considering the position of the fossiliferous Independence shale the testimony relating to its original discovery at the type locality must carry great weight. True, the initial artificial sections are no longer accessible, but the statements of Calvin and others show with hardly a possibility of doubt that the fossiliferous shales at Independence were found by excavating through the fossiliferous limestones now seen at the base of the Independence quarries. If this is the case, the place of the shale is indisputably below the *Gyroceras* beds (Upper Davenport limestone). A shaft sunk at random through drift on a hillside might encounter a pipe filled by squeeze from below, or an erosion valley filled by deposit from above, but the limestone of a quarry floor furnishes a certain datum for an excavation made beneath it.

The first statement on this point by Calvin is as follows:[38] "A dark shale had been exposed in working out the layers in the bottom of one of the limestone quarries near Independence."

In an article on the Geology of Linn county published in the Cedar Rapids Republican under date of Feb. 21, 1880, Norton, who had visited the locality and collected fossils about the mouth of the shaft, gives the "section of the exposure in Kilduff's quarry where the shales were discovered." This section is stated to have been furnished by Mr. Kilduff.

	FEET
"Fossiliferous Hamilton limestone	20
Black fissile bituminous shale	12
Gray fossiliferous shale	4
Hard gray rock with pyrite	2"

In 1891 Calvin stated: "About a mile east of Independence the Gyroceras beds may be seen resting on the Independence shale. In the old Kilduff quarry northeast of the city, where the shales were explored for coal, the Gyroceras beds were penetrated and 'petrified snakes' attracted much attention."[39] In his report on the geology of Buchanan county Calvin[40] mentions "shafts sunk at the old Kilduff quarry, now owned by Thos. O'Toole," and again "It was in an abandoned pit a few rods west of the O'Toole quarry that the first shaft which brought to light the Independence shales of this locality was put down." It was no doubt on the basis of the facts set forth in these statements that Calvin in the report just cited placed the Independence shales below the *Gyroceras* beds and the brecciated limestones termed by Norton the Lower Davenport. The explanation of the fact that so few occurrences of fossiliferous Independence shales have been discovered lies in part in the weakness of the terrane. The shales soon become graded by the weather to slopes covered with soil and mantled with vegetation. The only natural outcrop, except those discovered near Brandon in 1917 by Thomas, is due to a mud flow in an artificial cut. But it is extremely probable that in the Independence fossiliferous tracts are rare, and that for the most part conditions were not favorable for the colonization of the sea floor or the preservation of animal and plant remains.

[38]Bull. U. S. Geol. and Geog. Surv., Vol. IV, No. 3, p. 725, 1878.
[39]Am. Geologist, Vol. 8, p. 143.
[40]Geol. Surv., Vol. VII, p. 222.

Unfossiliferous shales.—Much of the Independence consists of impure limestones, but true shales are also found widely distributed. A thin seam of black carbonaceous shale is noted in Cedar county (p. 537). In Linn county bluish or buff clayey shale, fissile or showing spheroidal weathering, occurs, especially near the base of the formation in sharp contrast with the Otis limestone. Typical sections will be found on pages 497, 513 and 529. In other counties as to a large extent in Linn county the more argillaceous beds of the terrane are involved in breccia (figure 51 and Plate VI).

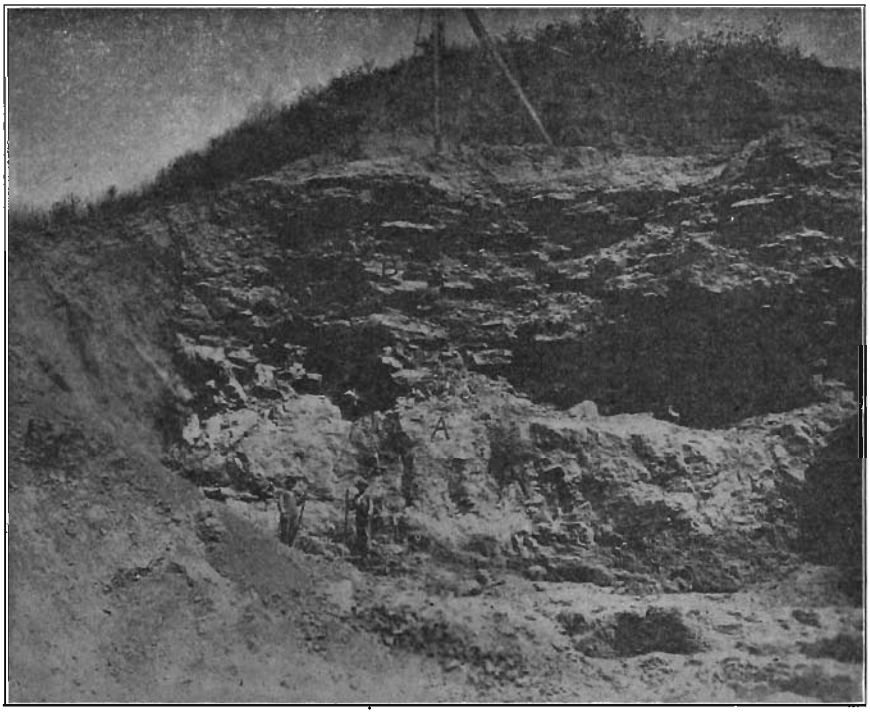


FIG. 51.—Snouffer's quarry, Cedar Rapids, Linn county. A, Otis massive upper beds. B, Independence shales. C, till. D, loess.

Impure limestones.—A large part of the formation consists of impure argillaceous buff and brownish granular or earthy limestones, weathering to clayey slopes. Occasionally a lighter rock is speckled with darker crystals, which have segregated themselves from the more argillaceous mass. Saccharoidal limestone appears in segregated thin lenticles and layers and in beds weathering to dingy crystalline sand. Rarely occurs a layer of brittle fine-grained limestone of brown or even of whitish tint.

Inclusions.—The Independence shows not rarely thin arenaceous layers whose sand consists of rounded grains of clear quartz and minute bits of black flint or of white chert. Elliptical nodules of quartz and calcite intercrystallized are common and characteristic (figures 59 and 60). These reach a foot or more in their greatest diameter. Their weathered surfaces are rough and carious from the solution of the calcite. Occasional lenticular masses are composed chiefly of clear saccharoidal calcite with some silica and much yellow clay included in the segregation area. Very rarely intercretions are met with in the shale whose interior is fissured and whose surface also is crackled. Flint of various tints is seen also.

Distribution.—Defining the Independence as the substage of shales and clayey limestones intervening between the purer limestones of the Lower Davenport and the Otis we find exposures of it in contact with either the higher or the lower terrane widely scattered over the area of the Wapsipinicon. In Scott county (p. 543), and in Cedar county (p. 536) it is in contact with the Otis. In Linn it occurs in contact with the higher as well as with the lower terrane. In Buchanan county it is found at several points in obscure outcrops.[41] In Benton, Fayette and Bremer counties the Independence occurs only more or less brecciated and intermingled with the fragments of other terranes.

The material of the Independence is so thoroughly diagnostic that it may be recognized far from its source. Thus on finding half a dozen of the silico-calcareous nodules on the slope of a hill at Canton, Jackson county, thirty miles east of any known Devonian outcrop (figure 61) the writer identified them with the Independence, an inference confirmed by finding later at the same locality small bowlders of brecciated Devonian limestone and a clay bed with fragments of silicified Devonian fossils overlying

[41]Clavin, S., Geology of Buchanan County: Iowa Geol. Surv., Vol. VIII, p. 223.

a bed of sandstone.[42] In the basal conglomerate of the Des Moines in Muscatine county Udden[43] identified similar nodules by texture and pitting as belonging to the Wapsipinicon and silicified blocks of breccia as from the same complex of terranes.

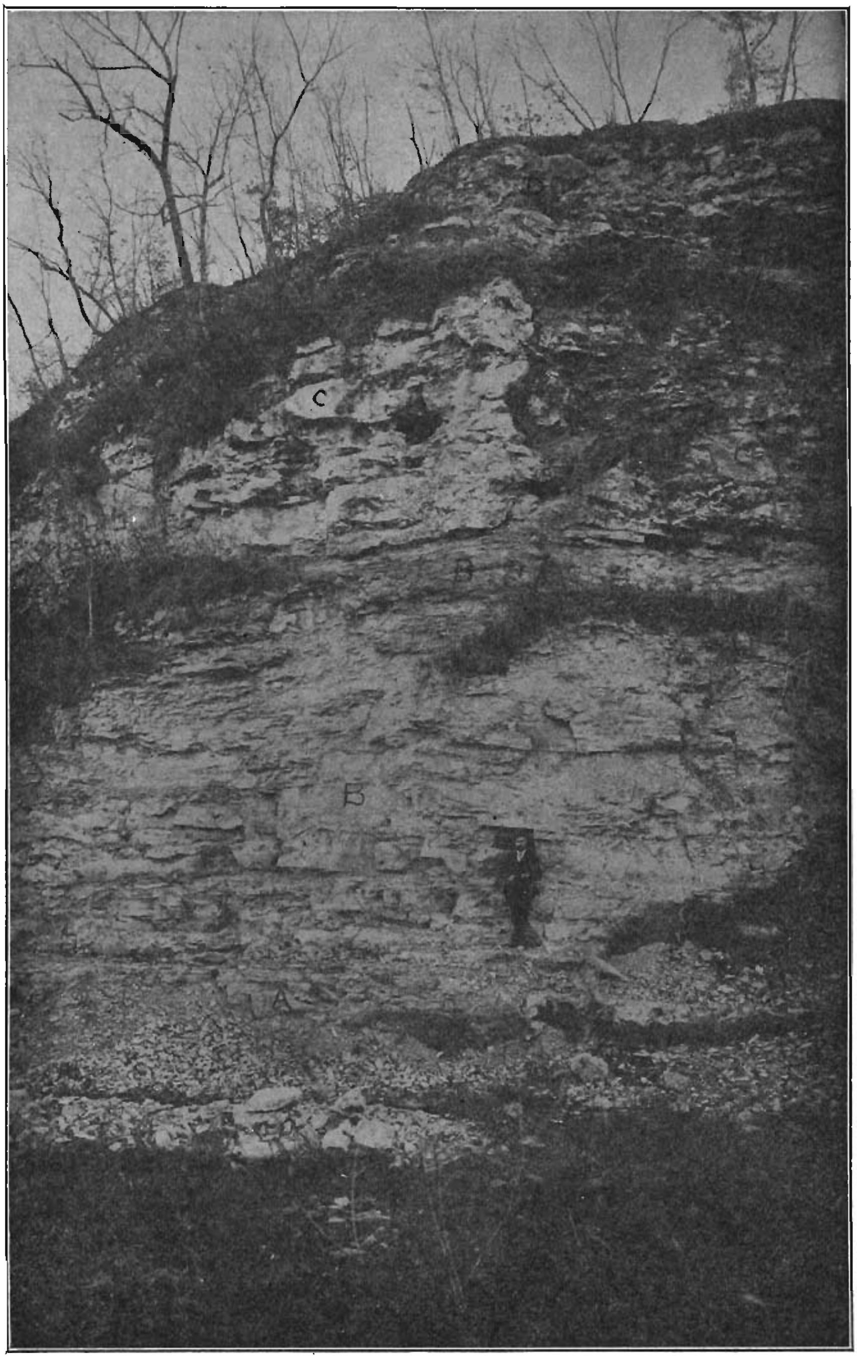
The Lower Davenport

At a number of localities[44] the earthy arenaceous and flinty limestones and the shales of the Independence are overlain by singularly pure calcilutites and crystalline limestones sufficiently in place to prove that the time of argillo-calcareous sedimentation had now given way to one characterized by the deposit of nearly pure lime carbonate.

At Davenport, and at one or two points in Cedar county and in Benton county, the fossiliferous Upper Davenport directly overlies similar calcilutites in beds but little broken up. These beds in place between the Independence and the Upper Davenport seem sufficiently well defined to constitute a distinct terrane, the Lower Davenport. Very generally they are completely brecciated. But even where brecciation has been most intense the Lower and Upper Davenport may in some places be found in contact in the same block, and zones and tracts of breccia are characterized by the prevalence of the Lower Davenport calcilutite fragments (figure 52). Where neither the Upper Davenport nor the Independence datum planes are found, outcrops may be classed with the Lower Davenport where the stratigraphy of the region compels, that is, where under normal dip of the strata the position of the outcrops is too high to be referred to the Otis, from which the Lower Davenport is lithologically indistinguishable.

The most common type of the Lower Davenport is a calcilutite, brittle, breaking with a conchoidal or splintery fracture. Massive in places, as at the West Davenport quarries and at Rochester, it is still more often found thinly laminated, as at Bettendorf and Rock Island. Massive layers graduate laterally into thin calcareous plates. The prevailing color of the rock is

[42] Iowa Geol. Surv., Vol. III, pp. 122-126.
[43] Udden, J. A., Iowa Geol. Surv., Vol. IX, p. 314
[44] As at Kenwood (p. 529), Sec. A, Felton creek, Cedar Rapids (p. 519), and the Aungst quarries, Vinton (p. 490).



Independence beds at Kenwood, Linn county. A, Otis limestone, fossiliferous. B, Independence shales. C, Independence earthy limestone. D, Lower Davenport calcilutite, partly brecciated.

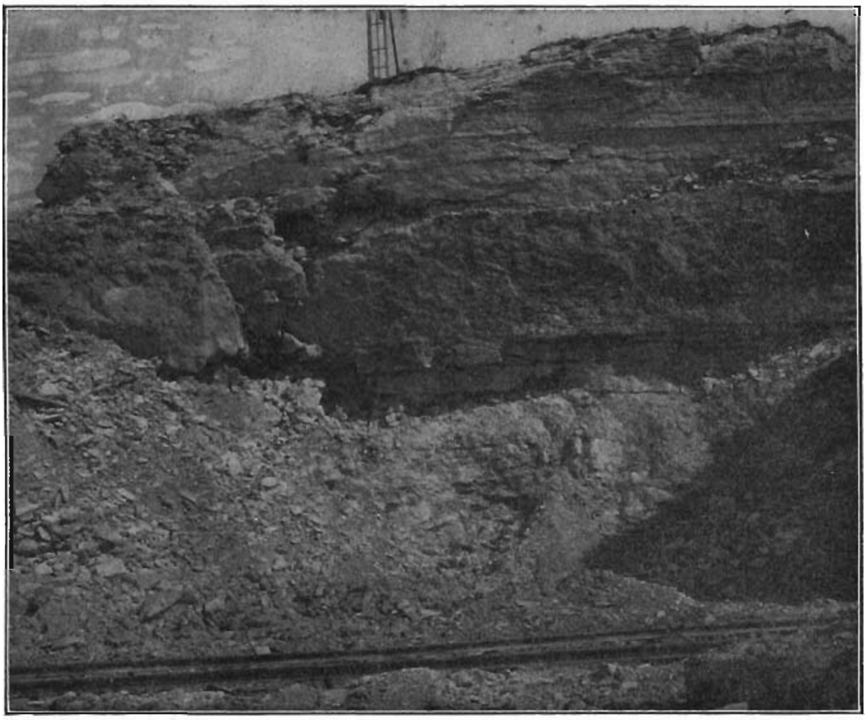


FIG. 52.—Lower Davenport limestone, Bettendorf Stone Company's quarry, Bettendorf, Scott county.

drab, or brownish drab, but like all the Wapsipinicon calcilutites it weathers to whitish gray. Crystalline limestones of whitish color are seen also and these are usually saccharoidal in texture.

Like the Otis limestone, the Lower Davenport effervesces briskly in cold dilute HCl, showing that the percentage of carbonate of magnesia is low.

The Lower Davenport is unfossiliferous. But one fossil, a cyathophylloid coral, has ever been found.[45]

[45]Udden, J. A., Journ. Cinn. Soc. Nat. Hist., Vol. XIX, p. 91.

ANALYSES OF LOWER DAVENPORT LIMESTONE

	I	II	III
$CaCO_3$	96.91	97.39	94.83
$MgCO_3$	1.93	1.54	0.25
Fe_2O_3	0.30	....	....
Fe, Mn and Al	....	0.14	2.52
SiO_2	0.86	....	....
SiO_2 and insoluble residue	....	0.28	3.22

I. Sample from ledge above Rochester on right bank of Cedar river.
II. Sample from Bettendorf.
III. Sample from Duck creek, north of Davenport.

The Upper Davenport

At their type locality in Scott county these beds form a ledge of gray granular limestone, about twelve feet thick, close textured, tough and hard, disposed in rough surfaced layers from six inches to a foot and more in thickness (figure 53). This

FIG. 53.—Upper Davenport limestone, Schmidt's quarry, Davenport, Scott county.

ledge lies between unfossiliferous calcilutites beneath and soft, highly fossiliferous shaly limestone above. These characteristics are maintained in Cedar and Linn counties. The bed in Muscatine county is described as a tough gray limestone seven feet thick in heavy ledges intercalated between unfossiliferous fine-grained limestones and fossiliferous shaly limestones as in Scott county.

In Johnson county the beds are shattered but are seen to consist of the same coarse granular stone. In Benton county about twelve feet of gray granular limestone in courses up to four feet thick represents this horizon. As in Johnson county the underlying calcilutites have been thoroughly brecciated. In Buchanan county beds lithologically similar occur at Independence and at Quasqueton in tumbled fragments and faulted ledges. At Independence they are reported to be succeeded by barren limestones. In Fayette county a bed of strong rather massive yellowish gray limestone eight to ten feet thick occupies the Upper Davenport horizon. It rests on a foot or so of fine-grained unfossiliferous limestone at Eagle Point which may represent the Lower Davenport. Beneath it lie shaly beds identified with the Independence. Thus from Muscatine county on the south to Fayette county on the north a well defined lithologic sequence generally prevails in the Wapsipinicon area as follows:

5. Shaly fossiliferous limestones.
4. Gray granular fossiliferous limestone. Upper Davenport.
3. Calcilutite. Lower Davenport.
2. Shales and impure limestone. Independence.
1. Calcilutites and magnesian limestones. Otis and Bertram.

The life zones above the Independence, which of course are far more decisive than lithologic facies, are by no means so well defined. No adequate statement is now possible, for the reason that the collection of fossils over a large portion of the field has not been sufficiently thorough and critical. The brecciation and intermingling of beds in numerous exposures has rendered the tracing of life zones extremely difficult. There appear, however, some outstanding facts from the investigations already made, which future discoveries may modify but will hardly overthrow. Tabulating the data at hand (table I) it is seen that after the Independence the Iowa Devonian area was held by five successive faunas during the Wapsipinicon and the early Cedar Valley. The First Fauna was composed, so far as now is known, of *Hypothyridina cuboides, Gypidula comis, Schizophoria macfarlanei, S. iowensis, Pholidostrophia nacrea, Stropheodonta demissa* of normal form and especially in a small quadrate and strongly plicated variety, *Atrypa reticularis* finely ribbed, *Atrypa aspera* var. *occidentalis,* and a giant *Gyroceras.* This fauna appeared immediately at the close of the deposit of the Lower Davenport calcilutites and spread throughout the entire extent of the Iowa field from Fayette county to the northern border of Muscatine county. In Buchanan and Linn counties the first fauna survived into the succeeding life zone and mingled with the second fauna with the exception of *Hypothyridina cuboides* and the giant *Gyroceras.* In all other counties the first fauna and the second fauna, at least in part, enter simultaneously at the same lithological horizon. In southern Buchanan county the second fauna follows closely upon the first. In central Buchanan county, at Independence, the two are separated by barren beds. The second fauna is led by *Spirifer bimesialis* and by *S. pennatus.* The first named species is more definitely characteristic of the zone, since the latter lingered on to mingle with later faunas.

In Scott and Cedar counties, and probably in Muscatine county also, there enter along with the first and second faunas the corals characteristic of the third fauna—*Phillipsastrea billingsi* and *Acervularia profunda.* In the counties to the north these corals occupy a distinctly higher horizon. Either these corals made their appearance earlier in the southern counties than in the northern, or the first and second faunas delayed their entry into the southern portion of the Iowa field. Taking as a scale the sequence in Buchanan county, where the faunas enter in due succession, the first fossiliferous beds in Scott and Muscatine counties may be held as contemporaneous either with the zone of fauna one or with that of fauna three of Buchanan county. Calvin judged the latter to be true, and stated that the brecciated calcilutites of Muscatine county, which lie immediately beneath the first fossiliferous beds, are the stratigraphic equivalent of the *Spirifer pennatus* beds of Buchanan county;

i. e., the zone of the second fauna.[46] This conclusion would be better supported by the evidence if the first fauna were absent from the lowest fossiliferous beds in the southern counties. Moreover, the brecciated calcilutites, the Lower Davenport beds, form a well defined bed traceable continuously from Muscatine and Scott counties to southern Buchanan county. In Muscatine county the lowest fossiliferous bed lies twenty-nine feet below the definitely fixed horizon of the fourth fauna, the *Spirifer parryanus* beds. For these reasons it seems more probable that the first fossiliferous horizon in Scott and Muscatine counties is contemporaneous with the zone of the first fauna of Buchanan county and that the corals of the third fauna entered Iowa from the south or southeast along with the first and second faunas and did not reach the central part of the field until some time after it had been colonized by the pioneering brachiopods. In Muscatine county, it is true, none of the first fauna have been reported excepting the two Atrypas. But there is here only one exposure of the first fossiliferous beds—that of Wressley's quarries. The few fossils reported from these beds are found at the same horizon—the Upper Davenport—in Scott county, where the first fauna is well developed. Furthermore, the exposure in Muscatine county is evidently continuous with that of Cedar county just across the county line and three or four miles distant, where the *Hypothyridina* fauna is seen mingled as in Scott county with the corals of the third fauna.

The fourth fauna is led by *Spirifer euryteines* (*parryanus*) and forms a very definite horizon. Few members of the earlier faunas survive. Among them are such long lived forms as *Atrypa reticularis, Schizophoria iowensis* and *Stropheodonta demissa. Spirifer subvaricosus, S. pennatus, S. asper* and *Pentamerella dubia* linger on. Associated with *Spirifer euryteines* (*parryanus*) in parts of the field are *Newberria johannis, Cyrtina unbonata* and *Athyris fultonensis.*

The fifth zone, the coral reef of *Acervularia davidsoni* and other corals, is well defined in the north, but in Muscatine county no Acervularias are reported after the entrance of the fourth fauna, while in Scott county *Acervularia davidsoni* occurs along with *Spirifer parryanus.*

[46]Iowa Geol. Surv., Vol. IX, Pl. 6, footnote.

TABLE I

PROVISIONAL LIST OF FOSSILS OF THE UPPER DAVENPORT AND CEDAR VALLEY LIMESTONES AS FAR UPWARDS AS THE ACERVULARIA DAVIDSONI REEF, WITH THE HORIZONS AT WHICH THEY HAVE BEEN OBSERVED. COMPILED CHIEFLY FROM COUNTY REPORTS OF THE IOWA GEOLOGICAL SURVEY.

	Buchanan County					Linn Co.		Benton County				Johnson County					Fayette County					Cedar Co.	Scott County				Muscatine County				R.I. Co. Ill.*
	Hypothyridina beds	Spirifer pennatus beds	Phillipsastrea billingsi beds	Spirifer parryanus beds	Acervularia davidsoni beds	Hypothyridina beds	Spirifer bimesialis beds	Hypothyridina and Spirifer pennatus beds	Acervularia profunda beds	Spirifer parryanus beds	Acervularia davidsoni beds	Hypothyridina and Spirifer pennatus beds	Phillipsastrea beds	Acervularia profunda beds	Spirifer parryanus beds	Acervularia davidsoni beds	Hypothyridina beds	Spirifer pennatus beds	Phillipsastrea billingsi beds	Newberria johannis beds	Coral beds	Hypothyridina beds	Hypothyridina and Phillipsastrea beds	Spirifer pennatus and Orthis vanuxemi beds	Spirifer parryanus and Acervularia davidsoni beds	Athyris fultonensis beds	Phillipsastrea beds	Othis vanuxemi beds	Chonetes scitula beds	Spirifer parryanus and Coral beds	Phillipsastrea beds
FIRST FAUNA																															
Hypothyridina cuboides	—					—						—					—					—	—								
Gypidula comis	—	—				—	—	—				—					—	—				—	—	—			—				—
Schizophoria macfarlanei	—	—				—	—										—					—	—								
Schizophoria iowensis var.		—				—	—	—	—	—		—	—	—			—	—						—		—					—
Pholidostrophia nacrea		—				—	—	—									—							—							—
Stropheodonta demissa				—		—	—	—	—	—			—																		
Stropheodonta demissa var. plicata		—				—	—		—																						
Atrypa reticularis (fine ribbed)	—	—				—	—	—									—	—					—								—
Atrypa aspera var. occidentalis		—				—	—	—				—	—				—	—	—				—	—			—	—			
Gyroceras sp.	—					—		—																							
Gomphoceras sp.								—																							—
SECOND FAUNA																															
Favosites alpenensis					—							—	—		—							—		—			—				
Favosites placenta								—				—					—										—				

Cranaena iowensis								—																							—
Cranaena romingeri								—										—													—
Crania crenistriata							—															—									
Chonetes cf C. cancellatus		—					—	—																							
Cyrtina hamiltonensis		—						—										—						—							—
Gypidula laeviuscula								—										—													
Newberria johannis			—																	—			—		—						
Pentamerella arata			—					—															—								
Pentamerella dubia		—		—						—						—	—						—	—							—
Pentamerella micula							—																—								
Productella subalata		—					—		—	—							—	—													—
Reticularia fimbriata							—												—				—								
Reticularia subundifera													—										—				—				—
Spirifer asper								—							—								—	—						—	
Spirifer bimesialis		—					—	—															—								
Spirifer pennatus	—	—					—	—		—		—	—				—	—	—			—					—	—			—
Stropheodonta perplana																								—							
Goniophora sp.							—																								
Proetus haldemani							—																								
Phacops rana							—											—					—								
THIRD FAUNA																															
Acervularia profunda			—						—				—						—	—	—		—								—
Acervularia sp.													—										—								
Phillipsastrea billingsi			—										—						—				—				—				—
FOURTH FAUNA																															
Spirifer parryanus				—						—					—	—									—	—				—	—
FIFTH FAUNA																															
Acervularia davidsoni				—	—					—	—					—									—		—				—
Megistocrinus farnsworthi													—	—																	
Athyris fultonensis																									—					—	—
Chonetes scitula																								—					—		
Crania hamiltoniae?																								—							
Cyrtia umbonata																								—					—	—	
Spirifer subvaricosus																								—	—						—
Tentaculites hoyti																—			—					—							

*From Correlation of the Devonian System of the Rock Island Region (E, b and E, c), W. E. Ekblaw, Trans. Ill. Acad. Sci., 1912.

THE BRECCIATED ZONES

The descriptions already given of the beds of the Wapsipinicon are based upon outcrops where they are but slightly if at all disturbed. But in very numerous sections over the entire area of outcrop of the Wapsipinicon its terranes are more or less completely broken up and intermingled. Almost every outcrop of the Wapsipinicon from Fayette and Bremer counties on the north to Scott and Muscatine counties on the south shows brecciation either incomplete or thoroughgoing. Roadside sections, small quarries and shallow railway cuts may exhibit certain general characteristics found over the entire field, but it is the larger outcrops which supply the key to their interpretation. The chief exposures are the deep railway cuts north of Vinton, west of Linn and at Fayette, the long cliffs along the Volga in Westfield township of Fayette county, the river bed and banks at Independence, Quasqueton, and Troy Mills, and several outcrops adjacent to Cedar Rapids.

At any one of these sections the first casual impression of the breccia is that of a chaotic hodge-podge of debris. A closer attention shows that the breccia is by no means uniformly heterogeneous. There are zones and tracts characterized by preponderating material and the remains of nearly obliterated structures. And one familiar with the lithologic characteristics of the different Wapsipinicon terranes can identify their contributions to the hodge-podge and recognize the different zones in each of which the material of some one terrane is preponderant or even exclusive. The breccia as a whole or any exposure of it is therefore best described by subdividing it into zones according to the terranes which make it up.

Characteristics Due to the Major Brecciation

The main characters of the breccia are referable to a single cause, as will be seen later, and these characters may be grouped as the effects of what we may designate as the *Major Brecciation.* But enigmatic features also are found which indicate a complexity of causes and show that the breccia is not the result of a single process, but embraces the results of a long succession of processes of different sorts. These features will be treated under *Minor Brecciations.*

As we proceed to describe the characteristics of the major brecciation under zones it must not be supposed that these zones retain either the horizontality or the sharply definite boundaries of their parent formations. Boundary lines are in many places vague and usually oblique. Zones arch, thicken and thin, are dislocated and interrupted. Nor in any zone are the materials of other than the parent terrane necessarily excluded. Thus the Independence zone, predominantly of clayey detritus from the Independence, may contain fragments of the brittle Otis and Lower Davenport calcilutites, blocks of the Upper Davenport, and even somewhat of the fossiliferous *Spirifer pennatus* beds. A very generalized section may assist in making these statements plain (figure 54).

BERTRAM BRECCIA

The Bertram beds experienced the same powerful stresses which brecciated the superior terranes, but in no case are its

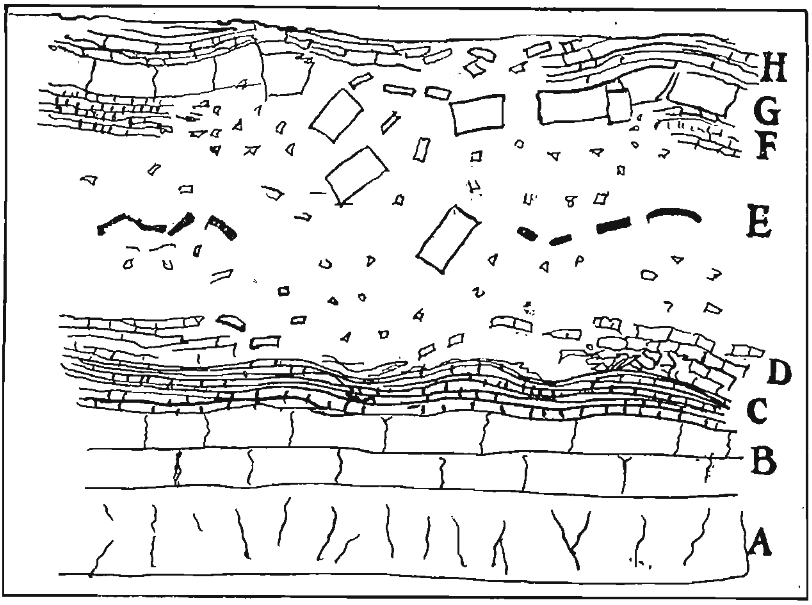


FIG. 54.—Generalized section of Wapsipinicon brecciated beds. A, Bertram. B, Otis, Coggan phase. C, Otis, Vinton phase. D, Otis, Cedar Rapids phase. E, Independence. F, Lower Davenport. G, Upper Davenport. H, *Spirifer pennatus* beds.

fragments intermingled with theirs. The entire body of the rock is shattered to a greater or less degree. Universally the ruptures have been filled with calcite and not with partly detrital material; hence when the stresses occurred, the rock was not accessible to the sediments of the sea floor. Thick beds are found shattered with rupture planes spaced to less than an inch apart. Upper weathered surfaces are covered with a network of incised lines whose rhombic meshes vary from a fraction of an inch to a few inches in width. These fissures vary from a hair line in width to nearly one-half inch. The surface of a fresh vertical fracture may show horizontal veins of calcite intercalated between the laminæ, as closely set, exceptionally, as ten to the inch. These veins occasionally branch and break across the laminæ. In places where they are not completely filled with interlocking calcite crystals the fissures between the blocks into which the rock has been shattered are lined with drusy calcite.

The stresses which so intimately shattered the Bertram beds did not convert them into rubble. The fragments are not dislocated, very few blocks are rotated and the major bedding planes are little disturbed. This may imply a considerable weight of superincumbent rock whose weight tended to keep the beds in place, while they yielded by crackling to the sudden stress. But the strength of this heavily bedded dolomite undoubtedly helped it to resist strains which would have completely broken up a weaker rock.

OTIS BRECCIA

As far to the north as Vinton the Otis limestones do not appear to have been involved in the major brecciation, to the extent of a commingling of their fragments with those of higher terranes. The beds on Crow and Pigeon creeks of Scott county are crackled. Those northeast of Rochester in Cedar county are fissured, with the planes of rupture filled with calcite, and those of Linn county are thrown into low gentle undulations and the more brittle beds are meshed with close-set calcite seams —all the result, it is assumed, of the major brecciation. Even these evidences of strain are confined to the upper beds of the

Otis, the Cedar Rapids phase. The basal beds, the Coggon phase, escaped brecciation so far as is known.

The lower magnesian beds which are exposed at Vinton show no effects of the major brecciation (figure 55) except local archings of the strata which may reach an exceptional dip of limb of 15°. The calcilutites which in places in the Vinton quarries immediately underlie the zone of the Independence, however, are shattered to crackle breccia or disrupted to a mosaic breccia of fragments which in many cases match along seams filled with calcite or with fine chinkstone[46a] of the same nature as the large fragments (figure 56). In places the calcilutites of the Otis have been broken into close-set rubble with which a few fragments and a scant matrix of the Independence and fossiliferous

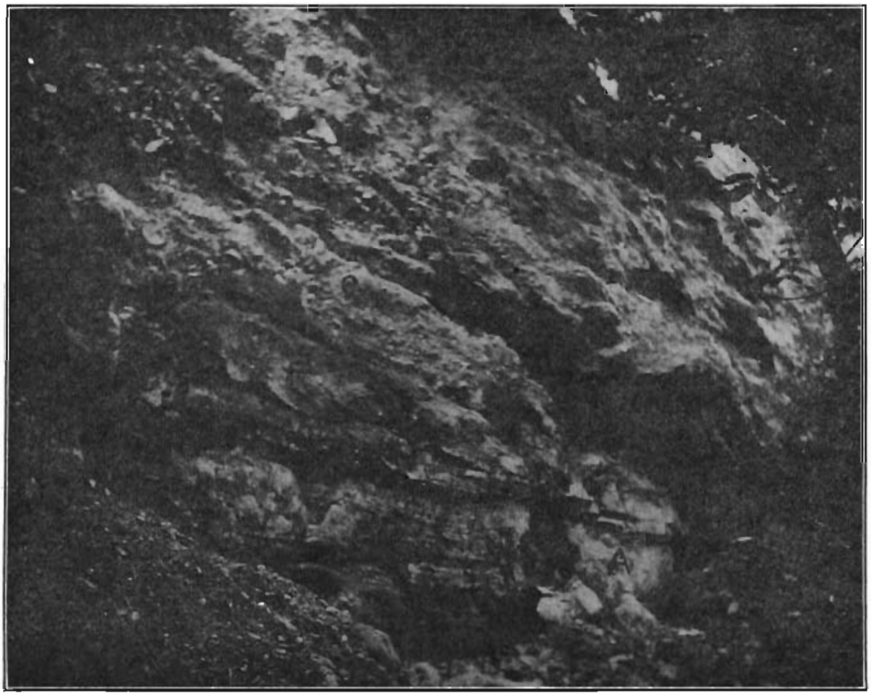


FIG. 55.—Otis limestone overlain by Independence breccia, Aungst quarries, Vinton, Benton county. A, closely laminated magnesian Otis limestone. B, massive upper layer of the same with sporadic fragments. C, breccia of Independence with calcilutite fragments also and fossiliferous blocks of Upper Davenport.

[46a]Chinkstone. Small fragments of stone which fill the chinks, or interstices, between larger fragments.

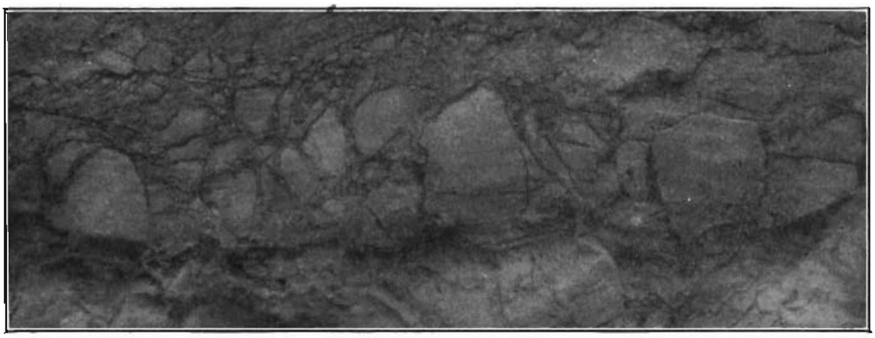


FIG. 56.—Otis calcilutite showing a disrupted layer at the base of the railway cut north of Vinton, Benton county. Scale, ¼.

fragments from higher beds are commingled. At one point (p. 493) this rubble forms a bed twelve feet thick which thins to six feet at an angle of 45° and rests immediately upon the buff magnesian layers of the Otis. Elsewhere amid the breccia of the Independence zone one finds fragments which may be referred to the horizon of the Otis calcilutites, such as fragments with hair-line blackish laminæ.

In Fayette county the basal beds in contact with the Silurian—the Westfield phase—were massive enough to resist completely the strains of the major brecciation. It is quite different with the thin-bedded, fine-grained limestones which rest upon them. These beds were bent into a series of low arches whose width is nine to twelve feet and whose height is less than two feet, while the laminæ have been fractured by a meshwork of close-set narrow vertical seams now filled with calcite (figure 57.) At Eagle Point the upper layers of this bed have been brecciated to a rubble of angular blocks some of which are two feet in diameter (figure 85.)

The Otis calcilutites of Fayette county seen at West Union and Fayette were less elastic and resistant and received greater strains than the beds beneath, perhaps because of their nearness to the yielding Independence. They were intimately shattered to a crackle or mosaic breccia to be recemented by calcite deposited by ground water, the original planes of bedding being largely retained. Or, yielding more fully to the stresses, they were crushed to rubble of small fragments to whose interstices more or less of the shaly detritus of the Independence found access. Large blocks were plucked away and left amid the Independence debris and thus in places the entire body of the rock was broken up and its bedding destroyed beyond possibility of recognition. This is the breccia described and figured by McGee as typical of the Devonian limestone breccia of Iowa. It will be noted particularly that this breccia bed belongs to the zone of the upper Otis calcilutites and that it has small admixture of the Independence and no commingling of higher fossiliferous beds. At Eagle Point the Independence is more intimately intermingled (p. 464), but no fragments of fossiliferous higher terranes appear.

THE INDEPENDENCE BRECCIA

This zone comprises the areas in which buff or rarely bluish argillo-calcareous detritus is conspicuous or predominant. It can be traced continuously from Fayette to Scott county and is

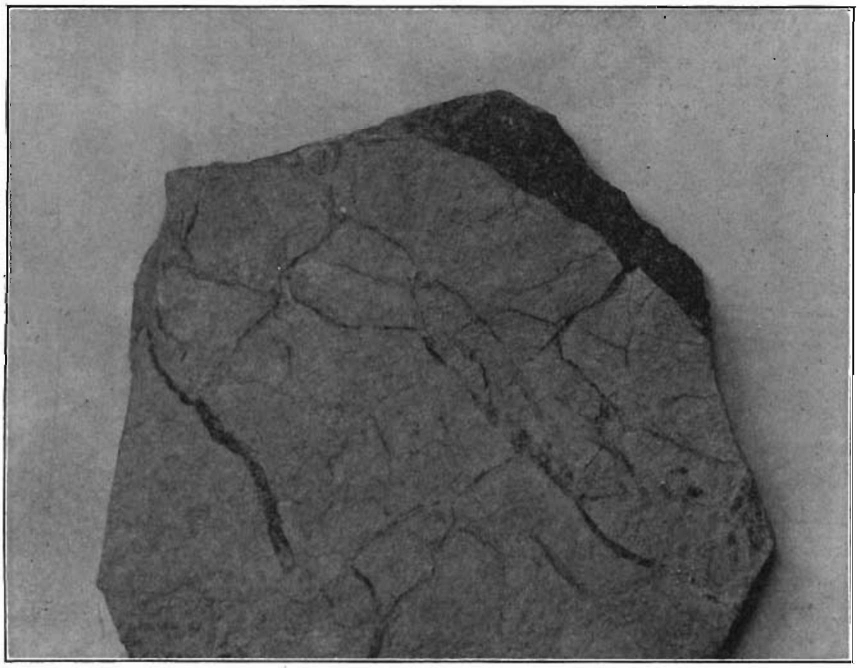


FIG. 57.—Crackled surface of detached lamina of Otis limestone near the base of the railway cut at Fayette, Fayette county.

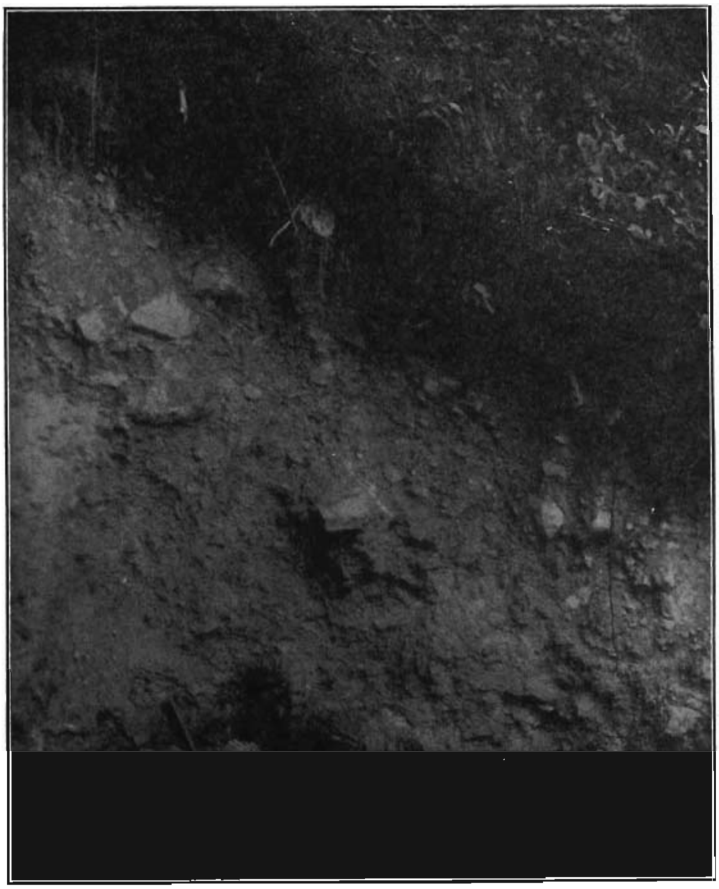


FIG. 58.—Unindurated breccia composed chiefly of Independence detritus. Kearn's quarry north of Vinton, Benton county. At the base are seen the magnesian beds of the Otis. Above the hammer may be seen layers of Independence shale arched and broken but not crushed.

everywhere found in the same position, immediately beneath the zone of the Davenport limestones. On account of the large amount of argillaceous material and poor cementation, the areas of the Independence are weak and weather back to slopes while adjacent tracts of the limestone breccias stand in strong cliffs or ledges. The breccia of this zone in some places is scarcely more indurated than glacial till, and fragments of limestone can be picked from it quite as easily as can pebbles from glacial stony clays. The two formations, so diverse in origin, have a strong superficial resemblance because of their common lack of bedding, their clayey base and the stones of all sizes promiscuously intermingled (figure 58).

The material in this zone which may be referred to the Independence comprises first the buff argillo-calcareous and in many cases sandy matrix. This is not laminated or bedded and shows no trace of sedimentary deposit in its present relations. Sporadic fragments show no signs of having been droppd on the sea floor in the midst of accumulating layers of argillo-calcareous sediments. Stratification would be easily detected, for the matrix is in places somewhat arenaceous with rounded grains of quartz and angular bits of flint, which soon are left in conspicuous relief on weathered surfaces. Such grains are without linear arrangement, and like the larger fragments are sporadic. The nearest approach to stratification is found in certain small areas of lumpy structure where the rock weathers to flattened irregular lenslike bodies two inches and more in diameter. Since this structure occurs also in the Independence where that is unbrecciated, it may be supposed that in these areas masses of the Independence have been preserved nearly or quite intact.

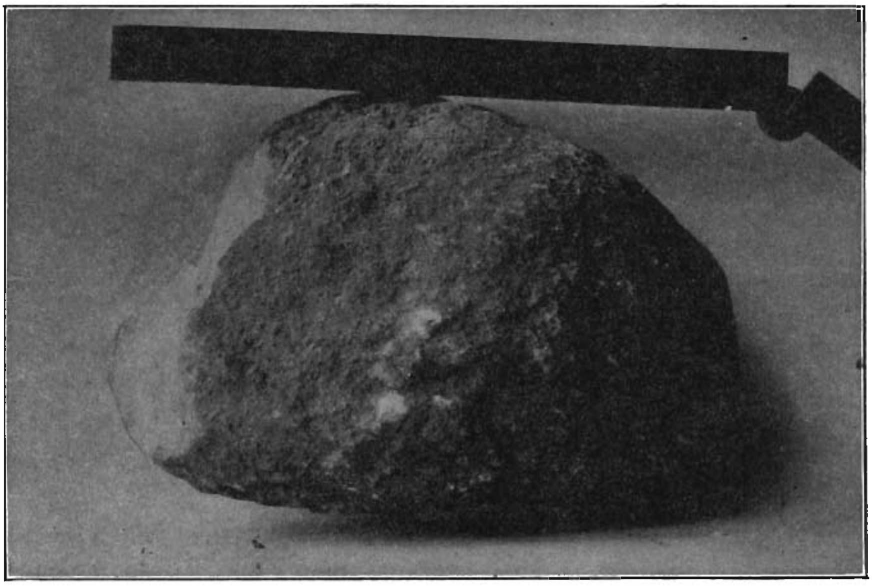


FIG. 59.—Siliceo-calcareous nodule, Independence beds.

There are also many fragments of various sizes of dingy buff limestone which may be difficult to detect from the matrix rock. Areas which seem at first sight to be composed entirely of the buff matrix may be found to be largely made up of fragments of the same texture, color, and apparent composition.

Siliceous material derived from the Independence beds embraces the rounded grains of crystalline quartz and the angular bits of black and white cryptocrystalline silica already noted.

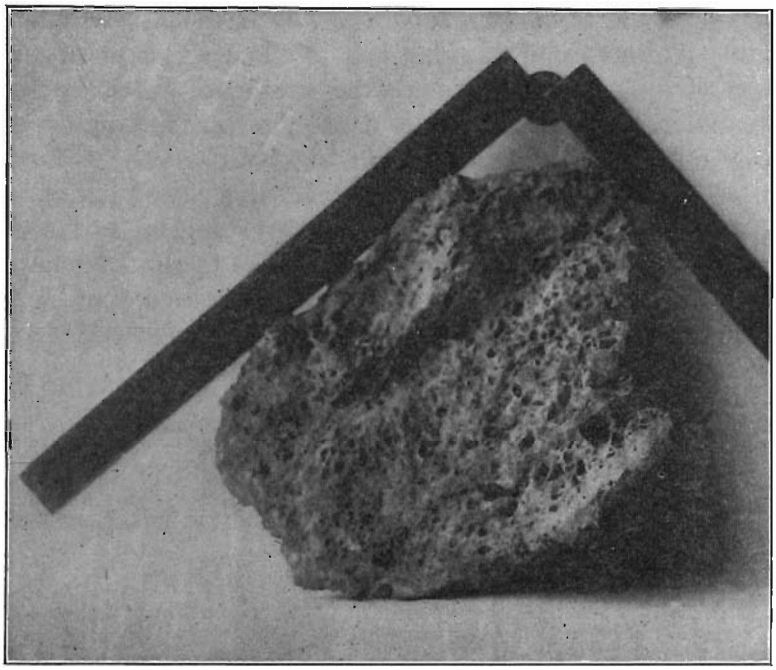


FIG. 60.—Fragment of a siliceo-calcareous nodule from which the calcite has been removed by solution. Independence horizon, Canton, Jackson county.

There are also sharp-edged fragments of flint of some size. Large nodules of intercrystallized quartz and calcite are as characteristic of this zone as they are of the Independence beds where those are undisturbed, and in the breccia these nodules are set at any angle (figures 59 and 60).

Ledges of massive limestone of Independence facies a foot and more thick occur—buff, impure, speckled, and in some cases minutely fragmental. These are in every instance tilted and

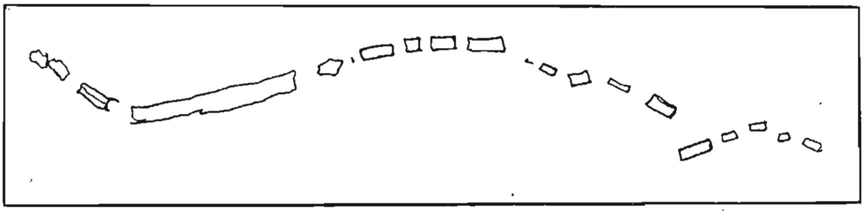


FIG. 61.—String of blocks of dingy brownish Independence limestone representing a flexed and broken layer. From the railway cut north of Vinton, Benton county. Scale, one inch equals ten feet.

discontinuous or broken into blocks which are surrounded on all sides with rubble breccia (figure 61). Beneath them one occasionally may find laminated shales up to a foot or so in thickness. That shales and limestone were not deposited upon the breccia beds beneath is clear from the fact that the underlying breccia contains (Vinton, p. 488, Linn, p. 506) fossiliferous fragments of Upper Davenport limestone. The shales and limestone were deposited in orderly succession during Independence time. Later, the stresses of the major brecciation, which crushed so much of the Independence to fine detritus, here left a ledge of limestone tilted with some of the underlying shale protected by it, and thrust underneath them a rubble of breccia with fragments from higher formations.

Small areas of similarly protected shales are sometimes found with their laminæ strongly arched (Linn railway cut, figure 62). These areas also represent parts of the Independence which have not been crushed out of all semblance to their initial structures.

FIG. 62.—Obscure flexures in shale of Independence zone, Linn section, Linn county. A, Strong breccia of limestone fragments. B, Buff laminated shale with a few sporadic limestone fragments, bent and fractured. C, Weak breccia with abundant buff Independence matrix.

At one or two stations the position of layers of some length or of strings of dislocated blocks of calcilutite strongly suggest that these beds are native to the Independence. It is true that where the Independence may be seen intact fine-grained limestones of the type of these calcilutites are almost unknown. The only instances observed are at Eagle Point (p. 464) and in a thin bed of fine-grained whitish limestone at the cut of the Chicago, Rock Island and Pacific Railway two miles southeast of Cedar Rapids and a layer of brown limestone in the quarries of the Chicago and North Western Railway at that city. Neither of the beds at Cedar Rapids adequately resembles the calcilutites of the breccia of the Independence zone. It is true that an immediate source for calcilutite fragments in the Wapsipinicon breccia beds is found in the calcilutites of the Lower Davenport and of the Otis and that their commingling with the Independence detritus is unquestionable. There is no need, however, to avoid the conclusion wherever evidence leads to it, that calcilutites indistinguishable from those of the Otis and Lower Davenport were laid to a limited extent in Independence time. We define the Independence lithologically as the period of the deposit of shales and impure granular limestones. This definition does not imply that colonies of lime-secreting organisms may not locally have produced thin beds of calcilutite in the midst of prevailing shales. The Independence breccia contains a large amount of foreign material. In the northern counties where the Otis has been broken up, it contributes ledges of limestone under which the Independence shaly breccia has been thrust. Where the fragmentation of the Otis is more complete an Otis rubble breccia may be seen to graduate into an Independence area with Otis sporadic fragments. In Linn and Johnson counties the Lower Davenport furnishes abundant small drab calcilutite fragments from its shattered laminæ. And throughout the area except in the extreme south the Upper Davenport and even the *Spirifer pennatus* beds supply their characteristic fossiliferous fragments which are often found far down in the breccia-zone of the Independence (figure 63).

Structure lines due to deformation are naturally not so obvious in the Independence zone as in the limestone breccia where brecciation has been less complete. The boundaries of the zone, however, indicate deformation even where brecciation has been most intense. In the Fayette railway cut the Independence zone displays low archings 140 feet in diameter, thin at the summit, thickening to the bases of the limbs. In the Linn section the areas of the Independence breccia alternate laterally with those of limestone breccia and their boundaries dip steeply outwards as if the Independence breccia here formed the axes of strong anticlines. At intervals of about fifty feet in places the limestone breccia stands in almost vertical towers while the weak intervening shaly breccia weathers back to slopes. Within the Independence zone are commonly seen, as in the Vinton railway cut, tilted ledges of the stronger Independence limestone in places continuous for several feet, and strings of blocks of some thicker limestone stratum each completely surrounded by brec-

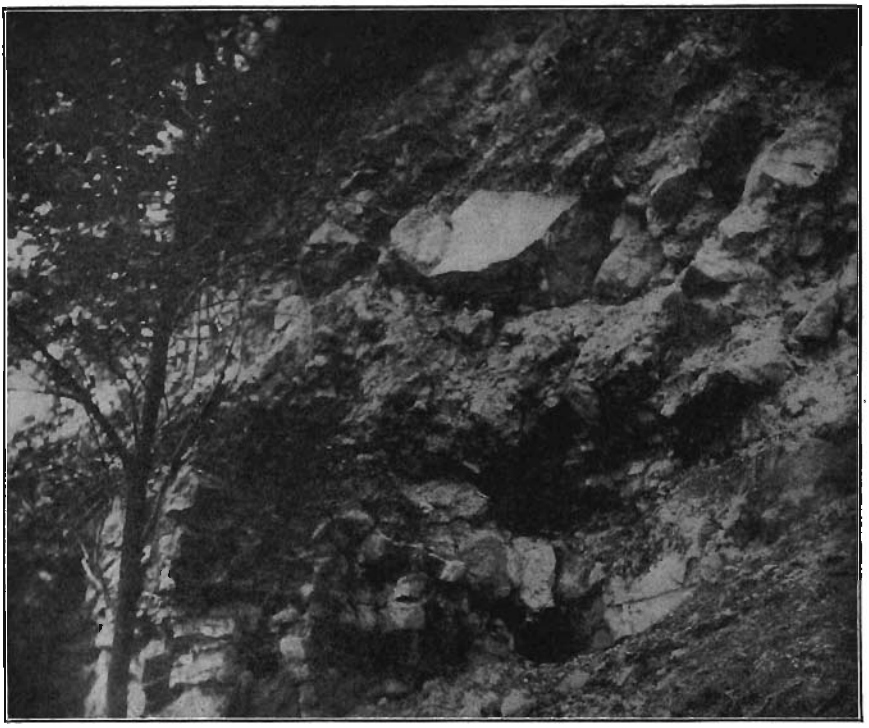


FIG. 63.—Otis beds overlain with breccia of the Independence zone. Aungst quarries, north of Vinton, Benton county.

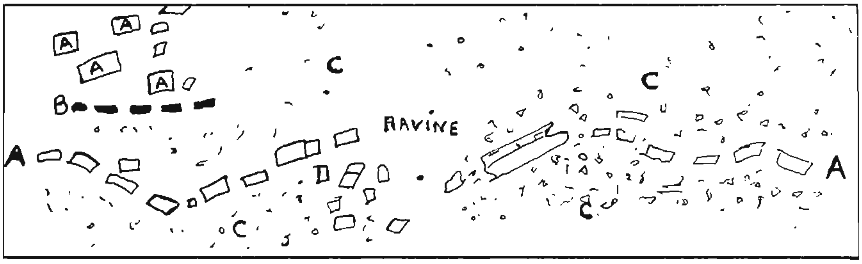


FIG. 64.—Structure lines in Independence zone. Railway cut north of Vinton, Benton county. AA, Blocks of whitish calcilutite in a sinuous broken line dipping 30° to the right of the ravine. A, Blocks of white calcilutite. B, string of fragments of buff impure limestone. C, Breccia of predominant Independence shaly fragments.

cia of shaly matrix. These blocks, parted and many of them somewhat rotated, still trace by their alignment irregular, in some cases faulted, folds and steep monoclines which may be traced with interruptions for as much as three or four rods in places (figure 64).

THE LOWER DAVENPORT BRECCIA

In the Lower Davenport zone all gradations may be traced from areas where the layers are closely crackled (figures 66, 67, 68, 69) and slightly bent, to those where the same layers are ruptured to mosaic breccia and on to where they have been more or less completely broken up into rubble (figure 70). At Quasqueton, at Kenwood, near Rochester in Cedar county, and about Davenport and Rock Island such gradations may be observed. The matrix in the crackle and mosaic breccias and in some rubble is of chinkstone and indurated powder of the broken rock together with calcite deposited at some later time by ground water. Rubble breccia, however, shows usually some buff interstitial matrix of the Independence detritus and may graduate into a pudding breccia where the Independence matrix is abundant and the sparse Lower Davenport fragments are sporadically distributed throughout it.

In all types the fragments are small as a rule, up to two or three inches in diameter, and many have the form which would naturally result from the breaking up of a thinly laminated limestone. In rubble they are set at all angles. Their edges retain their initial angularity and no trace can be seen of bedding or sorting after their fragmentation. In mosaic breccia some of the laminæ are slightly bent and may be seen to have broken where the fold was sharpest. But the brittleness of these calcilutites, like their fracture, approaches that of flint, and they rupture under very little strain.

The rubble breccia of this horizon is perhaps the most common of all the Wapsipinicon breccias exposed. This is due not so much to its extent and thickness as to the strength of its well cemented masses. It stands in ledges and buttresses where the

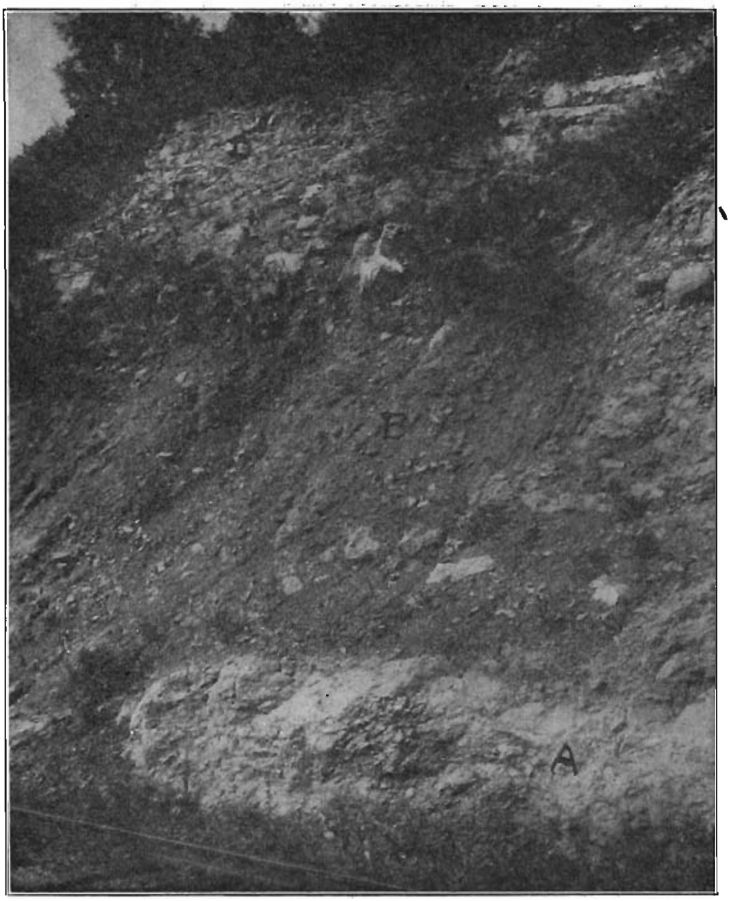


FIG. 65.—General relations of the Independence zone of brecciation. Railway cut north of Vinton, Benton county. A, Ledge of Otis calcilutite, brecciated. B, Independence zone. C, Upper Davenport beds, brecciated. D, Barren beds, arched, in places brecciated.

abutting clayey breccia of the Independence weathers down to slopes. More than any other terrane the Lower Davenport limestone is apt at any point to be completely involved in the brecciation and to leave no evidence of itself except a rubble breccia more or less intermingled or interfingering with the Independence.

North of Independence the Lower Davenport is very thin and its presence is questionable. On the contrary in Scott and Muscatine counties it reaches a thickness of over forty feet. In

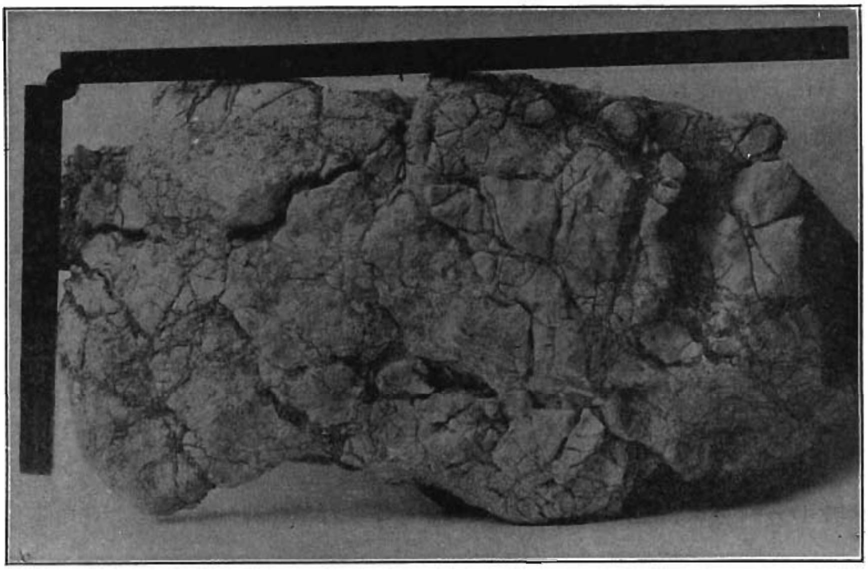


FIG. 66.—Crackle breccia. Upper surface of layer of Lower Davenport limestone. Section E, Felton creek, Cedar Rapids, Linn county.

and about Davenport these beds lie in low arches up to 100 feet in diameter the centers of whose synclines are in some cases broken into breccia. On Rock Island areas of mosaic and rubble breccia seldom exceed a rod or so in length (Plate VII).

Besides thinly laminated and more massive calcilutites the Lower Davenport also contains saccharoidal limestones finely displayed in the quarry of the Bettendorf Stone Company, Davenport (figure 52 center), and in exposures about Cedar Rapids. These also are involved in the brecciation at several points as

Area of brecciated laminated Lower Davenport limestone, Rock Island, Illinois.

FIG. 67.—Block of massive Lower Davenport limestone, in part crackled, in part crushed to rubble. Felton creek, Cedar Rapids, Linn county.

at the Linn section and in Section E, Felton creek, Cedar Rapids, where they appear in dislocated ledges and large blocks.

THE UPPER DAVENPORT BRECCIA

The ledges of tough granular heavily bedded Upper Davenport limestone yielded to brecciation by breaking into blocks which reach large sizes. There may be but slight movement of the blocks in the gently undulating stratum, a movement indicated by slickensides, or, with more strongly marked archings of the bed, the blocks may be rotated and disparted. Thus at the railway cut west of Linn and in the cut north of Vinton the Upper Davenport zone is marked in places near the summit of the section by undulating lines of tumbled blocks which in some places have a diameter of three to five feet and in a few cases are eleven feet in diameter. The fracture planes commonly are smoothed and grooved and the slickensides break across bedding planes and cut sections in the thick shells of *Gypidula comis* and other brachiopods (Plate VIII).

Where, as along the Volga cliffs west of Fayette, the Upper Davenport remains for rods practically horizontal it is yet sharply flexed upward in places or broken down for a few feet in a tumble of big blocks imbedded in the Independence. Where the stresses have been evidently greater, as in the Vinton and Linn sections, the Upper Davenport is found in places deep down in the breccia in masses of rotated blocks, accompanied by fragments of the superior fossiliferous or barren limestones (figure 71). The river sections at Independence, Quasqueton and Troy Mills exhibit the zone of the Upper Davenport mingled with both *Spirifer pennatus* beds from above and the Lower Davenport and Independence from below. At Quasqueton the ledge of Upper Davenport north of the dam is largely in place but displays at one point a conspicuous thrust.

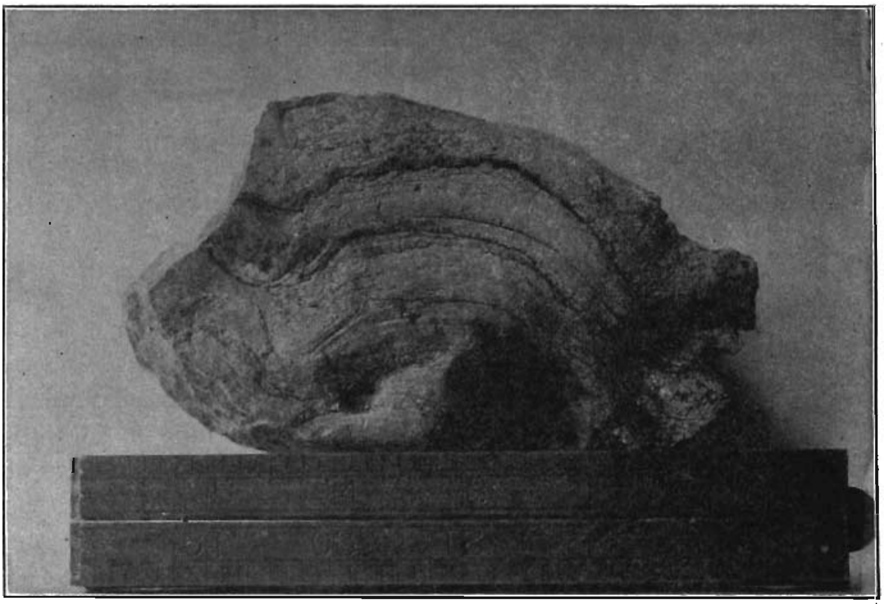
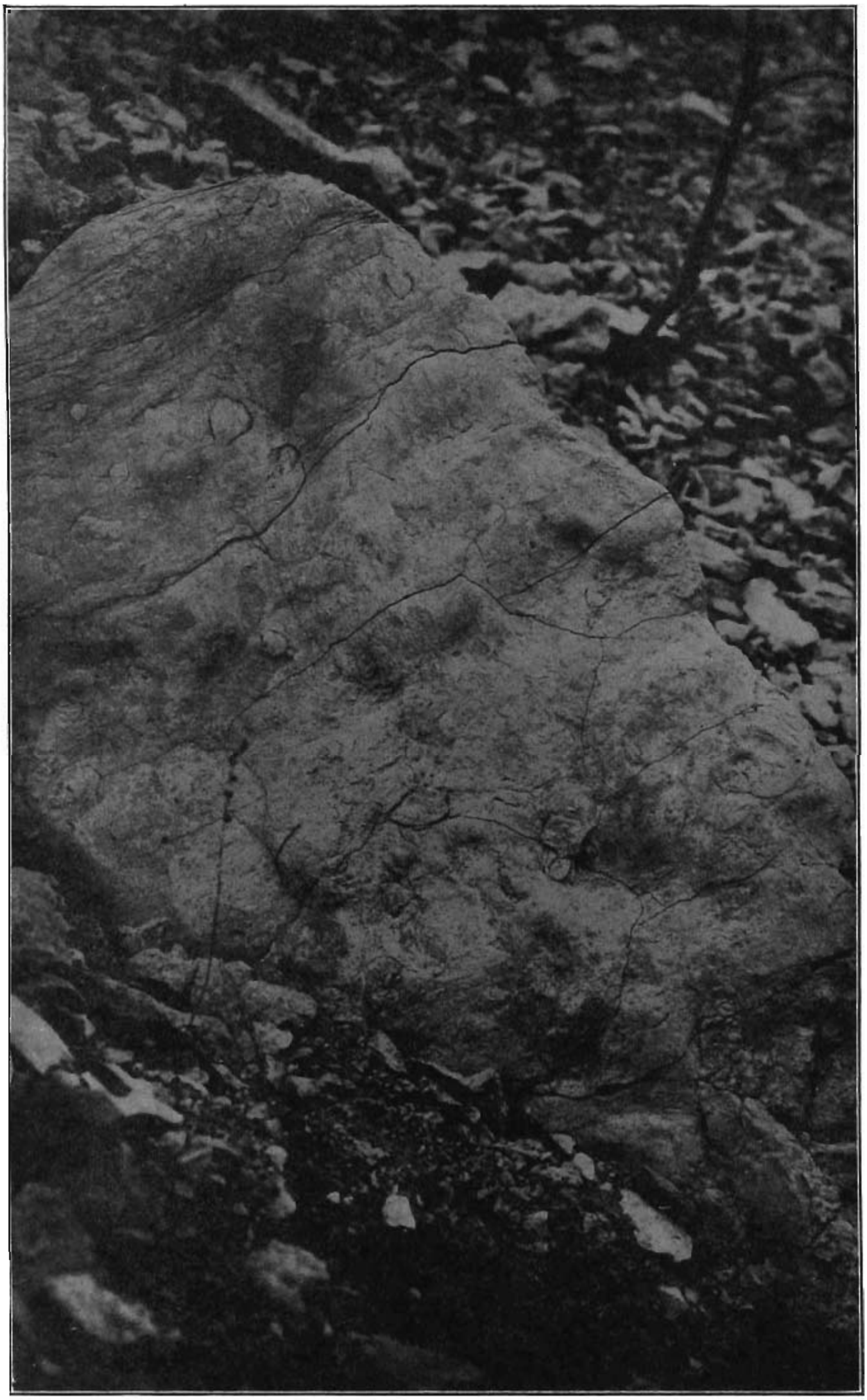


FIG. 68.—Flexed laminæ of Lower Davenport limestone. Duck creek, Scott county.



Slickensides on block of Upper Davenport limestone, Linn section, Linn county.

BRECCIATION OF THE SPIRIFER PENNATUS BEDS

The limestones above the Upper Davenport are usually but slightly involved in the Wapsipinicon brecciation. But at several points, as at Linn and at Troy Mills, their fossiliferous fragments are found deep down in the breccia commingled with those of inferior terranes. In very many cases they are affected by

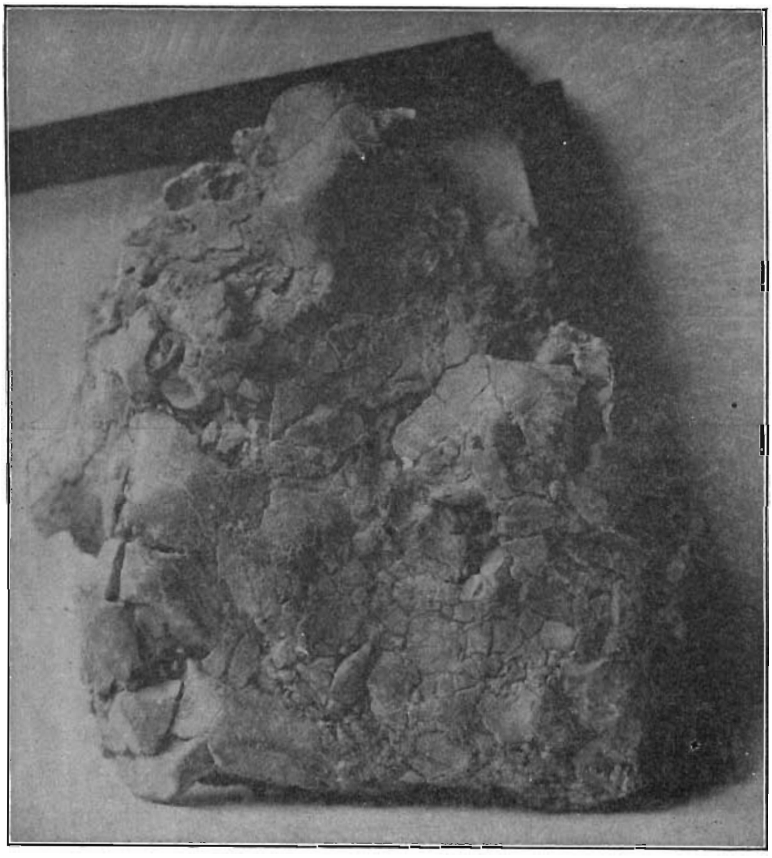


FIG. 69.—Mosaic breccia of Lower Davenport limestone. Rock Island, Illinois.

folding and lie in long gentle undulations whose dips seldom exceed fifteen degrees. Shattering is also a common phenomenon at this horizon. Thus in Sumner township, Buchanan county, there lies above the *Gyroceras* beds a body of limestone "not distinctly bedded but very much shattered and cut by joints

FIG. 70.—Ledge of Lower Davenport laminated calcilutite largely crushed to rubble. Section E, east end, Felton creek, Cedar Rapids, Linn county.

that intersecting at every possible angle, divide the bed into a great number of shapeless fragments which still retain their relative position unchanged.''[47]

While the shattering effects of frost on superficial beds of limestone are well known, the phenomena of slickensides very extensively developed on the joint walls led Calvin to infer the ''tremendous crushing, and shearing strains to which these rocks have been subjected.''[48]

THE SIGNIFICANCE OF FOSSILS IN BRECCIAS

The question whether the zones of breccia just described are fossiliferous or unfossiliferous is one of moment. A fossiliferous matrix such as that of the glacial breccia uplifted from the sea floor to form the Chaix Hills, Alaska, has obvious

[47]Calvin, Geol. of Buchanan County: Iowa Geol. Surv., Vol. VIII, p. 225.
[48]Ibid, p. 226.

implications. Fossiliferous fragments admit of several explanations. It was early stated by McGee[49] of the breccia at Fayette that "both fragments and matrix are sometimes fossiliferous and their fossils are identical." The fragments of the breccia are abundantly fossiliferous when the *Spirifer pennatus* beds or the Upper Davenport are involved. No fossils have yet been found in fragments from the Otis. This terrane is not involved in the major brecciations to the south where it is fossiliferous, and so far as is known it is unfossiliferous north of Linn county in the area where it contributes to the breccia. The Independence certainly has its highly fossiliferous tracts, but these appear to be so few that no fossils have been found in the Independence breccia zone except in the one little-disturbed fossiliferous tract of the Linn section (p. 388). The characteristic

FIG. 71.—Large blocks of Upper Davenport limestone along the top and at the right. Railway cut north of Vinton, Benton county.

[49]McGee, W J, Pleistocene History of Northeastern Iowa: 11th Ann. Rept. U. S. Geol. Survey, Pt. 1, p. 319, Washington, 1891.

fossils of the shale are fragile, it is true, but if they had been contributed in any large numbers to the breccia, they surely would have been recognized.

The matrices of all zones are entirely unfossiliferous, so far as is known. This statement is hardly necessary for the limestone and calcite matrices of the crackle and mosiac breccias and the close-set rubbles of the Otis and Lower Davenport zones. Where the Independence detritus constitutes the matrix some caution is needed in observation. The fossils of the *Spirifer pennatus* beds are very readily detached and may be picked up free of inclosing lime rock on any weathering outcrop. It is therefore to be expected that where the *Spirifer pennatus* beds contributed to an Independence matrix breccia not only fossiliferous rock fragments but also an occasional detached fossil may be found. In three instances detached shells of an *Atrypa* or an *Orthis* have been observed in the Independence matrix. In each case the *Spirifer pennatus* beds contributed to the breccia of the zone in which the fossils were found. In no case did the appearance of the shells or their filling warrant the assumption that they originally belonged to marine sediments which now supply a matrix to fragments which had been deposited among them. The filling of these shells was hard limestone of the *Spirifer pennatus* beds facies, and not soft earthy Independence matrix. In no case has a fossil been found in the Independence matrix where the upper fossiliferous beds have not contributed fossiliferous fragments to it.

Cause and Conditions of the Major Brecciation

The extent of the Wapsipinicon breccia at once removes it from the class of merely local breccias such as those due to landslide or composed of talus. The universal angularity of the fragments as well as a number of other considerations forbid its classification as a residual or as a bajada breccia. The close association of crackle, mosaic and rubble breccia proves that it cannot be a shoal, a reef, or a beach, subaqueous breccia, or a raft breccia of any variety.

Subaqueous glide as the cause of the major brecciation cannot be so summarily dismissed from consideration. The glide upon the sea floor of partly indurated sediments may be supposed to produce sharply angular fragments in the hardened beds and a gradation from crackle to rubble and even to a breccia of sporadic fragments. A zonal arrangement of material is to be expected where the gliding mass includes a sequence of different beds. Weak beds such as shales will supply matrix out of their detritus. More stable tracts may remain unaffected in the midst of a widespread creep. Moreover, subaqueous glide breccias are normally associated with foldings of the strata. In all these particulars the Wapsipinicon breccia tallies closely with those caused by subaqueous glide.

An effective objection to this hypothesis hardly lies in the wide extent of the Wapsipinicon breccia of Iowa. True, all breccias recently referred to glide, so far as the writer is aware, are quite local. But our knowledge of the phenomena of the slump of sediments of continental deltas which are overloaded—or shaken by severe earthquakes—or of sediments laid on slopes accentuated by deformation, is too limited to prescribe the extent possible in such movements.

In glides, however, a certain plasticity of the sediments is necessary—the plasticity of sediments but partly indurated. The summit beds of the gliding mass are the muds and oozes of the sea floor, and these will mix as matrix with fragments of lower beds which have become hard enough to break. In a brecciation so nearly contemporaneous with even the deeper strata involved, beds may be found some distance beneath the surface which will remain so poorly cemented as to flow plastically. But nothing is clearer than that the summit beds of the Wapsipinicon breccia, the *Spirifer pennatus* beds, were thoroughly indurated at the time of brecciation. They were bent but slightly before they were shattered into angular fragments. In no instance do they intermingle as matrix with fragments of deeper beds. From summit to base of the terranes involved, all limestones show only the slightest capacity for yielding plastically to strain, while shales are crushed instead of flowing plastically as mud.

The overlying beds of a subaqueous glide are undeformed. The glide does not die out above, but ends sharply at a horizon above which the beds are undisturbed. The contact is accordant when the glide has been reworked and leveled by the waves. In this case the overlying beds contain at bottom fragments of the strata of the glide, either rounded and forming a basal conglomerate, or partly angular, forming a breccia-conglomerate with the same significance. If the slidden mass is reassembled below wave base, the superincumbent beds are free from fragments, but the contact is discordant. As we have seen, the Wapsipinicon breccia has no such upper limit. It is covered neither by a basal conglomerate nor by a discordant stratum. The deformations which accompany it have no defined upper limit. They die out gradually.

The base plane of a slidden mass should be accounted for by the composition of the sediments involved. The plane of shear in a glide would hardly traverse well indurated limestones. Shale with superincumbent limestone furnishes an ideal base for a creep down slope of oceanic sediments or for a more vigorous debacle, just as it conditions many subaerial landslides. It is true that the Independence shale is involved in the Devonian breccia of Iowa, but it is not its base. In the northern counties the chief brecciated beds are underlying limestones, thoroughly indurated at the time, as seen by their intimate shattering. Everywhere the strains which gave rise to the brecciating process extended far below the level of the base of the Independence.

Excluding the hypothesis of subaqueous glide for the reasons just given, we reach by elimination the class of endolithic breccias. Of these we may dismiss expansion breccias as far too local, and founder breccias for want of evidence either of foundering or of conditions leading to it. There remains the species of endolithic breccia due to deformation, known as tectonic breccia. Three varieties of tectonic breccia are discriminated, fault breccia, fold breccia, and crush breccia, according to the manner in which deformation is accomplished. It is believed that a satisfactory explanation of the major brecciation of the Iowa Devonian is to be found in deformation by folding accompanied with some faulting parallel or nearly parallel with the bedding planes.

The association of brecciation with folding of the strata in the Iowa Devonian is of the closest (figures 72 and 73). The degree of brecciation is in proportion to the degree of folding and the brittleness of the rock. From a central zone where both folding, faulting and brecciation are most intense, all three effects decrease vertically in both directions, and finally die away. Where deformation is comparatively slight, brecciation is limited to areas, such as the bottoms of anticlines, where the change in direction of the fold is greatest and the

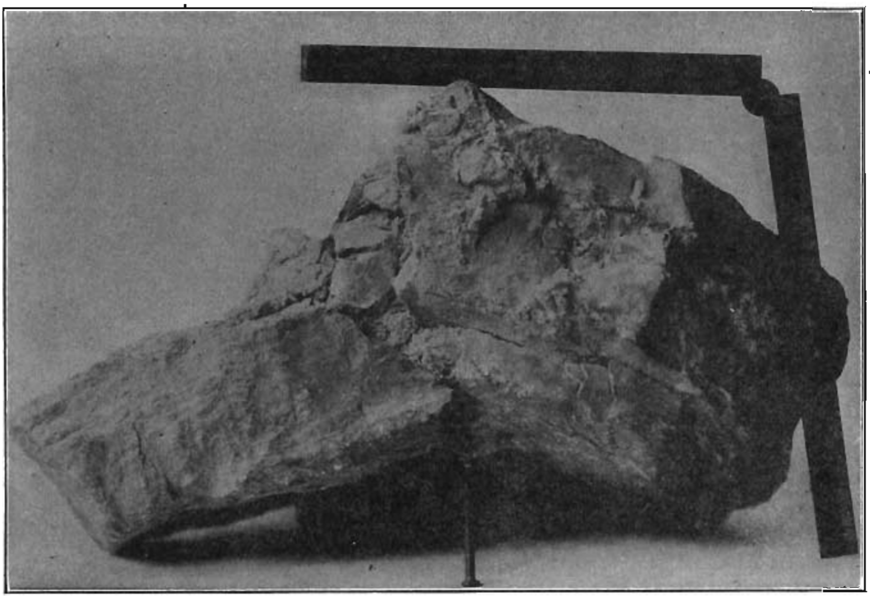


FIG. 72.—Faulted fold in a fragment of Lower Davenport limestone, Linn section, Linn county.

strain most severe. Every gradation may be traced from ruptured and shattered beds to rubble breccia in which fragments of other and different beds are intermingled, so that there can be no doubt that the disruption of the rock into both crackle and rubble breccia are due to the same internal strains.

The degree of disruption varies also inversely with the competency of the stratum. Thick beds of tough granular Upper Davenport limestone break into large blocks which grind upon each other and are more or less rotated and displaced accord-

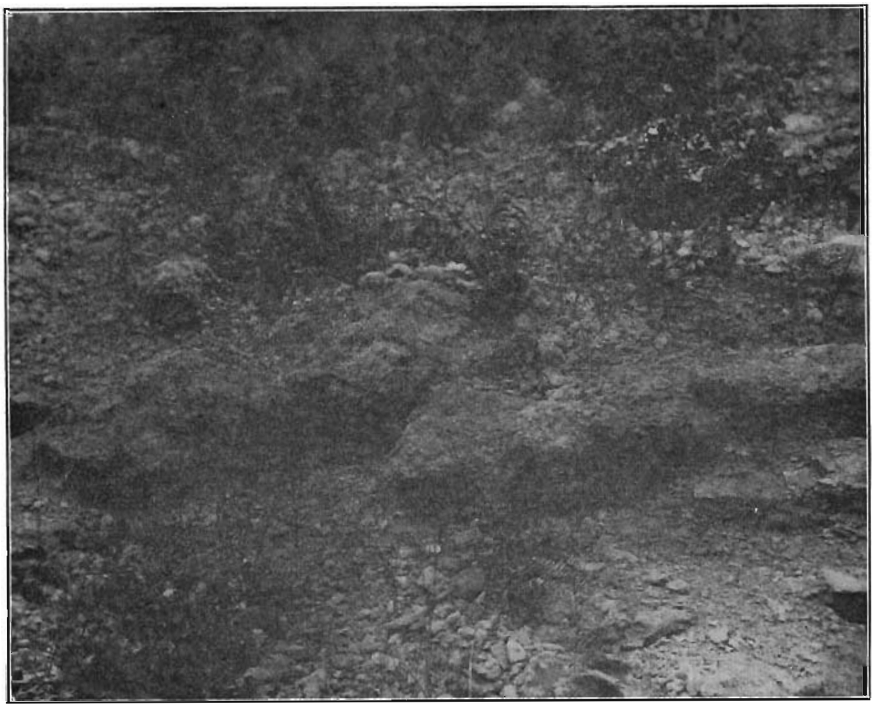


FIG. 73.—Faulted massive bed of Lower Davenport fragmental limestone. Base of Section E, Felton creek, Cedar Rapids, Linn county.

ing to the intensity of the stresses and the movement of the underlying beds.

The terrane of special weakness in the Wapsipinicon complex is clearly the Independence. At this horizon brecciation is most intense. This body of shales and impure limestones is locally crushed to fine detritus which serves as a matrix to the fragments of the inclosing limestones and of its own more resistant beds. Because of the yielding of these shales the limestones either immediately above it or below, or both above it and below, receive the maximum strains and are broken up more completely than those more distant. The horizon of the Independence is therefore the horizon of the major brecciation. The Lower Davenport is brecciated readily and in many places completely both because of its nearness to the Independence and also because of the brittleness of its thinly laminated limestones. It seems in places to have broken to pieces under strains hardly more severe than those necessary to brecciate beds of chert of equal thickness. Indeed, there are exposures, e. g., near Cedar Rapids and along the Mississippi north of Davenport, where the Lower Davenport is partly brecciated, while the more elastic Independence seems to have very largely escaped. The Otis shows compressive strains in its low undulations which are generally sufficient to shatter its calcilutites, but leave its basal granular magnesian limestones little affected, while the still deeper brittle Bertram beds are only intimately crackled.

The sharp angularity of the fragments of the breccia in all its zones also points to a tectonic origin (figure 74). Wear by ocean waves and streams after fragmentation is entirely precluded. The angularity of the fragments even offers some difficulty to the theory of fold and crush. The intimate commingling of beds suggests considerable horizontal movement in drag folds and along planes of shear under which more wear by mutual attrition might be expected than is actually to be observed.

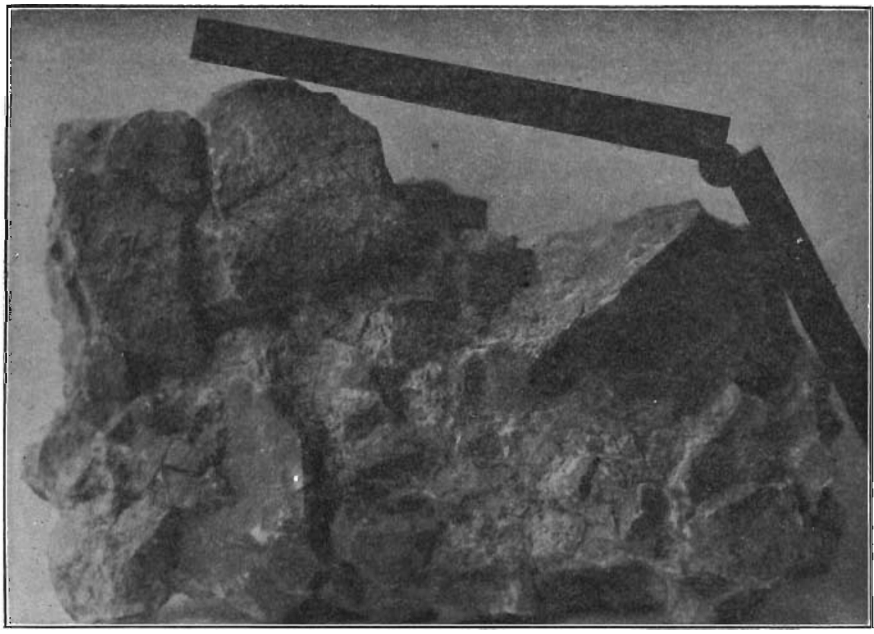


FIG. 74.—Breccia of Lower Davenport limestone fragments. Schmidt's quarry, Davenport, Scott county.

The date of a tectonic deformation is fixed as not earlier than the latest strata involved. As we have seen the strains of the major brecciation die out in the Cedar Valley limestone. Here and there, as at Osage, local folding accompanied by brecciation occurs well up in the Cedar Valley limestone, but these occurrences are so limited in the thickness of the rocks affected that they may perhaps be best explained by subaqueous glide. We may therefore conclude that at some time later than the deposition of the limestones of the lower life zones of the Cedar Valley, the Devonian terranes suffered deformation under lateral pressure. The Wapsipinicon complex was thrown into low troughs and arches. The Independence and the laminated calcilutites immediately adjacent to it formed a zone of special weakness and these terranes were crushed and brecciated and their fragments intermingled. The Upper Davenport and the *Spirifer pennatus* beds also were involved in the brecciation largely because of the incompetency of the supporting strata. It remains to be stated that the foldings of the various beds of the Wapsipinicon are accordant. This is best seen where the folding is least intense as at the Cedar Rapids quarries where a single set of low undulations involves both Otis and Independence, and along the cliffs of the Volga west of Fayette where the same accordance is seen between the Independence and the Davenport and Cedar Valley limestones. Where the stresses were more severe the Independence naturally yielded in more numerous and sharper folds than affect the more competent beds.

From the accordance just stated we may infer that the major brecciation was due to a single diastrophic movement dating not earlier than the Cedar Valley, rather than to a succession of deformations.

The Minor Brecciations

The theory of a single tectonic deformation occurring not earlier than the Cedar Valley stage accounts, as we have seen, for the larger phenomena of the Wapsipinicon breccias. But there remain certain outstanding facts still unexplained.

Davenport brecciations.—We may mention first a number of lines of evidence converging in proof of a minor brecciation of the Lower Davenport at a time about its close. Blocks of this limestone are found not infrequently which themselves are brecciated (figure 75). Such a block is composed of detached laminæ imbedded in a paste identical in texture and nearly of the same color as the fragments. The block itself, along with other blocks and fragments of the Lower Davenport, the Upper Davenport, and some of the stronger rocks of the Independence, is

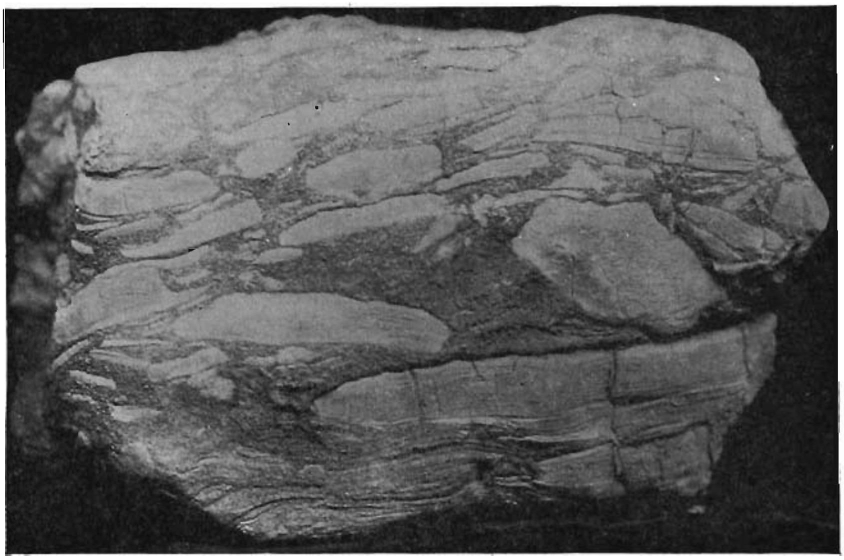


FIG. 75.—Complex brecciation, with parallelism of detached laminæ in fragment. Linn section, Linn county.

mingled with the Independence buff and earthy detritus. The major brecciation fully accounts for the breaking up of ledges of thoroughly hardened Lower Davenport and the incorporation of the blocks in the chaotic mass of debris. But the structure of the block can no more thus be explained than the intimate structure of a bowlder imbedded in till can be explained by glacial plucking. The brecciated structure of the block shows clearly that while the calcareous oozes of the Lower Davenport sea floor were still unset, laminæ already indurated were somehow broken up and mingled with the oozes to form new layers. In many cases the fragments of the laminæ retain much of their parallelism and their attitude suggests incorporation by mass movement rather than by ordinary sedimentary deposition of the fragments by wave and current. A few blocks show distinctly the effect of movement under pressure. In figure 76, from the Linn section, a mass of minute fragments of thin plates shows distinctly convergent and divergent lines on either side of a narrow gate between the ends of a broken thicker layer. The attitude of the laminæ strongly suggests movement under pressure through the gate.

The same radiation of lines of unequiaxed fragments of broken laminæ at a parting in a thicker layer was observed in fragments at Troy Mills.

Contemporaneous brecciation is seen also in fragmental saccharoidal limestones, which are found at a number of exposures of the Lower Davenport. Thus at Bettendorf the Lower Davenport limestone includes toward the base of the quarry section white saccharoidal limestone which contains sparse fragments of drab calcilutite whose fragmentation must have antedated the formation of the layer in which they are imbedded. Here the major brecciation left the strata undisturbed. The same phenomenon occurs in No. 7, Section A, Felton creek, Cedar Rapids (p. 520). At Section E on the same creek the lower zone exposed exhibits faulted and tumbled blocks of heavily bedded fragmental limestones whose fragments include several different lithologic types (p. 522). The breaking up of the original beds and the assemblage of the fragments in the heavily bedded limestones must have long preceded the major brecciation which faulted the ledges and left their tumbled blocks at the base of a breccia hodge-podge which includes fragments of the Upper Davenport.

In a number of blocks contacts are seen between the Upper and the Lower Davenport, which indicate a brecciation of the lower bed so nearly contemporaneous that the upper had not had time to become indurated at time of brecciation. Blocks indeed are sometimes found which show the lower surface of the Upper Davenport resting upon the parallel unbroken laminæ of the Lower Davenport. Here there is entire conformity.

But in other cases the upper layers of the calcilutite, the only ones present in the block, have been crackled, or more completely shattered and the paste of the Upper Davenport fills the fissures to some depth, as in figure 77. It will be noted in this

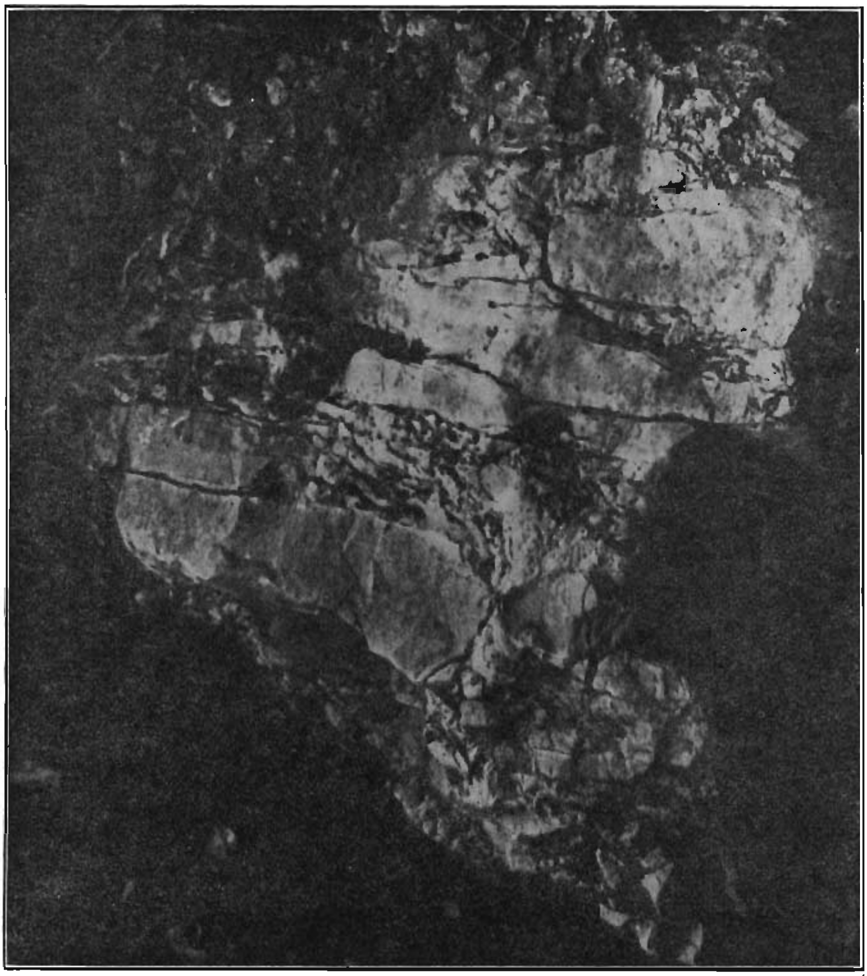


FIG. 76.—Fragment showing complex brecciation. Linn section, Linn county.

figure that the whitish calcilutite beneath is a mosaic breccia. The fragments largely match along their apposed surfaces and for the most part retain their original horizontality. Their position is not that of a bed of fragments assembled on the

FIG. 77.—Block of breccia. Section E, Felton creek, Cedar Rapids, Linn county. Light rock, Lower Davenport. Dark rock, Upper Davenport.

ocean floor by waves to be covered later by the gray limestone of the Upper Davenport. The brecciation of the calcilutite evidently did not precede the deposit of the darker limestone upon it. It occurred after the deposit of the basal layer of the Upper Davenport, but while the latter was still so pasty that it could be pressed in plastically among the fragments into which the brittle calcilutite underneath it had been broken.

From Davenport to Independence the basal layers of the Upper Davenport limestone or the blocks into which it has been broken contain sparse, small angular fragments of calcilutite of the Lower Davenport facies (figure 78). They do not form a sedimentary layer and they show no signs of water wear. They are distributed sporadically and set at all angles but blocks are seen on whose surfaces the fragments seem to have been impressed, leaving the surface of the block and that of the fragments flush.

These fragments are to be distinguished by their shape and attitude, if not microscopically by their structure, from the thin horizontally lying lenses of organic origin which have been already mentioned as occasionally found in the Upper Davenport.

Angular fragments of a stratum of limestone incorporated sporadically in the stratum immediately above are so rare among sedimentary rocks that some cause outside the ordinary course of sedimentation is to be inferred. A reef of calcilutite might perhaps be plucked by waves and its fragments mingled with a coquina depositing in deeper waters. But all of the phenomena just mentioned which prove an early fragmentation of the Lower Davenport limestone are associated together, and a common cause is to be found for all if possible. The incorporation of fragments is to be explained by the same cause as that invoked to explain complex brecciation. That this common

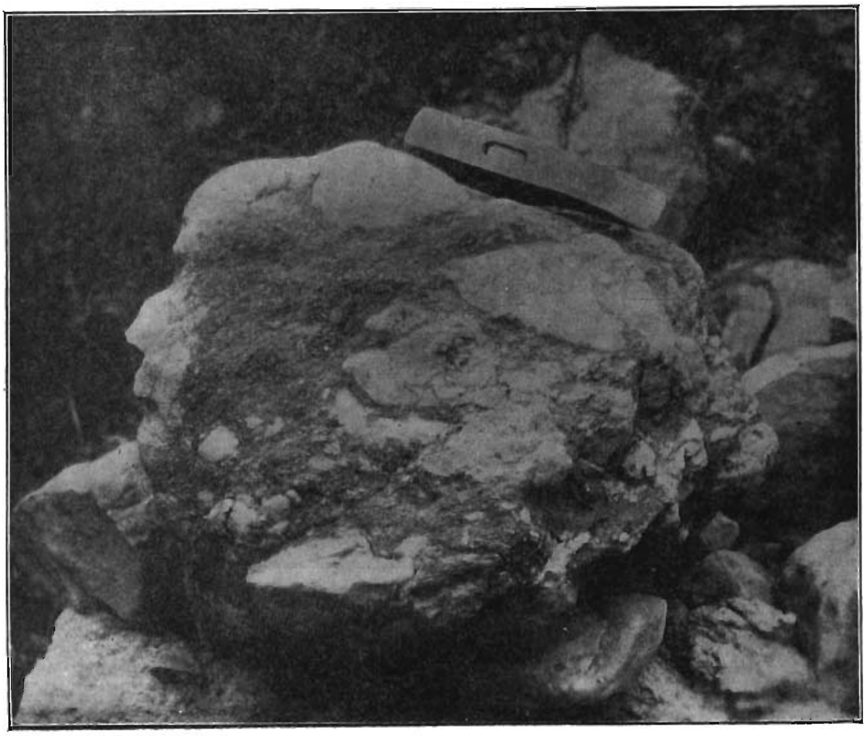


FIG. 78.—Block of dark granular Upper Davenport limestone with included fragments of Lower Davenport calcilutite. Aungst quarries, north of Vinton, Benton county.

cause is to be found in brecciation under internal strain is confirmed by an example of Schmidt's quarry, Davenport (figure 79). At one point in this quarry fragments of Lower Davenport calcilutite are more conspicuously intermingled with the Upper Davenport coquina than at any other locality known, and they range from the bottom of the beds to include the coralline layer near the top. At this particular point the beds are strongly deformed. A bed of Lower Davenport rubble breccia (A), two feet in thickness is pressed up at an angle of 40° against a mound of blocks of Upper Davenport with which fragments of the same calcilutite are intimately commingled both within and between the blocks. Evidently the incorporation of fragments

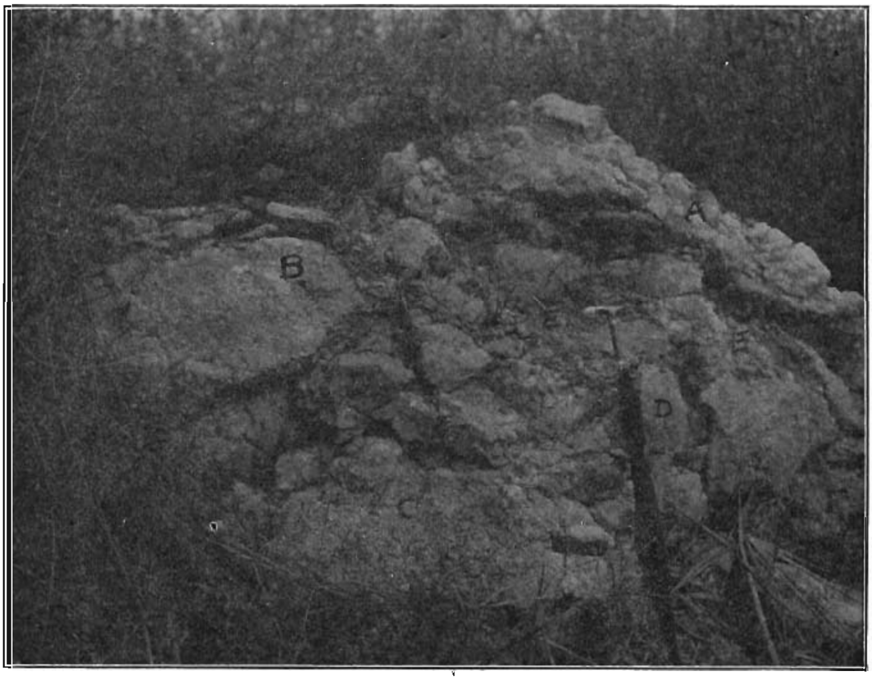


FIG. 79—Mound of Upper Davenport limestone, with small fragments of Lower Davenport calcilutite commingled. Schmidt's quarry, Davenport.

A. Rubble of small close-set fragments of Lower Davenport calcilutite in tilted bed two feet thick, matrix of chinkstone and like fragments.
B. Block of Upper Davenport limestone with a central horizontal zone in which small calcilutite fragments are sporadic. Corals are imbedded both above and below this zone.
C. Block in which Lower Davenport fragments are thickly inset in Upper Davenport matrix.
D. Blocks in which Lower Davenport fragments are very few.
E. Rubble breccia similar to A.
F. Rubble breccia of Lower Davenport fragments in a sparse buff matrix.

in the Upper Davenport and the deformation are due to a common cause and both took place while the Upper Davenport coquina was still plastic and the Lower Davenport calcilutite was firmly set.

An alternative hypothesis is that while the Lower Davenport fragments were incorporated in the Upper Davenport while the latter sediments were still unindurated, the deformation, the formation of the tilted bed of Lower Davenport breccia (figure 79-A) and of the breccia of the same type imbedded between the Upper Davenport blocks (E) occurred later, presumably at the time of the major deformation. Against this hypothesis stands the close similarity in size and facies of the fragments of the rubble breccia and the sporadic fragments within the blocks or deeply impressed upon their sides. The number of the imbedded fragments here in the Upper Davenport is entirely exceptional. Hence the improbability that precisely at the point where the Upper Davenport sediments had somehow become commingled to such an extraordinary degree with fragments of the Lower Davenport a later local deformation should have again crushed the Lower Davenport beds to breccia. While all the phenomena appear to be caused by a single deformation, it is possible that this deformation was that producing the major brecciation, *provided that the major deformation took place while the Upper Davenport sediments were still unindurated.* This is impossible if the Upper Davenport beds are to be dated by the First Fauna which they contain, that is, if they are contemporaneous with the *Gyroceras* beds of Linn and Buchanan counties. For the major brecciation certainly occurred in these counties after the arrival of the Fifth Fauna and the deposit of heavy beds of limestone upon the Upper Davenport. The hypothesis may be entertained if the Upper Davenport beds of Scott county were contemporary with the arrival in the north of the highest fauna which they include. To what extent the higher Devonian limestones of Scott county share the deformation of the Upper Davenport has not been ascertained. The Upper Davenport itself is largely in place. Contacts with higher beds are found only at a single locality—Schmidt's old quarry, where exposures of the higher beds are few and small and obscure. Against this hypothesis lies the fact that the inclusions of fragments of Lower Davenport calcilutite in the Upper Davenport beds is common throughout the Wapsipinicon area as far north as Independence, and it is probable that the inclusion took place under the same conditions and at the same time. In the northern counties this inclusion could not be due to the major deformation, since that took place long after the deposit of the Upper Davenport and its induration. The phenomena in question seen in figure 79 are therefore referred to the minor brecciation which occurred soon after the close of Lower Davenport time.

The entire group of phenomena seem best explained by a succession of subaqueous glides producing local mass movements of the sediments. Beds of more or less indurated rock would thus be broken up. Their fragments would be mingled with unconsolidated sediments and thus in moving on to form new beds would retain their angularity far more than if handled only by wave and undertow. Thus fragments of Lower Davenport calcilutite were imbedded in a paste of the same nature, and saccharoidal and other limestone fragments were completely commingled. Still later indurated beds of Lower Davenport were shattered and their fragments were taken up in glides of the Upper Davenport sediments which then formed the sea floor.

The crackle breccias into whose seams the Upper Davenport paste is injected, and the accompanying deformations, as at Davenport, suggest as an adequate cause of these glides a slight ridging of the strata under lateral pressure with perhaps a shattering by accompanying earthquakes.

Independence brecciations.—The evidence for contemporaneous Independence brecciations is somewhat different from that of the superior terranes. This evidence consists of fragmental limestones and local beds of breccia where the formation as a whole has been little disturbed. In the Chicago and North Western Railway quarries at Cedar Rapids, for example, the Independence contains a bed of fragmental limestone, a rubble breccia of small fragments with an hummocky upper surface (No. 8 of section, p. 518). The bed is formed in situ by the breaking up of a layer of laminated limestone, for in places there exists a complete lateral gradation into crackle breccia. So far, this might all be due to the strains of the major brecciation. But in places the fragmental layer graduates upward into soft buff earthy Independence limestone in which its fragments are sporadic. Fragmentation here took place before the deposit of the beds of the Independence which rest upon the fragmental layer. In places in the Independence zone of breccia fragmental limestones occur in blocks which are of characteristic Independence facies. Matrix and minute, in some cases sporadic, fragments are commonly much alike, although fragments of a different lithologic type may also be present. The matrix is not of chinkstone and calcite—the typical matrix of a bed of rocks crushed after complete lithification but not intermingled with other fragments. Even a calcite matrix in a fragment of breccia which itself is brecciated demands explanation. But in these cases the matrix appears to be of contemporaneous sediments and thus is proof of contemporaneous brecciation. Nor is it to be expected that the same stresses which crush a rock to minute bits will break the recemented layer into blocks and imbed them in very heterogeneous breccia.

Where the Independence is very little disturbed there are limited tracts which show complete brecciation. Such could be accounted for by the yielding of certain weak beds to the lateral pressure of the major brecciation while the stronger beds which inclose them took up the thrust without deformation. For example, at Cedar Rapids (No. 3, Section C, Felton creek, p. 521) we have a rubble breccia six feet thick intercalated in impure limestones which remain about horizontal. The beds have suffered lateral pressure, for the lower two and one-half feet of the thickly bedded limestone immediately above the breccia is bent to low undulations. The pressure was sufficient to brecciate thin-layered limestones and shales at this horizon, for the thick-layered limestone above the breccia is broken into large blocks at the axis of a syncline. So far there is nothing which cannot be explained by deformation at the time of the major brecciation. But the breccia contains a large variety of lithologic types. It seems improbable that six feet of the Independence or some commensurate larger vertical dimension, should contain so many types. Certainly no such variety is anywhere in evidence in Independence outcrops within equal limits. On the other hand a subaqueous glide collecting its material from different depths and spreading it in varying thicknesses could readily assemble all the debris of the breccia bed and upon it would be deposited the horizontal limestones of the section. Later, under the strain of the major brecciation, the limestone in immediate contact with the breccia was slightly bent and at one point broken.

To what extent the intermingling of different beds of the Independence and those of the Otis limestone seen in the Independence zone of breccia is due to contemporaneous subaqueous glides in Independence time is impossible to determine. The major brecciation wherever complete effaced evidences of former brecciations except that of brecciated fragments. The fragmental limestones of the Independence where of depositional

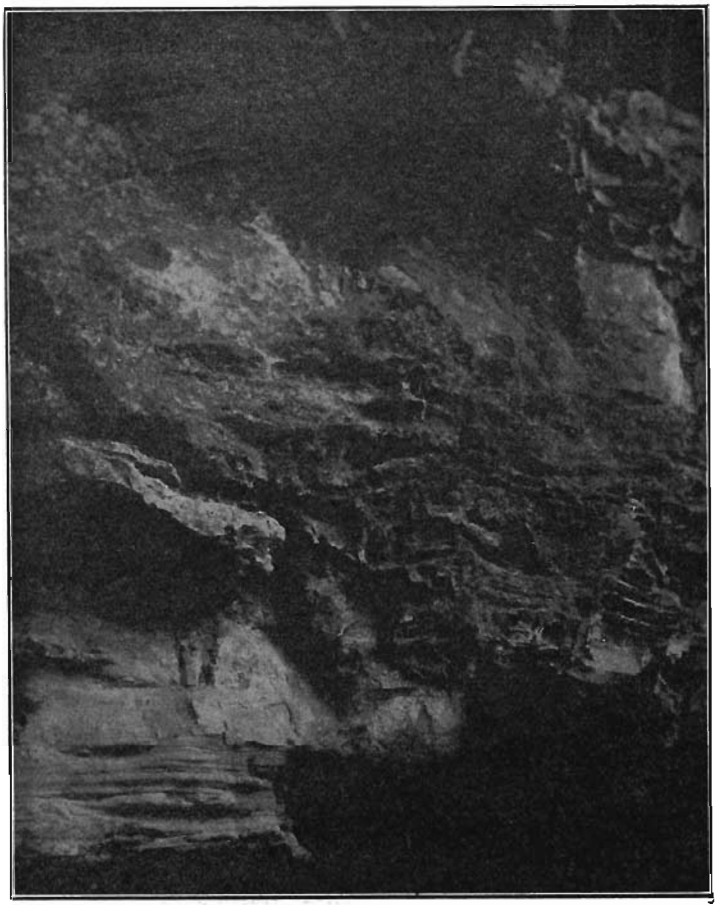


FIG. 80.—Portion of cliff, "Cedar Bluffs," on Wapsipinicon river about three miles southeast of Troy Mills, Linn county.

origin, either found now in continuous beds or in detached blocks imply no great disturbance at the time of their formation. They may be due to very local glides extremely limited in depth, or to the action of waves and tides on shoals. Fragmental layers of similar origin are to be found both in the Otis and in the Bertram limestones, but they require no further description than that already given in the sections of the outcrops of these formations.

The Independence in some places presents angular cavities due to the removal of fragments under weathering. Where the fragments were close set there results a reticulated surface as the matrix is left standing in narrow partition walls in high relief. Such surfaces are common on stacks and cliffs of the Monroe breccia of Mackinac Island, Michigan, and the adjoining shores of the mainland. In the Independence breccia they are seen along the Wapsipinicon river outcrops and are specially noteworthy at "Cedar Bluffs" three miles southeast of Troy Mills (figures 80 and 81).

SECTIONS OF THE WAPSIPINICON

Fayette County

In all the sections of the Wapsipinicon in Fayette county the breccias are very much alike, and with the exception of some minor phenomena all are referred to the major brecciation.

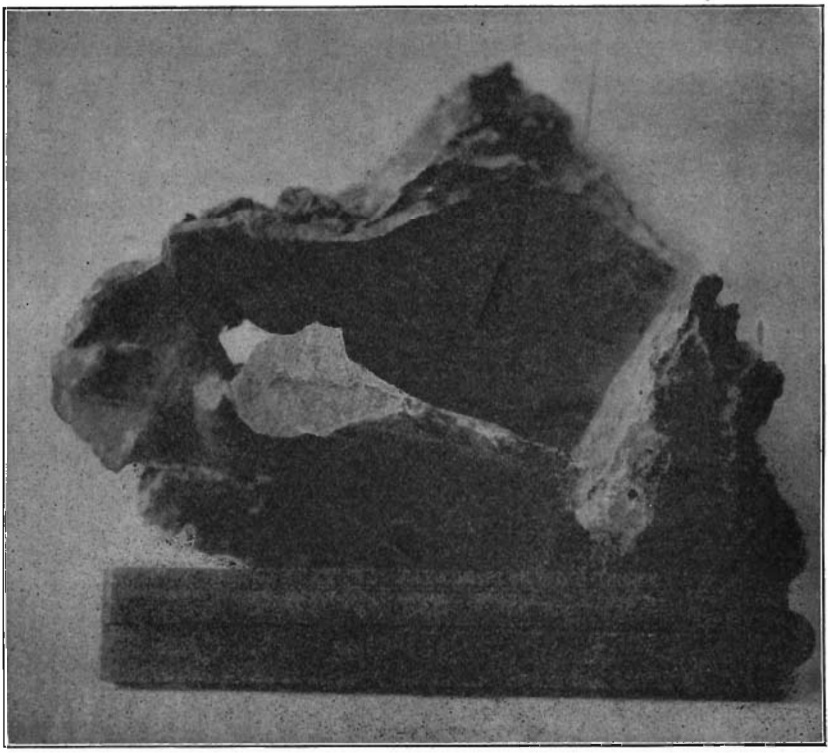


FIG. 81—Matrix from which fragments have been removed by weathering. Independence beds, on Wapsipinicon river at Cedar Bluffs, about three miles southeast of Troy Mills, Linn county.

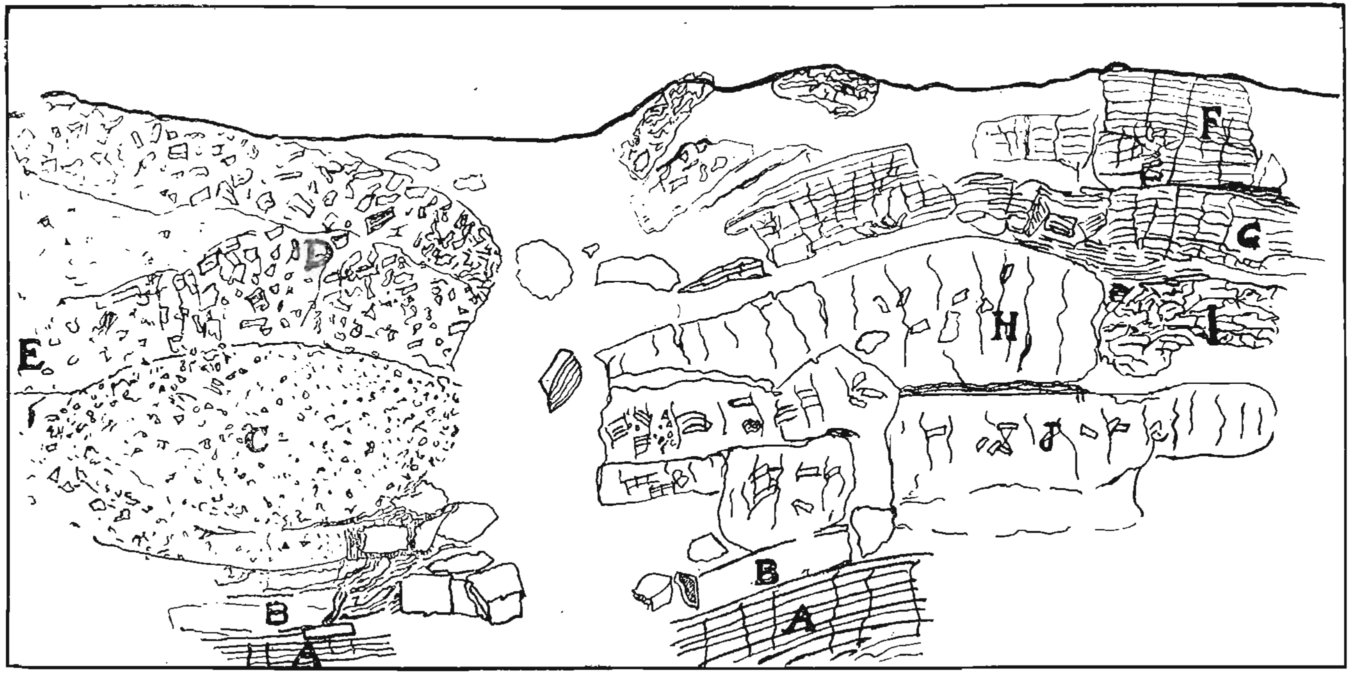
Under the horizontal pressure of this brecciation the strata adjacent to the weak zone of the Independence were all folded together. The shaly portions of the Independence were crushed to minute fragments and thick limestone beds were broken and displaced. The Davenport limestones generally were only gently arched but in places they were abruptly bent or were broken down into the zone of the Independence. The Otis calcilutites immediately beneath the Independence in many instances remained in place. Here they were crackled and in some cases broken to endostratic mosaic breccia passing into rubble. In places they were completely removed and broken up. The thinly laminated Otis beds beneath were in places heavily dragged along their upper margin where the Otis calcilutite ledge also was torn away, as at Eagle Point. Everywhere they were bent to low folds and crackled. They were also brecciated along joint planes and the axes of synclinal folds. The massive basal dolomites of the Otis, the Westfield phase, supported by the Niagaran strata, were strong enough to endure the strain without visible signs of deformation.

Fragmental limestones of the Independence seem to imply disturbed sedimentation during that period. Further brecciation during Independence time may be responsible for some of the sporadic breccia of this zone, but of this there is no clear proof.

Northern Sections.—The most northern exposure of the Wapsipinicon lies in the northwestern township of Fayette county on Crane creek, where a cliff of Devonian limestone thirty-five feet high embraces beds which range from the *Acervularia profunda* beds at the top to brecciated calcilutite beds at the bottom.[50] About a mile and one-half to the east of this section there is exposed on the bank of a small stream a succession of beds of which the two lowest are described as follows by Savage.[51]

	FEET
2. Bed of yellowish gray limestone in rather indistinct layers which are checked with numerous joints; containing *Productella subalata, Pentameralla dubia, Gypidula comis, Spirifer pennatus, Atrypa reticularis, A. aspera* var. *occidentalis*	8

[50]Savage, T. E., Geol. of Fayette County: Iowa Geol. Surv., Vol. XV, p. 511.
[51]Ibid, p. 509.



Section in City quarry, West Union, Fayette county. Outlines drawn from a photograph. A, Laminated Otis limestone, No. 2 of quarry section. B, Otis limestone, No. 3. C, Lens of broken Otis calcilutite continuation of H—J. D. Rubble of Otis breccia, many fragments of which are three to four inches in diameter. E, Rubble breccia of large Independence matrix with Otis fragments. F, Crackled laminated Otis calcilutite, in places a mosaic breccia. G as F, but somewhat more brecciated, faulted, and laminæ bent in places and rotated. H, Massive, finely crackled and some fragments displaced. I, Mosaic breccia. J, Ruptures chiefly vertical, mosaic-crackle breccia.

1. Bed composed largely of light colored shale in which a few irregular fragments of limestone are imbedded. Such fragments become more abundant in the lower part; talus-covered to bed of stream...................... 7

Although this and the preceding outcrops were not visited by the writer, we may easily identify No. 1 with the Independence zone of breccia since No. 2 is the horizon of the Upper Davenport.

West Union.—A quarry opened within the corporate limits of the city of West Union on the left bank of a small creek exhibits the laminated Otis limestone, somewhat folded and crackled; and resting upon it brecciated Otis calcilutites, and in places breccia of the Independence type.

1. The lowest beds now visible in the quarry are apparently the same as the more massive magnesian limestone seen at the bottom of the railway cut at Fayette and situated near the base of the Devonian.
2. Upon these lies thinly laminated nonmagnesian limestone about four feet thick. As at Fayette this member has been thrown into gentle undulations about six feet from crest to crest. The laminæ also show slight crenulations two or three inches in width, and are everywhere crackled. The mesh work is as fine as an inch in diameter and the ruptures are filled with calcite. Under the weather this bed breaks into thin ringing plates (Plate IX, A).
3. Number 2 is capped in entire conformity by a nonlaminated layer of pinkish calcilutite about six inches thick. The faces of the layer are smooth, but the layer is finely fragmental, especially toward the top, and is made of fragments two or three millimeters in diameter. It is thicker in places and thinner in others, and the upper surface is irregular (Plate IX, B).
4. At the north end of the quarry No. 3 is succeeded by Otis calcilutites about seven feet thick. These layers, like those below, are bent into low arches, but either because of stronger stress or of less ability to withstand it, they are partly brecciated. The layers retain for the most part their continuity. In part they are shattered to a mosiac breccia with close set vertical calcite seams and most of the small intercepted fragments still in place. A few, however, are rotated from their original position and here and there the laminæ are bent and faulted (Plate IX. F, G, H, J). At one point is seen a lens (Plate IX, C) two feet thick made of cemented fragments some of which reach an inch in diameter, although most of them are minute. At the left this lens and the layers above it break down into a rubble breccia, and the same is true of the entire thickness of the Otis calcilutite bed a few yards to the right. Here the Otis is completely broken up and mingled with buff Independence debris; and the latter is predominant in the center of the east side of the quarry (figure 82).

Here for a distance of a few feet the Independence rests directly upon the minutely fragmental layer which tops the thinly laminated Otis beds. Immediately to the right of the view ledges of Otis calcilutite again appear arching upward on the limb of an anticline which includes the entire vertical sequence of the quarry beds. The same removal of the Otis calcilutite ledges—or their lack of deposition—over extremely limited areas, and their replacement by a breccia of predominant Independence debris with some shaly beds remaining uncrushed is seen at Eagle Point near Fayette and in the quarries north of Vinton.

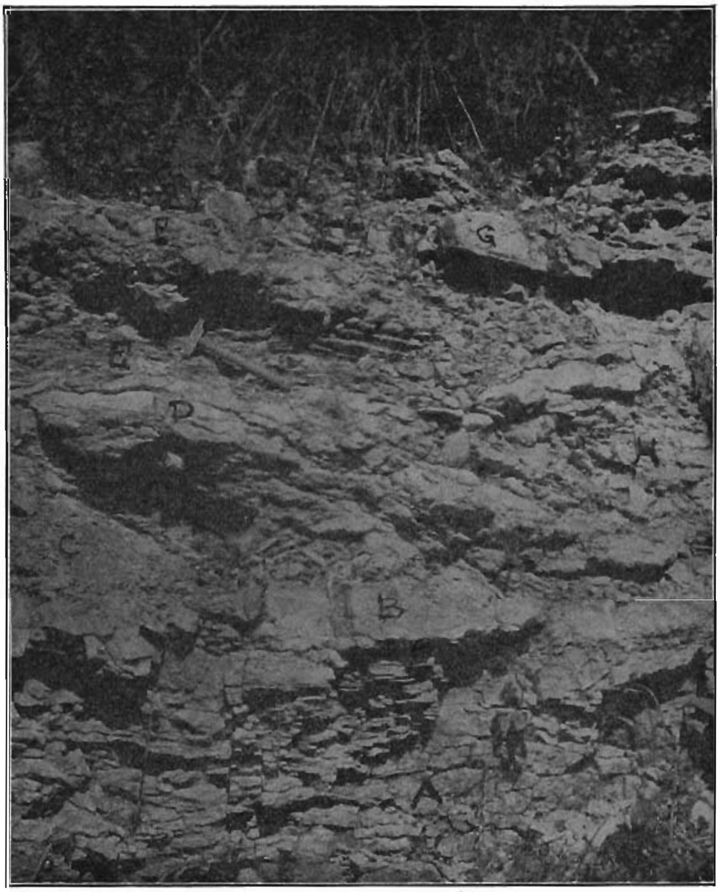


FIG. 82—H. Layer of calcilutite four inches thick underlain by a few inches of buff thinly laminated shale.

G. Breccia of Otis calcilutite fragments well cemented passing to the right into strata of Otis in place.

F. Breccia of Independence zone; much soft buff detritus, fragments mostly under three inches in diameter.

E. Shale, buff, thinly laminated. At right of hammer is an inch layer of minute fragments of calcilutite in a yellow matrix intercalated in shale.

D. Earthy buff limestone of Independence type, in part fragmental, over which the shale of E arches.

C. Breccia, Independence buff shale preponderating in fragments, with sporadic fragments of calcilutite which is more numerous to the left until in a few feet C graduates into a rubble breccia of Otis calcilutite.

B. Otis limestone, minutely fragmental upper layer.

A. Otis, thinly laminated beds, limestone plates bent and crackled.

Westfield Bridge Section, Fayette.—The upper part of this section is given by Savage as follows:

		FEET
13.	"Decayed zone composed of thin fragments, which in places are crowded with valves of *Newberria johannis.* Weathered individuals of *Acervularia profunda, Cystiphyllum americanum, Cladopora iowensis,* and Favosites sp. occur in the upper part	1
12.	"Bed consisting of fine-grained, yellow impure limestone in layers two to eight inches thick. The layers are somewhat broken, and contain the fossils *Atrypa reticularis* and *A. aspera* var. *occidentalis.* Small cavities lined with crystals of calcite are not rare	5½
11.	"Bed of yellow colored impure limestone in three layers. * * * besides the fossils in No. 12, *Pentamerella dubia* and *Spirifer pennatus* occur in the lower layer	7
10.	"Bed of rather massive yellowish gray limestone, less magnesian than the layers of No. 11 above, somewhat broken, but the large fragments lie in the general plane of the original layers; containing in the upper portion Favosites sp., *Pentamerella dubia, Gypidula comis, Spirifer pennatus, Atrypa reticularis, A. aspera* var. *occidentalis* and *Hypothyridina cuboides.*[52]	8"

The lower part of the section is supplied by the writer:

9.	Limestone, Independence, buff, unfossiliferous, in irregular layers, in part fragmental, fragments of buff limestone like matrix usually lighter in color, some of two or three inches diameter, but mostly minute. In places the layers are broken into fragments, some of two feet diameter, set at all angles. Some layers are arenaceous with white chert sand. Nodules of whitish crystalline silica occur. Considerable calcite is seen in interstitial seams. Upper surface somewhat irregular with depressions two inches in depth with a horizonal diameter of six inches, filled with the limestone of No. 10. In places upper surface is crossed by close unhealed fissures whose general direction is NNE. Bed graduates beneath into clayey shale	7
8.	Breccia, Otis calcilutite, Cedar Rapids phase, in highly irregular courses, in places massive, endostratic, fragments and matrix of light brown calcilutite weathering to gray. In places occur layers of laminated calcilutite, undulating but not brecciated	10
7.	Limestone, Otis, gray, fine-grained, weathering to thin plates, which on dislodgment fall with a submetallic tinkle	11
6.	Limestone, buff, effervescence rapid in cold dilute HCl; laminated, with some brownish partings. Upper surface irregular, graduating in places laterally into the thin plates of No. 7. In two layers	3
5.	Limestone, blue-gray where unweathered; in two irregular layers, the upper 1½ feet thick, for the most part massive, but in places laminated to one-half inch; effervescence slow. Distinguished by angular fragments of white chert of which few exceed three or four mm. in diameter, giving to certain bands the appearance of	

[52]Savage, T. E., Iowa Geol. Surv., Vol. XV, p. 502, Des Moines, 1905.

	a chert sandstone. With argillaceous partings from beds above and below....................................	2
4.	Dolomite, gray, highly arenaceous with minute angular bits of cryptocrystalline silica and rounded grains of fine quartz sand....................................	3
3.	Dolomite, yellow-gray, upper 1½ feet massive, lower foot in layers from ½ to 3 inches. Thin shaly partings in places between the two members. Highly arenaceous with coarse angular chert sand......................	2½
2.	Clay, greenish yellow, plastic, gritty........ ....1-12 to	2-3
1.	Dolomite, Niagaran, yellowish, upper surface irregularly curved; chert nodules abundant; small cavities numerous; layers up to five feet in thickness. Fossils identified by Savage as *Lyellia americana, Favosites favosus, Halysites catenulatus, Leptaena rhomboidalis.* To level of Volga river	15½

The basal bed of this section, No. 1, was recognized as Silurian by McGee[53] and was proved by Savage to belong to the Delaware stage of the Niagaran.[54]

The beds of arenaceous dolomite which rest upon No. 1 resemble it somewhat in general facies, but with some marked distinctions. They are separated from it by shaly partings along an irregular surface which simulates or constitutes a parallel unconformity. They are unfossiliferous. The chert which they contain is in the form of layers of sand and gravel instead of in nodular concretionary masses. They thus represent a wholly different type of sedimentation from that of the quiet waters and coral dotted sea floor of the Niagaran as preserved in the fossiliferous dolomite of No. 1. The cherty nodules of the Niagaran had now been broken up by long weathering during an erosion interval or by the attrition of waves upon the shore. The minute fragments to which the cherts had been reduced were swept by comparatively powerful currents and mingled with limy oozes to form Nos. 3, 4 and 5 of the Westfield section. These beds are regarded by Savage as belonging to the Niagaran. But although they resemble the Niagaran in their dolomitization, they are here assigned to the Devonian because of their arenaceous content which gives them the characteristics of a basal conglomerate, which derived its material from the obdurate constituents of the subjacent stratum. Similar beds occur at the same horizon in Bremer county (p. 470). The contact between the Silurian and the Devonian is thus held to occur at the summit of No. 1.

[53]McGee, W J, Pleistocene History of Northeastern Iowa: 11th Ann. Rept. U. S. G. S., p. 315, Washington, 1891.
[54]Savage, T. E., op. cit., p. 502.

Number 7 is unquestionably Devonian and No. 6 belongs with it structurally and because of its small magnesian content. Number 8 is the zone of brecciated Otis calcilutites, and No. 9 is the Independence.

A section a short distance east of the center of section 5, Westfield township, shows the same contact relations.[55]

	FEET
7. "Bed composed of fragments of drab-colored fine-grained limestone, imbedded in a matrix of calcareous material which also is fine-grained in texture, but lighter in color, without fossils. The layers show slight undulations....	12
6. "Bed composed of fine-grained yellowish colored limestone which is very finely laminated; upon weathering the material splits along the lamination planes into thin fissile fragments; without fossils....................	9
5. "Irregular band of yellow colored dolomite, coarse-grained in texture, in places appearing somewhat arenaceous; nonfossiliferous	1½
4. "Bed of yellow impure dolomite in layers four to eight inches thick bearing some chert and containing *Favosites favosus* and *Halysites catenulatus*......................	3"

Number 4 is stated to rest on beds of fossiliferous Niagaran limestone containing chert concretions and aggregating about eight feet in thickness. Number 7 of this section is identical with No. 8 of the Westfield Bridge section and both belong to the Otis calcilutite zone. Number 6 of this section is the same as the bed of calcareous plates of the Westfield Bridge section, No. 7, which also is referred to the Otis. Number 5, which Savage includes in the Niagaran, is placed by the writer in the Devonian for the reasons stated regarding Nos. 3, 4, and 5 of the Westfield section.

Cut of the Chicago, Milwaukee and Saint Paul Railway, Fayette.— This rock cut, 600 feet long and 50 feet deep, presents a section quite similar to that of the Westfield bridge. Owing to the nearly vertical walls it is less accessible for close study and it does not reach to the Niagaran horizon. The description of the three upper beds is abridged from Savage.[56]

	FEET
7. Limestone, fine-grained, yellow, impure, in somewhat shattered layers three to nine inches in thickness, containing *Atrypa reticularis* and *A. aspera* var. *occidentalis*......	11½
6. Limestone, yellow, magnesian, similar to No. 7, in imperfect layers one and one-half to three feet in thickness, containing *Gypidula comis*, *Spirifer pennatus*, and the Atrypas	8½

[55]Savage, T. E., op. cit., p. 497.
[56]Savage, T. E., Iowa Geol. Surv., Vol. XV, pp. 506, 507.

5. Limestone, gray, somewhat fractured, yet not so thoroughly brecciated but that the original layers can be recognized. The large fragments contain *Favosites placenta*, *Stropheodonta demissa*, *Pholidostrophia nacrea*, *Productella subalata*, *Orthis iowensis*, *Gypidula comis*, *Spirifer pennatus*, *Atrypa reticularis*, *A. aspera* var. *occidentalis*, *Athyris fultonensis*, and tritors of *Ptyctodus calceolus*..10

The lower layers are as follows, as studied by the writer:

4. Breccia, the Independence zone, No. 9 of the Westfield Bridge section, weak, retreating under weathering beneath the cornice of No. 5. Predominant material: soft, yellow calcareous shale or argillaceous limestone, and bluish shale, the former in broken and tumbled blocks set at all angles or in certain tracts largely still in place. Many of these limestone blocks are minutely fragmental with fragments of the same texture and composition as the matrix. Spheroidal weathering gives the appearance of coarsely conglomeratic structure in places. Characteristic siliceous nodules are found here and there. Structure lines are marked by low arches a few feet wide which consist of dislocated blocks, by a tilted stratum, or by a string of blocks which in places lie at angles as high as 35°. The zone itself is disposed in broad arches which reach 140 feet in diameter. The upper surface is fairly even, but in a few places rotated blocks of the Davenport limestones are seen to be broken down into the Independence zone in masses four or five feet thick. With this exception the Davenport limestones do not mingle with the breccia beds beneath and the breccia is, therefore, unfossiliferous. The lower surface is extremely irregular, giving large variation in thickness of the zone. The broad arches above mentioned thin at top to two or three feet and thicken to ten feet and more at base of the limbs. The zone also thickens where the breccia beneath it drops abruptly to the west by a fault-like offset. The Independence may interrupt and displace the breccia beneath and rest for a short distance, as at the limb of an arch, directly upon No. 2. Blocks of Otis calcilutites are intermingled in many places along the base of the Independence zone and where the Otis ledges are most completely shattered small fragments of the Otis are set in an Independence matrix.

3. Breccia, Otis calcilutite zone, No. 8, Westfield Bridge section. Where brecciation is most complete this bed forms a rubble of well cemented small quadrangular fragments whose colors vary from whitish to light drab, purplish and brown. Some fragments are laminated, others not, but all are of fine grain and some of lithographic texture and marked conchoidal fracture; matrix fine, of buff and bluish Independence detritus, and of gray Otis chinkstone. Fragments are left in relief on weathering.

   Where brecciation is somewhat less complete there obtains a rubble breccia of fragments as before with a sparse chinkstone and calcite matrix. Where the strata have not been completely broken up and their fragments intermingled, they are shattered to a crackle or mosaic endostratic breccia with a calcite matrix. Tracts are numerous, especially at the base of the zone, where

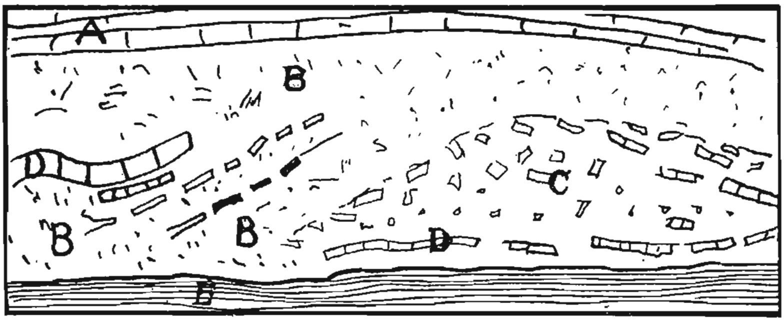


FIG. 83.—Section in the railway cut at Fayette, Fayette county, on the south side west of the bridge. A, Davenport limestone. B, Independence zone of buff shales and limestone, brecciated. C, Breccia of Otis calcilutite. D, Detached and broken layers of Otis calcilutite. E, Otis thinly laminated limestone.

the layers remain largely in place. At the west end of the cut the basal stratum can be traced with some interruptions for seventy feet.

In the midst of the rubble breccia of this zone and reaching into the Independence zone may be seen layers of calcilutite a foot thick and continuous for as much as ten feet, tilted or flexed but only a little broken. These layers and similar strings of dislocated blocks mark parallel structure lines in the breccia accordant with its broad arching and also smaller flexures of as little as two or three feet radius (figure 83).

The lower limit of the zone is fairly even and regular, resting on the unbroken but gently undulating surface of No. 2. But in places the breccia of this zone invades No. 2 in angular depressions a foot or so in depth, beneath which No. 2 is apt to be brecciated itself along a narrow inclined zone. At two points thirty feet apart, No. 2, here undisturbed, is sharply cut off at troughs of synclines to a depth of about two feet (figure 84). Above one of these offsets the Independence zone itself is offset about eight feet.

The upper limit of the zone is highly irregular from intermingling with the Independence and from broad accumulations in convex masses eighty feet and more in diameter, where the Otis attains its maximum thickness and over which the Independence arches and thins as mentioned above.

The breccia is well cemented and by differential weathering projects beyond the inclosing beds. Over No. 2 it forms a cornice which in places overhangs as much as three or four feet.

2. Limestone, Otis, light yellow-gray, rapid effervescence in cold dilute HCl, finely laminated, weathering to thin plates. Laminæ often close and delicate. In places they include very thin brown partings as many as eighteen to the inch, which are due to clayey admixture. Strata gently flexed. Some of the most marked synclines measured have a depth of a foot or a foot and a half with a width of nine or twelve feet measured from the crest of the including anticlines. Joints run N. 60°E. and

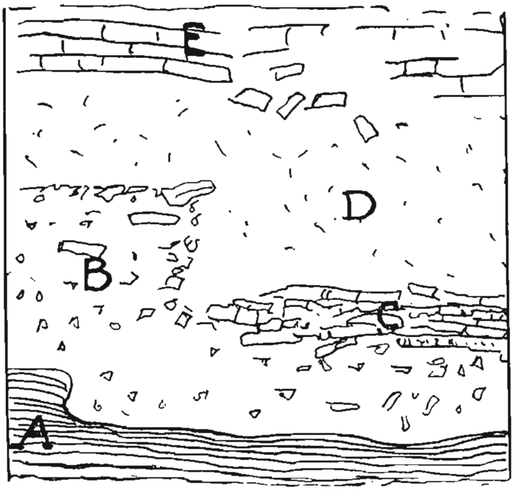


FIG. 84.—Offsets in the railway cut at Fayette, Fayette county. Scale, one inch equals twelve feet. A, Otis thinly laminated beds. B, Rubble breccia of Otis calcilutite, small close set fragments. C, Ledge of Otis calcilutite. D, Independence buff breccia. E, Davenport beds.

E. 15° S. Laminæ traversed with numerous narrow close-set vertical fractures healed with calcite; some of the larger fractures noted trend about north and south (figure 57). In limited areas mostly at axes of synclines the laminæ have been broken into a mosaic breccia whose apposed fragments are tilted at all angles. Small thrust faults with a throw of a foot or so occur.

The upper layer of No. 2, differs from those below as at Vinton and West Union. At the west end of the cut it is seen to be six inches thick and fragmental with minute sporadic fragments of the same nature as the matrix rock. It is overlain in places with a shaly breccia from one to three inches thick upon which rests the calcilutite breccia of No. 3.

The upper surface of No. 2 exhibits irregular breaks a foot or two in depth filled with breccia composed of laminated fragments of No. 3 set in a sparse interstitial, rather hard, buff matrix. There are other angular depressions filled with breccia largely but not wholly composed of fragments of No. 2........................10

1. At east end of cut. Limestone, Otis, light buff, granular, effervescence slow in cold dilute HCl, irregularly bedded in courses a foot and a half in thickness, sparingly vesicular, some ellipsoidal cavities reaching a diameter of 8 mm.; in places contains minute brown spots. In a few small areas contains sparse small rectangular fragments of laminated limestone of same general facies as the matrix rock. Lenticles occur of white intercrystallized quartz and calcite interleaved at edges with laminæ of buff limestone. At one place at base of cut on the north side this stratum graduates into a soft bluish argillaceous rock and at one point becomes fragmental with numerous small chert fragments and fragments of blue calcareous shale and buff limestone set in matrix of the

buff limestone. This stratum graduates into No. 2, by lenses of the massive rock up to six feet in diameter which appear along the base of the laminated limestone.. 3

No. 1 is referred to the Niagaran by both McGee and Savage, doubtless because of its magnesian content. But in general facies, in the character of its vescicles and siliceous inclusions and in its graduation into stratum No. 2, it appears to the writer to be clearly Wapsipinicon. The Niagaran, as is seen in the Westfield Bridge section, lies some distance below the base of the rock cut.

Eagle Point Section.—The most accessible exposures of the brecciated beds of the Devonian at or near Fayette are to be found one and one-half miles west of the town at Eagle Point and the long line of cliffs on the opposite bank of Volga river in the northern half of section 31, Westfield township. These cliffs measure sixty or seventy feet in height according to Savage, and by far the larger part of this height belongs to the Cedar Valley and the Upper Davenport stages. The zone of brecciation as seen at the base of the cliffs comprises about twenty feet of Otis and Independence beds. The section of the south face of Eagle Point is as follows:

	FEET
5. Limestone, Cedar Valley and Upper Davenport. (F. figure 85.)	40
4. Limestone, unfossiliferous, fine-grained, resting directly and apparently conformably on vertically shattered rocks of No. 3. Upper foot light brown, massive, with obscure lamination, lower six inches gray, with undulating narrow brownish bands	1½
3. Breccia, Independence zone (C, figure 85), soft, argillaceous, buff with blue-gray cores. Courses arched but otherwise little disturbed at top. In central part the layers are broken into blocks which still preserve something of their parallelism and horizontality. The lower part of this member is pretty thoroughly brecciated. The layers in places form endostratic breccia composed of minute angular fragments of soft buff limestone similar to matrix. Sporadic small quadrangular fragments of brown and gray calcilutite occur in restricted areas. Some quartz and some pyrite nodules of one or two inches diameter are found. Blocks of calcilutite, one foot in diameter, occur sporadically and set at all angles. Midway in this breccia, on the west face of the cliff, a bed one foot wide of brown finely laminated calcilutite extends for eight feet horizontally and is continued by two dislocated and somewhat rotated blocks. This bed is entirely similar to the brown calcilutites of the subjacent member. It ends abruptly with vertical fracture	

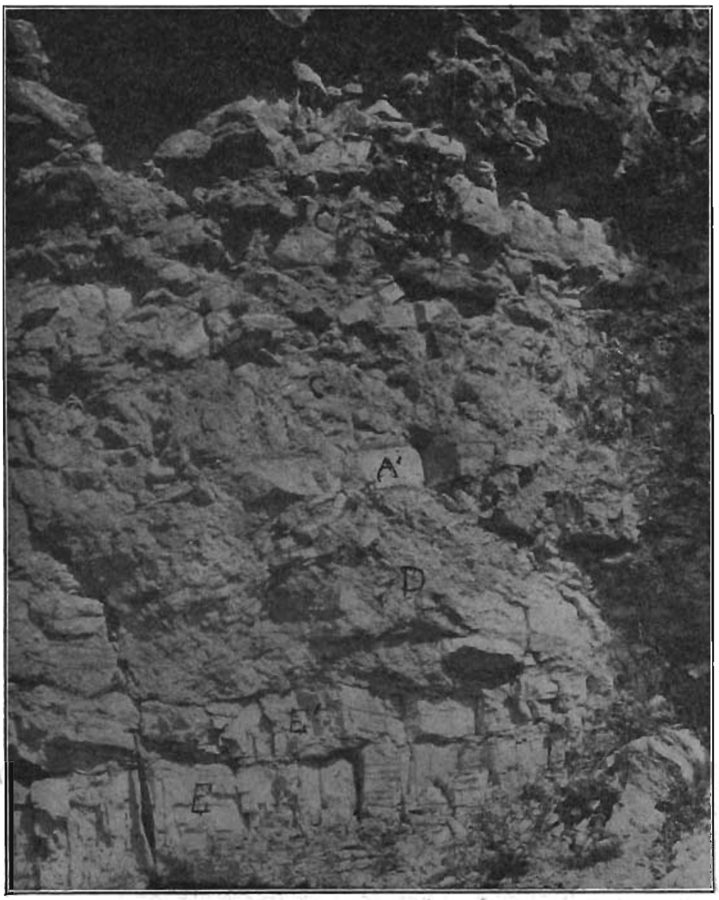


FIG. 85.—Portion of the south face of Eagle Point near Fayette, Fayette county, as high as the base of the Upper Davenport limestone.

planes abutting on the soft buff limestone of No. 3, and not with the thinning edges of a lens deposited in place.

The juncture of this member with the arching cornice of the more resistant No. 4 is fairly even. At its base it breaks down deeply at several points along narrow vertical planes of fracture into the zone beneath........ 9

2. Breccia, Otis calcilutite zone (D, figure 85), fragments predominately of calcilutite, the fragments of a layer often preserving some of their initial attitude. The upper limit of this member is marked by an undulating line of blocks about one foot thick evidently belonging to a single layer, the general dip of the line being about 8° W (A, figure 85). On the west side of the cliff this layer forms a gentle syncline brecciated at the axis but elsewhere well-nigh continuous. The rock

of this layer is a light gray calcilutite with close and coherent laminæ. In places the laminæ show sharp flexures with narrow downfolds and upfolds four inches wide. Here the laminæ are broken and independently flexed within the limits of the layer. This layer in places contains many spheroidal cavities one or two millimeters in diameter filled with soft white calcium carbonate, probably the moulds of foraminifera. On some surfaces these are so close as to become confluent.

For three or four feet below the layer just described the breccia is mostly a rubble (D, figure 85), but many of the larger fragments, which reach a length of half a foot, preserve traces of flexures antecedent to their dislocation. The matrix of this breccia is of chinkstone, and also of buff soft granular rock with sand of white chert. Some fragments are, like the matrix, composed of buff cherty limestone. Beneath this breccia are calcilutite layers which have been flexed and broken and whose dislocated blocks still retain something of the gently bent planes of bedding. The uppermost of these layers (H, figure 86), about six inches thick, is traceable for eighteen feet along the south face of the cliff. At top this layer is a light brownish gray calcilutite, in places finely fragmental with matrix of the same rock as the

FIG. 86.—The base of the south face of the bluff at Eagle Point near Fayette, Fayette county, showing the folding and disruption of the upper part of the thinly laminated limestone (E).

minute fragments. At bottom it is a drab or buff laminated rock sandy with much angular chert and well rounded grains of clear quartz. The two facies represent continuous deposition, but under stress the upper part of the layer has been shattered and recemented. The basal portion of No. 2 is a breccia of small fragments of broken calcilutite laminæ in a clayey and sandy matrix, in thickness ranging from one to twelve inches. Where thinnest it becomes a yellow shale...5 to 6

1. Limestone in thin calcareous plates, enquivalent to No. 2 of the railway cut and to No. 7 of the Westfield Bridge section. It consists of the following members:
   d. At top folded, faulted, broken into angular blocks up to two feet in diameter, tilted at all angles, lower surface of this zone of brecciation in undulations with a length of four feet and a height of three inches. At east end this bed is only slightly disrupted. E, figures 85 and 86) 1 2-3
   c. An undulating, lenticular layer of buff limestone associated with clay.................................... ¼
   b. A layer obscurely laminated, finely fragmental, made of bits of broken laminæ a fraction of an inch in diameter in matrix of same.......................... ½
   a. Layers slightly undulating but unshattered........ 5

At the long line of high cliffs on the south side of Volga river a few rods upstream from Eagle Point the Independence and the Otis calcilutites together with the superjacent limestones are all gently arched together. The thinly laminated beds of the Otis, No. 2 of the Fayette railway cut section, appear only in places for a foot or two at the base of the section.

The Otis calcilutites are for long stretches little disturbed. Their thick layers may be shattered to a mosaic breccia but each bed retains its continuity unbroken. The upper bed, here traceable for long distances, consists of remarkably pure calcilutite a foot or a foot and a half thick. Close set laminæ are disposed within the layer in a peculiar way—in sharp narrow synclines and broader flatter anticlines. This layer is especially characterized also by spherical cavities a millimeter or so in diameter taken to be of foraminiferal origin. This layer is capped in places by three or four inches of minutely fragmental calcilutite. The thickness of the Otis calcilutite zone is about five feet, corresponding thus in thickness as in character and brecciation with the same beds at West Union, Fayette, and Vinton.

The Independence zone of breccia reaches a thickness of about fifteen feet, but in many places is much thinner. Its contact with the Otis is very irregular where the latter is displaced and broken up. Thus one may see where the upper layer of the Otis with its spheroidal cavities, tilted, and in part crushed to rubble, abuts on buff Independence breccia, and where the Independence breccia thrusts tongues of buff detritus three feet long diagonally into the Otis calcilutite rubble, the boundaries of these intrusions being parallel with the arches or overthrusts of the breccia. But where the Otis is not displaced the line of contact with the Independence breccia is even.

Where the Otis is undisturbed there is a notable absence of strings of blocks of calcilutite in the Independence. On the other hand, where the Otis calcilutites are disrupted and displaced large blocks of calcilutite characterize the Independence zone. The inference is obvious that the presence of these blocks in the Independence zone is due to thrust and shear which has intermingled the disrupted ledges of Otis calcilutite with the buff shaly detritus of the Independence.

As at Vinton and at the Linn section, large blocks of limestone in the Independence are in some instances accompanied by blue fissile shale a few inches thick, alongside the edges of a block, with the laminæ inclined at high angles—70° in one instance—parallel with the side of the block.

Where the Otis is least disturbed, the Independence above it consists of massive buff shaly detritus. Sufficient is left in place to display spheroidal weathering and the rounded cores might on casual inspection be mistaken for rounded included breccia fragments. In blue shale, however, the rounded masses are always blue, while all buff masses are sharply angular. In buff shale there occur rounded buff masses identical with the rock, while angular fragments of like and unlike rocks also are found. In comparison with other sections the amount of shale present and its continuity is very marked. But even where apparently it is little disturbed it contains sporadic fragments of soft buff and bluish limestone and of fine-grained hard limestone, all sharply angular. These included fragments may be sparse or thick enough to form rubble breccia. Much of the matrix rock is made of minute broken particles rather than of sedimentary granules. Sporadic fragments are noticeable not only where the shale is massive, but also where it has a lumpy structure approaching a thin irregularly lenticular lamination. Siliceous nodules are here rather numerous, but commonly are less than an inch in diameter. The breccia is sufficiently well cemented that fragments can not easily be detached without a hammer. Here the general facies is that to be expected from a local subaqueous glide.

The upper part of the Independence zone shows buff soft limestone in irregular but unbroken courses above which appears the even cornice of the Davenport limestones.

Bremer County

A low dome which brings the Niagaran limestone to the surface as an inlier, far within the Devonian area of outcrop, lifts also the Wapsipinicon to view in several outcrops along Cedar river and its affluent creeks southeast of Waverly. These are the most northern exposures of the Wapsipinicon noted in the reports of the Iowa Geological Survey in the valley of the Cedar. To the south, in Black Hawk county, the Wapsipinicon sinks below the surface again to emerge as the country rock in Benton county north of Vinton.

In Bremer, as in Fayette county, the thickness of these beds is much abridged from that in the counties to the south and southeast. The first incursions of the Devonian sea transgressing upon the Niagaran old land are recorded, as in Fayette county, by a basal conglomerate whose arenaceous content includes well rounded grains of clear quartz sand whose source may be referred to the waste of Ordovician and Cambrian sandstones outcropping to the north, and also angular bits of flint which could be supplied by the chert nodules of the Niagaran.

As in Fayette county, the uppermost stage of the Niagaran, the Gower limestone, is wanting and the basal conglomerate rests directly upon the Hopkinton. The gap between the Silurian and the Devonian is further widened by the absence on the Devonian side of the Bertram limestone and the basal magnesian beds of the Otis—the Coggon phase. Immediately on the basal conglomerate rest the Otis calcilutites. These reach a thickness of fifty feet in places. The few incomplete outcrops show characteristic structures in both massive and laminated fine-grained limestones, which in places are mottled and fragmental. Some disturbances of sedimentation, or stresses experienced while the layers were yet plastic are thus recorded. But, as a whole, the Otis remains much as it was laid during a normal course of sedimentary deposit.

The Independence probably is thin, as in Fayette county. Only two unsatisfactory outcrops occur. Both show thorough brecciation, and the included fragments suggest, but do not prove, that the brecciation is of that which we have designated as the major brecciation and was of the tectonic type, commingling fragments of the Upper Davenport with the calcareo-argillaceous material of the Independence.

The Lower Davenport in two small exposures shows a mosaic-rubble breccia with which the Independence and higher fossiliferous beds are not commingled. Parallelism of detached laminæ imbedded in a limestone paste of the same nature as the fragments indicates contemporary brecciation.

The massive beds of the Upper Davenport with the *Gyroceras* fauna do not appear. The *Spirifer pennatus* fauna holds the basal fossiliferous beds of the Devonian. It has been seen in excavations near the mill dam at Waverly and in the bottom layers of the quarries north of town. The species collected here are *Spirifer pennatus, S. bimesialis, Atrypa reticularis* (large), *A. aspera* var. *occidentalis* (coarse ribbed), *Schizophoria iowensis, S. macfarlanei, Cyrtina hamiltonensis,* and *Productella subalata.*

QUARTER SECTION RUN SECTION

(Southeast quarter of the southwest quarter of section 20, township 91, range XIII west).

		FEET
5.	Limestone, upper part in one massive layer four feet thick, lower part in layers about eight inches thick; mottled, light brownish drab weathering to lighter gray, slightly vesicular, surface in places scoriaceous, in places smooth, fracture uneven	6
4.	Concealed	15
3.	Limestone, of facies of No. 5, but in separable laminæ	1
2.	Cherty sandstone, in layers from four to six inches thick. Chert fragments angular, small, those of an inch and one-half being rare. Sand, fine, of moderately well rounded grains of clear quartz, cement calcareous. Not seen in place but scattered in slabs over a slope of	5
1.	Niagaran limestone, exposed a few rods down stream, greenish yellow, subcrystalline, argillaceous, weathering to irregular rough-surfaced layers from one to four inches	

thick. Dip south at varying angles reaching as high as 13°. Among the fossils collected are *Leptaena rhomboidalis*, *Encrinurus nereus* and *Halysites catenulatus*.. 8

A few rods farther to the west the same series outcrops on the left bank of the run in the following section.

	FEET
5. Slope of hillside strewn with gray bowlders of weathering, massive, of facies of No. 5 of preceding section, but generally smooth-surfaced	38
4. Concealed	10
3. Slope strewn with fragments of cherty sandstone, as No. 2 of preceding section	5
2. Niagaran limestone, No. 1 of preceding section, layers horizontal	6
1. Concealed to water's edge	2

It will be noted that in the last section the thickness of the Otis reaches about fifty feet. Up valley from the mouth of Quarter Section run the following general section may be taken:

GENERAL SECTION, CEDAR RIVER, LEFT BANK

(*Southwest quarter of the southeast quarter of section 18, township 91, range XII west*).

3. Breccia, in places of mosaic type, fragments close set, small, of drab thin layered calcilutite; matrix sparse and drab in color, like fragments. Exposed at twenty-five feet above water level in river.
2. Breccia, of pudding type, matrix buff, containing sporadic sharp-edged fragments of finely crystalline gray limestone, exposed some rods to the north of No. 3, eight feet above the river.
1. Limestone, light brownish drab, nonmagnesian, in irregular, rough-surfaced layers eight to twelve inches thick, composed of coherent laminæ, some hard and dense alternating with others of lighter color, and weathered in places to a scoriaceous surface; laminæ irregular, undulating, and in places broken, giving here to weathered rock a finely fragmental appearance; outcropping between Nos. 2 and 3, at water's edge in a ledge five feet thick.

Here No. 1, which closely resembles No. 5 of the Quarter Section run section, is assigned to the Otis. Number 2 is of the Independence type of brecciation, so that No. 3 may safely be referred to the Lower Davenport.

About two miles north of these outcrops (northwest quarter of the northeast quarter, section 12, township 91, range XIV west), a ledge five feet thick outcrops three feet above water level. This ledge is of breccia of small fragments of drab calcilutite weathering to lighter gray, of lithographic fineness of grain, set in a gray calcareous matrix. In part, long, detached laminæ retain their parallelism. Flexed fragments are also to be seen. The position of this outcrop below the Cedar Valley limestone of the quarry of the Cedar River Stone Company, as well as its structure, place it with the Lower Davenport.

A most interesting section is afforded on Baskin run, two miles and three-quarters southeast of the last outcrop mentioned.

LIMEKILN QUARRY SECTION

(*Southwest quarter of the southeast quarter, section 17, township 91, range XIII west*).

		FEET
3.	Breccia, fragments sharp, angular, of drab calcilutite, laminated, the laminæ in places flexed and broken, but retaining an approximate parallelism; matrix gray, interstitial	1
2.	Sandstone, filled with small angular fragments of white chert, in two or three layers, resting with apparent conformity on No. 1	½
1.	Dolomite, light buff, crystalline, vesicular, in heavy, rough-surfaced horizontal beds; fossiliferous, with numerous *Halysites catenulatus*, base about thirty feet above level of Baskin run	13

In this section No. 1 is Hopkinton dolomite and No. 2 the basal conglomerate of the Wapsipinicon. Number 3 has the facies of No. 3 of the preceding section and is accordingly assigned to the Upper Davenport.

JANESVILLE SECTION

	FEET
Left bank of Cedar river at the milldam. Breccia: matrix soft yellow earthy limestone, in which the fragments are set without apposition or arrangement; fragments sharp edged, showing no signs of wear, usually small, those exceeding an inch in diameter being rare, many from one to three millimeters in diameter; fragments mostly of drab, laminated calcilutite, many surfaces crackled. Some fragments of buff earthy limestone similar to the matrix. Some of these are so arenaceous with sharp sand of chert and rounded grains of clear quartz as to deserve the name of sandstone. In places the breccia has weathered to a yellow calcareous clay with residual masses of dingy limestone, highly vesicular from the removal by solution of the calcilutite fragments. Total exposure to water's edge	14

Some rods up the river are exposed the fossiliferous beds at the level of the water in the mill pond. Apparently the breccia, whose matrix is of the Independence type, and whose calcilutite fragments are supplied from the Lower Davenport, lies immediately beneath these fossiliferous beds.

Buchanan County

In this county no section of the Wapsipinicon reaches the base of the Independence. The Lower Davenport limestone is found in force affected both by the major brecciation which has broken it, usually to rubble of small fragments, and by earlier brecciations whose evidences appear in blocks of brecciated limestones in which fragments of calcilutite are imbedded either in a similar Lower Davenport paste or in an Upper Davenport coquina. The Upper Davenport is much more broken up and its blocks are more intermingled with the fragments of inferior beds than is the case in Fayette county.

Independence Sections.—The quarries at Independence lie above the horizon of the Independence shales and therefore also above the main zone of brecciation. But evidences of the stresses which crushed the terranes subjacent are to be seen in the more competent beds of the Cedar Valley limestones. Thus, Calvin[57] has noted that in a quarry in the eastern edge of the town the *Spirifer pennatus* beds are "interrupted by a great number of joints" and that "the phenomenon of slickensides is developed on the joint faces on an extensive scale." He observed also in the quarry about one mile south of town the great shattering of a body of soft gray limestone which overlies the *Gyroceras* or Upper Davenport beds.[58] The natural section exposed along the river in the town at water level below the wagon bridge exhibits the most thoroughgoing brecciation. A more graphic description could hardly be penned than that of Calvin in describing these beds.[59] "The breccia is here composed of angular fragments of limestone varying in character, evidently the product of many distinct layers, and all cemented together by a calcareous matrix. The fragments range from small pieces with dimensions of a fraction of an inch up to masses a yard or more in length and width and a foot in thickness. There are fine-grained dark drab fragments which break with conchoidal fracture and there are finely laminated fragments of the same color. There are pieces of fine-grained light colored lithographic limestone, and coarser dingy yellowish colored beds were also in-

[57]Calvin, S., Iowa Geol. Surv., Vol. VIII, p. 229, Des Moines, 1898.
[58]Ibid, p. 225.
[59]Ibid, pp. 224, 225.

volved in the general destructive process, whatever it may have been, which reduced a large number of limestone layers to the brecciated condition. The fragments large and small, of different color and of different texture are promiscuously tumbled and heaped together, some on edge and others at all possible angles with the original position.'' The general horizon of the breccia at the Independence bridge is that of the Upper Davenport, but along with its broken blocks are commingled fragments of Lower Davenport calcilutites and of the buff argillaceous limestone of the Independence shales, while small areas show also the sandy and clayey matrix of the Independence. One area on the left bank shows a surface twenty-one feet long and six feet wide predominately of blocks of the fossiliferous granular Upper Davenport. Of these blocks five are of large size. In these blocks of the Upper Davenport coquina are seen embedded fragments of calcilutite from one to three inches in diameter. There are also blocks of calcilutite some of which show complex brecciation of another type. One of these blocks, on edge, one foot and eight inches long, consists of finely laminated brown calcilutite weatnering to whitish gray. Along one of the bedding surfaces the laminæ are bent, broken and dissevered and at the middle a soft yellow matrix appears. This block, itself a fragment of a brecciated bed, now forms part of a wide brecciated zone. A rod away another block of brown laminated calcilutite nine feet long exhibits the same phenomena. What may be considered the lower part, some eight inches thick, is in thin plates, while the upper part, four inches thick, is composed of small fragments, some of which are three or four inches in diameter. Both matrix and fragments are of the same rock.

On the right bank immediately beneath the bridge a ledge of breccia extends within two feet of water level. Most conspicuous is a block of gray, granular Upper Davenport, on edge, five feet long and five and a half feet high. The lower foot and a half is crowded in places with valves and entire shells of *Gypidula comis. Schizophoria macfarlanei* also is common. This part of the block includes sparse quadrangular fragments of calcilutite one or two inches in diameter. A foot above this zone and at one point coming within two inches of it is a zone of rather plentiful *Spirifer pennatus,* with large *Atrypa reticularis,* and rare *Orthis* (one imperfect specimen). The rock of both zones is the same. Adjoining and even with the top of this interesting block is dark buff Independence limestone with sparse small fragments of calcilutite, small fragments of light yellow earthy limestone, and cavities of the shape which would be produced by the solution of calcilutite fragments. Blocks of the same soft buff limestone, one foot in diameter and set at all angles, occur higher up the bank. In one of the uppermost of these blocks the buff limestone is covered with brownish gray calcilutite of the Lower Davenport type, crackled with calcite seams and brecciated into a mosaic of closely apposed matching fragments. The calcilutite fills a conspicuous depression in what is taken as the upper surface of the buff earthy limestone.

Adjoining the block just described is a block of fossiliferous Upper Davenport limestone with a Lower Davenport base of laminated calcilutite, in part in place, and in part broken into angular fragments and involved in the gray granular Upper Davenport. The block also contains four or five lenses of calcilutite parallel with the bedding.

The ledge is composed chiefly of large blocks of the Upper Davenport limestone. Thus touching the *Spirifer pennatus* block described is one of the same type of limestone which is five feet through and is nearly horizontal. On this block rest two more on edge, which are from the same bed. The horizon is clearly that of the large tilted blocks of Upper Davenport limestone.

About a mile south of Independence on the south bank of Wapsipinicon river the Independence zone of brecciation is exposed at water level. Here a soft yellow clay weathering from shaly beds contains sparse small fragments of buff soft limestone and of drab calcilutite. The Upper Davenport appears along the bank in blocks containing a large *Gyroceras,* plentiful *Gypidula comis,* and an occasional *Orthis.*

Quasqueton Sections.—The Wapsipinicon beds are finely displayed on both sides of Wapsipinicon river. On the left bank there are continuous ledges north of the bridge both above and below the site of the old mill dam. On the bank below the dam there is exposed at low water a wide rock floor swept clean of waste by floods. The vertical sections of about fifteen feet exposed on the left bank are thus supplemented by this extensive horizontal section of brecciated rock.

On the right bank below the dam the Independence occurs at the base of the ledges in tracts of lumpy buff soft argillaceous massive limestone with small sporadic fragments of calcilutite. The upper surface of one of these tracts, about twenty feet in length, slopes notably to the south, the general direction of structure lines in the breccia at this point. Above and between these tracts of brecciated Independence occurs a rubble and mosaic breccia which is composed of fragments of calcilutite. Blocks several feet long appear in place, but show the stresses to which they have been subjected. One block three feet long, of wavy laminated calcilutite, light brown weathering whitish, is heavily crackled and is surmounted by a four-inch layer of non-laminated fragmental limestone composed of close-set minute fragments of the same limestone as that of the crackled limestone underneath, with a matrix of angular limestone sand and some interstitial calcite. This upper minutely fragmental layer is seen on other blocks also in the same ledges. The same structure appears immediately beneath the Upper Davenport above the dam. In another block three feet long and eight inches thick and resting on a nearly horizontal plane, the layers of brown calcilutite of which it is composed are largely in place but are partly brecciated, the interspaces between the fragments being composed of minute chinkstone like the larger fragments and of calcite.

In other areas mosaic and crackle breccia gives way to rubble in which all traces of initial bedding have been destroyed. Here the breccia is composed of close set fragments of various strata. Gray granular blocks of Upper Davenport are seen within a foot of the base of the ledge while near the top of the ledge occur fragments of brownish Lower Davenport calcilutite. Highest at this outcrop is a light buff fossiliferous limestone carrying *Spirifer pennatus*.

Above the dam the fossiliferous beds are better exposed on account of the greater height of the section. Here from weathered surfaces the following fossils were collected: *Atrypa reticularis*, *Chonetes* cf. *C. cancellatus, Cyrtina hamiltonensis, Pentamerella dubia, Pholidostrophia nacrea, Spirifer bimesialis, Spirifer pennatus, Stropheodonta demissa* var. *plicata.*

At a little lower horizon large blocks of Upper Davenport limestone, more or less tilted, lie approximately in the same plane. Mingled with them in places are light yellow fossiliferous blocks from a higher horizon. At one point the Upper Davenport beds are continuous for thirty feet and dip to the southeast. At the extreme north end the angle of dip is 14°, at the center 10°, while at the south end the bed is bent down abruptly at 18° to a thrust fault beyond which the bed dips 5° north.

Several large blocks show that the deposition of the granular Upper Davenport fossiliferous beds followed directly on that of laminated calcilutite. One block four feet long and nearly two feet thick, gently flexed, is made of Upper Davenport above, while the lower portion consists of unshattered laminæ of calcilutite, parallel with the flexed surface of the Upper Davenport above. Another block shows at top one and one-half feet of fossiliferous Upper Davenport limestone, with elliptical horizontally set lenses of light brown calcilutite similar to that of the layer underneath imbedded near the base. A middle layer consists of brownish calcilutite, three inches thick, whose laminæ are flexed, broken and detached, but retain their parallelism for the most part. Some fragments are lenticular. The paste in which they are imbedded is the same as the fragments. At base is a four inch layer of brown crystalline limestone.

In these ledges occur small irregular areas of buff matrix rock highly arenaceous with angular white chert and well rounded grains of clear quartz and containing sparse small sporadic fragments of drab calcilutite.

On the west side of the river the breccia of the horizontal section is largely made up of calcilutite mingled with large masses of the Upper Davenport. There are small areas of pudding breccia in which the buff arenaceous Independence is conspicuous. Here blocks may be seen which include adjoining layers of the Upper and Lower Davenport, and exhibit their relations as originally deposited. Along the line of junction the Upper Davenport comes down into crevices and surrounds detached laminæ of the calcilutite. The Upper Davenport paste was clearly intruded into the Lower Davenport calcilutite during or after its shattering, and at the time the Upper Davenport must have been in highly plastic state. In certain blocks the parting between the Upper Davenport and the Lower Davenport is extremely intricate, with interlocking areas. In these blocks the laminæ of the Lower Davenport are greatly broken up. In places the blocks of the Upper Davenport are shattered, and show wedge-shaped fissures up to three inches in width, filled with calcite, much as in the railway cut at Vinton. There are also blocks of Lower Davenport limestone in which the laminæ are bent and detached, but retain more or less of their parallelism and are imbedded in a matrix of calcilutite indistinguishable from that of the fragments except by a somewhat lighter color.

The outcrops at Quasqueton include the horizon of the Upper Davenport tilted blocks, but include also the underlying zone of the Lower Davenport, with some involvement of the Independence.

Benton County

The chief exposures of the Wapsipinicon beds in Benton county are located four and five miles northwest of Vinton along the right bank of Cedar river. As noted by Savage[60] a long and narrow ridge here faces the flood plain of the river, rising to the height of eighty feet above it. For the distance of a mile and a quarter along this bluff numerous excavations have been made, and near the southern limit of these quarries the ridge is trenched by the deep rock cut of the Chicago, Rock Island and Pacific Railway. The northernmost of the quarries, located near the center of the east side of section 36, Cedar township, is that of Mr. Niels Degn. About half a mile farther south is Kearn's quarry and a few rods beyond the numerous excavations of the Aungst quarries begin, extending into the southern half of section 6 of Taylor township.

The beds exposed in the railway cut and quarries are:

Barren beds
Upper Davenport beds
Lower Davenport beds

[60]Savage, T. E., Iowa Geol. Surv., Vol. XV, p. 158. Des Moines, 1905.

Independence limestone and shale
Otis calcilutite beds
Otis buff lime quarry beds

The barren beds have been extensively shattered. The Upper Davenport beds have been broken into huge blocks, in part in place and in part commingled with the fragments of lower terranes. The Lower Davenport beds are seldom found in place, but to this horizon are referred many calcilutite fragments mingled with the Independence shale in a common brecciation, which includes also fragments of the Otis. The Otis calcilutites are seen in an endostratic rubble of minute fragments and in crackle and mosaic breccias. The Otis buff beds also furnish at top a thin endostratic rubble or pudding breccia, but with this exception the beds are little disturbed.

Otis Buff Limestone.—This stone is singularly uniform from top to bottom and from end to end of the quarries it is everywhere a buff, heavily and evenly bedded laminated limestone, soft and crystalline-granular. The sparkle of the calcareous crystalline grains is even suggestive of an arenaceous content, but quartz sand is entirely absent from the rock, so far as the writer has observed. Along joint planes the etching of the weaker layers by the weather brings the laminated structure into conspicuous relief (figure 45). The laminæ vary in thickness from a quarter of an inch to layers so fine that eleven or twelve may be counted to the inch. The usual alternation is between rather soft buff laminæ and those of a light brownish tint, harder and more compact. Hair-line dark laminæ in the midst of wider bands of lighter color may be seen. In some of the lower beds lamination is somewhat obscure, but is nowhere wanting. In places the stone is minutely vesicular especially toward the top of the bed. The lines of lamination run parallel with the major bedding planes and with each other. In evenness of lamination the stone approaches the Anamosa phase of the Gower limestone of the Silurian. In this respect it differs from the Otis beds in the Cedar Rapids quarries, with which it is entirely akin in closeness of lamination and in hair-line brown partings. More quiet conditions of deposition and perhaps deeper water are indicated than obtained in central Linn county. The laminæ are coherent and while under prolonged weathering the rock splits into layers from one to three inches thick the quarries exhibit undivided beds up to six feet in thickness.

Joints at Degn's and Kearn's quarries run in two sets, southeast-northwest, and northeast-southwest, and are from three to ten feet apart. The rock lies in gentle undulations which in some cases scarcely depart from horizontality, or in places attain dips of 3° to 7°. In one instance an exceptional dip of 15° is reached. These are referred to the stresses of the major brecciation. The thickness of the beds exposed at any one place is about fifteen feet, but the base is not reached by the excavations, some of which extend below flood plain level. A few rods north of the railway bridge the summit of the beds appears twenty-four feet above low water in the river.

No fossils have been found to certify the place of this terrane in the Wapsipinicon but its lithology and general relations refer it with little doubt to the Otis. In close lamination and in freedom from high magnesian content it differs from the bottom beds of the Otis, the Coggon phase, which probably here lies still deeper.

The uppermost layer of the Otis buff beds shows disturbed sedimentation. This layer has an irregular hummocky upper surface, and is more or less fragmental in structure. For a depth ranging from a few inches to two feet from the surface the rock contains sparse angular fragments. These are of the same lithologic nature as the matrix rock or differ from it in kind as the laminæ differ from one another. In places the laminæ of rock are bent or shattered into bits. The fragments are minute—a diameter of one-half inch is exceptionally large. The continuity of this fragmental layer is not interrupted by fractures. It will be recalled that a similar fragmental layer caps the laminated Otis beds in the Fayette county outcrops and that lenticles affect the same horizon at Cedar Rapids.

Otis Calcilutite.—In places, but not continuously, there rests upon the Otis buff beds a ledge of brownish calcilutite weathering to gray. Under the stresses of the major brecciation it is shattered in places to crackle breccia, in places it is further disrupted to a mosaic breccia of fragments which in some cases match along seams, which are filled with calcite or with fine chinkstone of the same nature as the larger fragments. There has been little or no intermingling of material from other horizons. In places the Otis calcilutite bed is absent either because of lack of conditions favorable to deposition or because it has been torn up and commingled with the breccia hodge-podge to which the Independence and the Upper and Lower Davenport beds also contribute.

The Independence Breccia Zone.—At the railway cut and at all the quarries the Otis is succeeded by a rubble breccia to which an abundance of soft shaly material is contributed by the Independence. While the Otis mosaic breccia layer just described forms a solid bed of firmly cemented fragments with little or no admixture of foreign rock, the zone of the brecciated Independence is scarcely more indurated than till. The Independence contributes also tabular fragments of a dingy buff earthy limestone. The Otis contributes fragments of buff granular crystalline rock indistinguishable from the buff basal beds of this locality and drab calcilutites with characteristic hair-line laminæ. From this source also come fragments with minute dark scattered linear crystals of celestite. Other fragments of calcilutite are contributed probably by the Lower Davenport beds, while the Upper Davenport furnishes blocks of all sizes up to five feet in diameter which come down within a foot or so of the base of the breccia. Masses of even the whitish limestone of the uppermost barren beds also are to be found well down within this zone, whose width is about fifteen feet. The usual siliceous nodules and sand of clear quartz and chert are present.

The relation of the Independence breccia zone with the lower beds is significant. In places the shaly Independence, little disturbed, rests directly and conformably upon the buff Otis beds. At Kearn's quarry one may see six inches or a foot of blue-gray or buff calcareous shale composed of laminæ a millimeter or less in thickness and continuous for several feet lying upon the undisturbed laminæ of the buff Otis. Here sedimentation apparently was continuous during the deposition of the two formations. At one point the basal four inches of shale passes laterally into limestone. At Degn's quarry in places the upper part of the laminated undisturbed buff Otis has its thin calcareous plates interleaved with greenish yellow argillaceous sediments. But for the most part the Independence shale, brecciated and thoroughly mixed with foreign limestone fragments, rests directly upon either the Otis calcilutite breccia, the undisturbed buff Otis or its minutely fragmental uppermost layer.

Structure lines in the breccia of the Independence zone may be picked out by occasional strings of fragments of once continuous layers of limestone which trace synclines and anticlines of moderate dip, and by much steeper boundary lines of areas of weak shaly breccia and of strong breccia of predominant limestone fragments.

Immediately beneath this bent and broken stratum in the railway cut there lies, for an extent of twenty-eight feet, a blue-gray fissile shale. This shale reaches a thickness in places of eighteen inches, is broken by joints which are one to three inches apart and is very thinly laminated, the leaves being only a fraction of a millimeter in thickness. It is calcareous and slightly gritty. It conforms to the slant of the stratum of limestone above it and to its irregular lower surface. The shale rests on Independence breccia four or five feet thick, which parts it and the broken stratum above it from the basal ledge of brecciated Otis calcilutite. This breccia of the Independence zone is unindurated, buff or bluish in color, with numerous small fragments of various types, including black and white flint and calcilutites with blackish hair-line laminæ. The lumpy argillaceous matrix is sandy in places with black and white grains of flint. The most important characteristic of this breccia is the presence in it of fossiliferous fragments—a block two feet long carrying *Chonetes* cf. *C. cancellatus*, and an angular fragment with an imbedded valve of *Orthis*. That the shale was not deposited subsequent to brecciation by inwash in an irregular cavity left beneath the ledge of strong rock either in the process of brecciation or afterward by the settlement of the breccia beneath the ledge is seen in the fact that the lamination of the shale is not horizontal, but follows the dip of the blocks above. All the relations of shale and limestone point to continuous sedimentation in their deposit. Consideration must be accorded the hypothesis that they were deposited upon the underlying breccia, and that later crustal movements involving the whole terrane folded and dislocated the limestone stratum with the protected shale beneath. In this case the breccia beneath the stratum must have been produced in Independence time. This hypothesis explains most satisfactorily the relations of shale and overlying limestone. Moreover, local contemporaneous brecciation is known to have occurred during the Independence as shown by the Cedar Rapids outcrops (p. 451). But the breccia beneath the shale is not made up wholly of fragments of the Independence and subjacent beds. It contains fossiliferous fragments belonging at least as high as the Upper Davenport. If the shale and limestone were laid upon a breccia so constituted they must be younger than the fossiliferous beds whose fragments are included in the breccia. The implications of this hypothesis are that all the types of rocks represented in the breccia of the Independence zone were deposited during Independence time or earlier. The heterogeneity of the zone of breccia is due to the heterogeneity of a single formation. During Independence time there were laid on the sea floor, not only shales and argillaceous limestones, but also fossiliferous limestones of different types identical lithologically and in their fossils with the limestones of known higher terranes. Such various deposits were laid contemporaneously over different tracts of the sea floor and on individual tracts in different succession. Such a theory would fully explain the variety of fragments in the Independence zone of brecciation. Conclusive evidence in its support would consist of beds of Upper Davenport or Cedar Valley facies and fossils interbedded with those of Independence facies in areas where strata are undisturbed, or so slightly disturbed that their initial positions can be traced. But in such areas the Cedar Valley horizon invariably overlies the Upper Davenport while still further down the stratigraphic column come the argillaceous beds denominated the Independence. Even the brecciated areas do not yield the evidence necessary to support the theory. The Upper Davenport limestones, whether seen in place or in broken blocks above the Independence, are massive and tough. Under brecciation which crushes soft weak rock to powder and shatters brittle rock to a rubble of small fragments, the Upper Davenport is commonly left in broken rotated blocks which largely preserve the bent surface to which the plane of deposition was deformed before rupture. Certainly if such layers had existed interbedded with shales and argillaceous limestones, they would now be found in the Independence zone in strings of fossiliferous blocks, similar to the strings of the stronger Independence limestones occasionally seen. Strings of Upper Davenport blocks are seen indeed, but always as a distinctly higher horizon than the rubble breccia with shaly matrix that marks the Independence zone. Where the Upper Davenport limestone occurs within the Independence zone of brecciation it occurs in single blocks or smaller fragments entirely unrelated to one another in position, or if in numbers in any tract, wholly chaotic in their lack of arrangement and without the slightest trace of an initial deformed plane of deposition. We are therefore compelled to abandon this hypothesis and to revert to the theory of the successive formations of the Wapsipinicon and Cedar Valley Devonian in the order adopted by the Iowa Survey. In the specific instance noted in the railway cut, we are compelled to believe that the fossiliferous fragments in the breccia beneath the shale and limestone layer are younger than the shale and limestone which now overlie them. The breccia of which they form a part is also younger and can not belong to Independence time but is of later date than the youngest fossiliferous fragment in it, and is to be referred to the major brecciation.

The Lower Davenport.—The Lower Davenport calcilutites are not found in force in these outcrops. In the most northern of the Aungst quarries they form a ledge of gray calcilutite five feet thick in layers from four to six inches thick which are greatly shattered and healed with calcite. The bed here dips 10° to 25° south. In other quarries large blocks of crackle breccia mark this horizon. Complex brecciation is seen also in blocks broken into fragments poorly cemented with a scant gray matrix or parted by fissures in some cases open or inclosing minute fragments. In one instance a fragment thus inclosed consists of a portion of the valve of an *Orthis,* imbedded in minute cemented chinkstone of calcilutite. The fossil, derived from the

Upper Davenport horizon, clearly indicates the zone of juncture of the two formations. The Lower Davenport also occurs in subangular fragments more or less rounded on corners and edges and imbedded in Upper Davenport blocks and ledges. This fact also shows that the deposition of calcilutite immediately preceded the deposition of the Upper Davenport coquina.

The Upper Davenport.—This limestone is heavily bedded at all outcrops and is largely broken into slickensided blocks. They form gently arched but disrupted beds at the summit of the breccia of the Independence zone, with which the Lower Davenport is usually commingled, or descend far into the zone in detached fragments up to five feet in diameter.

Some of the blocks of Upper Davenport carry lenticular masses conspicuous because of contrast in color and texture. These lenses are half an inch or more in vertical diameter and two to three inches in their longer horizontal axis. Fresh fracture shows a brownish calcilutite or a subcrystalline structure of finest grain. Exposed surfaces have weathered to whitish gray. They lie parallel with the bedding planes. Thus forming horizontal rows of narrowly spaced whitish lenses in the midst of the gray limestone, they are conspicuous even at a distance of several rods. Their shape, their spacing and attitude, the fact that they are not assembled like beach shingle or like the sporadic fragments of a breccia suggest their formation *in situ* by colonial organisms, such as stromatopora or sponges. In one instance this is demonstrated by the structure remaining on the upper surface of the lenticle.

Associated with the blocks of gray granular limestone characteristic of the Upper Davenport are large blocks, also similarly slickensided, of a blue-gray earthy limestone which weathers to yellow. A large *Chonetes* akin to *C. cancellatus* is specially common and characteristic of this bed, which also contains *Stropheodonta demissa.*

The following fossils collected at the railway cut and identified by Savage[61] are probably all from the Upper Davenport horizon.

[61]Savage, T. E., Iowa Geol. Surv., Vol. XV, p. 184.

Fistulipora constricta Hall
Stropheodonta demissa Conrad
Pholidostrophia nacrea Hall
Orthotetes chemungensis Conrad
Chonetes cf. *C. cancellatus* Calvin
Productella subalata Hall
Schizophoria iowensis Hall
Pentamerella arata Conrad
Gypidula laeviuscula Hall
Gypidula comis Owen
Atrypa reticularis Linn. Independence type
Atrypa aspera var. *occidentalis* Hall
Spirifer pennatus Owen
Spirifer asper Hall
Paracyclas elliptica Hall
Gyroceras sp.
Phacops rana Green

Barren Beds.—These beds are best seen in the railway cut where on the west side near the north end they form a ledge of light gray limestone about ten feet thick. The layers run in undulating courses parallel with the synclines and anticlines of the Upper Davenport massive bed beneath. The rock is shattered and in one area at the north end it is completely broken up.

Cut of the Chicago, Rock Island and Pacific Railway north of Vinton.—This section, of about thirty-five feet, has its base about twenty-five feet above the river and embraces all the zones of the Wapsipinicon as far down as the buff Otis lime rock, which lies slightly below its level.

	FEET
4. Limestone, light buff, weathering to whitish gray, unfossiliferous, in undulating courses, in places shattered and completely broken up; estimated thickness	10
3. Upper Davenport limestone, gray, granular, in heavy courses up to four feet thick, broken and faulted into large slickensided blocks which in places follow undulating courses parallel with those of No. 4. In places the interstices between the blocks are filled with dark gray, nonlaminated clay, or with chinkstone of the same rock, or with both intermingled. In these interstices several fossils of the Atrypas are found as parts of rock fragments. In one instance a large finely ribbed *Atrypa reticularis* was found in an interstice completely detached and imbedded in the clayey matrix, but this is regarded, like the others, as a fragment instead of as a constituent part of the matrix. In places the rocks are shattered and healed with calcite. Rarely in these rocks occur lenticles of calcilutite with their long axes parallel with the bedding	4-10
2. Zone of the Independence. This zone is well demarked from those above and below. On account of lack of cementation, and because of the abundant shaly material, it generally forms a steep slope, while the stronger rocks which inclose it stand in nearly vertical ledges. Exceptional areas of better cementation and less shale form outstanding crags. The color, a dingy buff or bluish gray, indicates the high argillaceous content and is in contrast with the whitish tints of the inclosing ledges. It is marked also by its heterogeneity and by the generally small size of the included fragments.	

The constituents of this breccia which may be referred to the Independence limestone and shales as their source are, first, the argillo-calcareous buff or bluish matrix. This is perhaps as well described by its negative as by its positive characteristics. It is not laminated or bedded and shows no trace of sedimentary deposit in its present relations. In places it is more than interstitial, and forms small areas in which small foreign limestone fragments are sporadic. But there is no evidence that these fragments were dropped into a sea-clay in process of deposition. The lumpy or amorphous nature of the matrix indicates rather that it, like the fragments, is the product of crush—it of weaker argillaceous beds, they of harder, stronger calcareous strata. Angular bits of black and of white flint in places speckle the matrix rock. Sand grains of clear quartz also are present. There are also fragments, small and large, of a buff argillaceous limestone some of which are themselves finely fragmental. These occur in strings, to be described more fully, and are taken to be native to the Independence. There are also strings of fragments of calcilutite beds which perhaps were deposited in the midst of the normal sediments of the Independence.

The foreign constituents of the Independence zone of brecciation are first, the blocks of the upper beds of the Wapsipinicon. At one point on the east side of the cut is an area of large fragments of the upper beds which comes down within four feet of the ledge of Otis calcilutite mosaic breccia at the base of the section. This area crosses the tracks diagonally with a northeast-southwest strike and appears on the opposite side. On the east side at the base of the area, is a block of Upper Davenport fossiliferous limestone five feet through. Above this block is a mass of whitish or light yellow limestone blocks, apparently the same as the barren beds at the summit of the section. A fragment of a large trilobite, however, was found in these. The matrix filling the interspaces of this mass is chiefly of calcite, seams as much as three inches wide being completely filled with white, brown, and clear crystals of this mineral. Chinkstone matrix of the same material as the blocks also occurs. One large block, five feet in length, is broken in two in the middle and the wedge-shaped fissure is calcite filled. Blocks of fossiliferous Upper Davenport limestone are found apposed to this mass and to a small extent intermingled with it. On both sides the area of large blocks touches tracts of shaly breccia with small fragments. It would appear that in brecciation the shales of the Independence here failed to penetrate to any extent the interstices of the large blocks of the area and these were left to form an easy way for ground water, which at some later time deposited calcite therein. There may be seen a few blocks of the bluish fossiliferous limestone, weathering buff, with the large *Chonetes* resembling *C. cancellatus* which occurs plentifully in the Aungst quarries.

The Lower Davenport calcilutites apparently were thin in this area and none are now left in place at the railway cut. The calcilutite fragments in the Independence zone are probably in part derived from the Lower Davenport, but no attempt is made to discriminate them from calcilutites from other horizons.

Calcilutite fragments in the Independence zone are in part derived also from the upper horizon of the Otis. Fragments with blackish hair-line laminæ and the rare ones showing minute celestite crystals may be referred to the Otis as their source.

The most pronounced structure lines in the Independence zone are those afforded by strings of fragments of once unbroken layers. Blocks evidently belonging to a single stratum, once continuous and horizontal, are now found more or less rotated, separated from one another by the same shaly breccia which forms the main body of breccia of the Independence zone. They are now aligned in irregular, in some instances faulted, folds or in steep monoclines, which with interruptions may be traced for lengths of three or four rods. Thus about six feet from the base on the west side of the cut, blocks of whitish calcilutite one foot to two feet in diameter are ranged along a sinuous line a rod and more in length in the midst of the shaly breccia (AA. figure 64, page 424).

Near the south end of the cut, on the west side, begins the outcrop of a broken stratum, about one foot thick, of light brownish granular rock with darker spots, weathering to buff. The lower part of the layer is gray, is speckled with black, and contains some small sporadic fragments like the mass of the rock. A sketch of a part of this outcrop shows graphically the degree to which this stratum has been folded, faulted and broken into detached fragments (figure 61, page 421).

1. Zone of Otis calcilutite. This member is best exposed and reaches its maximum height of five feet at the north end of the cut. Declining to the south it passes below the level of the rails in about 120 feet. It reappears toward the south end of the cut but its structure here is less typical. Where the bed of Otis calcilutite passes below the level of the rails at the north end of the cut it is about twenty-five feet above low water in the river, or about the same height at which the summit of the Otis buff lime rock is found a few rods up river in the Aungst quarries. The rock is a finely laminated calcilutite brownish or drab in color but weathering to light gray. The close set laminæ are etched on weathered surfaces. A marked type is a light gray rock with rather distant dark hair-line laminæ. In places exceedingly minute dark short acicular crystals of celestite speckle an area of a square inch or two. At the north the calcilutite is found in a bed brecciated to a mosaic but without admixture with fragments of other strata. Many of the fragments are apposed along the fractures and retain something of the original plane of deposition, but in places they are rotated to all angles and form a rubble. The matrix consists of interstitial calcite filling the seams of the crackle and mosaic breccia, and chinkstone of the same rock as the fragments in the larger interspaces. The sandy buff granular shaly matrix of the Independence zone is not seen in this bed.

At or near the upper surface of this bed there occur in places one or more layers a few inches thick which are composed of minutely fragmental calcilutite in angular bits from the size of sand to a diameter of a quarter of an inch with a very slight and interstitial matrix of granular rock of the same color. These layers, which weather to fretted surfaces, are thus contrasted with the evenly laminated layers which bound them.

DEGN'S QUARRY SECTION

FEET

3. Breccia, Independence zone, gray, shaly, uncemented, with the general appearance of a clayey till. Fragments in rubble, small, sharply angular, of various lithologic types—thin, brittle, cracked calcareous plates, drab and brown calcilutite, finely laminated brown calcilutite, fossiliferous Upper Davenport limestone, blocks of shattered and recemented brown laminated calcilutite whose fragments generally are matching and apposed and whose fissures are filled with chinkstone or are open at the surface. Areas of breccia which are drab in color and more clayey with smaller fragments may be distinguished from other areas which are more yellow in color with larger fragments, but no structure lines are visible. Matrix supplied by Independence shale, which also furnishes some lumpy fragments; estimated thickness 12
2. Limestone, Otis, in plates from a fraction of an inch to two inches thick; in lamination, texture and color like beds beneath, in part fragmental; in places thin leaves of greenish yellow clay part the thicker laminæ of limestone. The latter are irregularly surfaced and slightly flexuous and the impression is given of continuous deposition rather than of the intercalation of the clay after the deposit of the limestone. Contact with No. 3 fairly even 2
1. Limestone, buff and brownish gray, fine crystalline-granular to earthy, of rapid effervescence in cold dilute HCl, in even parallel beds from two and four inches beneath to five feet nine inches above, laminated with rather obscure slightly wavy laminæ marked by slight differences in color, in places vesicular with minute spheroidal cavities, joints southeast-northwest and southwest-northeast, from three to ten feet apart...................... 9

KEARN'S QUARRY SECTION

5. Limestone, Upper Davenport, with sparse inclosed calcilutite fragments, in ledges on hillside.
4. Breccia, Independence zone, a rubble, shaly, light blue-gray or yellow; fragments of shale of several inches diameter observed which retain initial lamination; many limestone fragments of different lithologic types, some of buff Otis, some of brown calcilutite, some slickensided blocks of Upper Davenport limestone, one of large size noted within three feet of base of breccia; a fragmental *Orthis macfarlanei* found five feet above base, fragments easily detached; estimated thickness.........................10
3. a. Shale, calcareous, buff, fissile, laminæ a millimeter and less in thickness, continuous for five feet horizontally, in places bent and broken but with no included foreign fragments, at base passes laterally for four inches into argillaceous buff laminated limestone..................½-1

b. Or, breccia, buff argillo-calcareous lumpy matrix, numerous small fragments of limestone of buff Otis........ 3

2. Limestone, Otis lime rock, light brownish drab, laminæ alternating buff and light, brownish gray, even and regular; some layers vesicular, vesicles filled with calcite; in layers up to six inches thick; gently undulating with the limbs of the low folds dipping from 5° to 7°; upper foot contains a few minute sporadic fragments of rock of same facies.. 6

1. Limestone, buff, granular-earthy, obscurely laminated with lighter and darker bands and with distinct brown hair-line laminæ graduating into browner rock beneath; undulations as in No. 2; the master joints of both run southeast-northwest and northeast-southwest............ 8

AUNGST QUARRIES

These quarries, opened by the Aungst Bros. for lime rock, extend for more than one-half mile along the bluffs bounding Cedar river and include representatives of all the members of the Wapsipinicon. With the exception of the Upper Davenport beds which were used many years ago in the construction of the buildings of the State College for the Blind at Vinton, the only stone quarried has been that of unbrecciated buff beds of the Otis which are used for lime. On account of the heavy cover of rock which overlies this basal bed, tunnels ten and fifteen feet high have been driven as far as one hundred feet under the hill and several feet below the level of the flood plain of the river. Large chambers attest the amount of rock which has been removed. The rock is identical with that of the buff Otis beds in the Kearn and Degn quarries, so that the description of these beds will not be repeated. While these beds lie approximately horizontal for the most part, the strongest anticlinal fold seen in the Vinton outcrops occurs in a quarry up river from the bridge where a dip of limb of 15° was observed.

The upper layer of the buff Otis beds differs from those beneath in its irregular upper surface and its fragmental nature. The following section at the roof of the tunnel of one of the southern excavations shows the relations of this bed:

FEET

3. Breccia, plentiful fragments of brown calcilutite and other lithologic types two and three inches in diameter, matrix soft, clayey.

2. Limestone, Otis, brownish, vesicular, in places minutely fragmental, some fragments soft, angular, buff, some

harder, brown; upper surface irregular, the breccia of No. 3 filling the depressions 1 2-3
1. Otis limestone, buff, finely and evenly laminated, forming roof of tunnel 1

The width of this upper bed of the buff Otis varies from a few inches to two feet. All the fragments are of the same type as the matrix rock or differ from it only in the kind and degree that the brown and buff laminæ of these beds differ from each other. The fragments are minute—one-half an inch in diameter would be exceptionally large—and many of them show by their quadrangular form that they are bits of broken up laminæ. The bed is massive, the fragments being scattered through the matrix rock or the whole forming rubble breccia of minute fragments.

Upon the fragmental massive upper bed of the Otis rests either the clayey matrix breccia of the Independence zone of brecciation, as at the northernmost quarry, or a ledge of calcilutite breccia.

At one exposure forty rods southeast of the railway bridge, the lime rock is overlain by a nearly horizontal ledge of calcilutite five to seven feet thick. The rock is of the usual type, light brown and finely laminated. It is irregularly bedded in courses about one foot in thickness. The rock is seamed and in part is fragmental. At base it changes to subcrystalline dark gray limestone. The entire ledge in places forms a rubble breccia of native fragments firmly cemented with chinkstone matrix and finer material of the same nature as the fragments. Many of the fragments are several inches in diameter. This ledge gives place laterally to a breccia of shaly matrix. In places the ledges of calcilutite have been shattered to rubble. As example there may be cited an exposure a few rods up river from the railway bridge. Here the summit of the buff beds is twenty-four feet above low water level, and at approximately the level of the rails in the railway cut. At this quarry a vertical wall of close-set rubble breccia twelve feet thick thinning to six feet at an angle of 45° rests directly on the buff Otis lime rock. The fragments are chiefly brown calcilutite. They are mostly small but areas occur where fragments from six inches to two feet in diameter predominate. Some of these larger fragments are themselves seamed, dislocated and healed with calcite. Most of these fragments can well be attributed to the breaking up of beds of Otis calcilutite, such as that seen at about this level at the bottom of the railway cut and that just described in the quarry forty rods south of the bridge. But the clayey matrix, the soft yellow limestone fragments and the lumpy fossiliferous fragments which form a minor part of the same breccia bed show that other and higher terranes also have contributed to it.

In all the Aungst quarries the horizon of the Independence is represented by a rubble breccia in which the shales and dingy buff impure limestones of the formation have been broken up and mingled with fragments of the limestone beds beneath them and above. The shales are easily crushed and contribute a matrix which is soft, lumpy and in places arenaceous.

Small areas of shale little disturbed or intermixed with other constituents occur where they have been protected by limestone blocks or ledges. Thus in the quarry forty rods south of the bridge dark gray shale is seen amid the tilted blocks toward the base of the zone of broken massive limestone beds which succeeds the Independence breccia zone along these outcrops. Underlying a broken arch of blocks is a mass of shale from two to six inches in thickness and a foot or so in length which remains largely intact although tilted with the adjacent surfaces of the limestone blocks to slopes of 35°, 45° and more than 50°. Siliceous nodules and chips of flint occur at this horizon, though not so numerously as in the Linn county outcrops.

Structure lines are seen in beds of strong rock which either remain unbroken for some distance, or if broken permit their courses to be traced by strings of fragments. The alignments of dissevered blocks are seldom if ever horizontal, nor are they continuous for any considerable distance. Within the limits of the face of the quarry they come to an end and give place to structureless rubble breccia. For example, in the quarry forty rods south of the railway bridge structureless rubble breccia rests upon the ledge of Otis calcilutite already described. A few feet up the slope it is interrupted by a string of blocks of brown calcilutite from one to two feet thick tilted at a moderate angle to the south. Higher up the quarry face there appears a short ledge of buff granular dingy limestone of the Independence type which is tilted more strongly in the same direction. A little to the east a syncline of dislocated blocks of brown calcilutite, some of them four feet long, appears high up in the Independence zone. In the quarry a few rods above the bridge, where twelve feet of rubble breccia with close-set calcilutite fragments overlies the Otis lime rock, this breccia is bounded above by an undulating bed of light brown calcilutite three feet thick in irregular massive beds about one foot in thickness. Weathering shows that the rock is minutely fragmental in structure. In places the ledge is broken and faulted. Immediately upon this rests for a short distance a soft buff limestone and a foot or so higher up is a string of large and small fragments of soft speckled buff limestone. A tract of weak breccia with shaly matrix separates these ledges from the zone of big blocks which lie above the Independence. At one of the most southern of the quarries, where a weak breccia with fragments from two inches to two feet in diameter, imbedded in soft clayey matrix, rests upon the buff Otis lime rock, a string of brown laminated calcilutite blocks appears above this breccia. The string has a distinct dip to the southeast, and a number of blocks of whitish calcilutite a few feet above show the same trend.

The Lower Davenport beds are seen in place only at the Aungst quarry adjacent to Kearn's quarry where they appear in the form of a cornice of drab and gray calcilutite five feet thick, dipping from 10° to 25° and greatly shattered, the seams being filled with calcite. Angular or somewhat rounded fragments of calcilutite are occasionally seen included in the Upper Davenport.

The Upper Davenport appears in massive ledges as in the railway cut. In large part they retain their initial position relative to the weaker lower beds. But great slickensided tilted blocks are found far within the brecciated Independence zone and smaller but characteristic fossiliferous fragments are found nearly to its base. Thus at a quarry up river from the bridge a twelve-inch fragment of the Upper Davenport occurs within one foot of the undisturbed buff Otis lime rock and a large block of the Upper Davenport may be seen within three and one-half feet of the same datum plane.

Linn County

The three trunk streams which trench the Wapsipinicon terrane in their courses across the county afford excellent sections of the beds involved in the major brecciation. These streams are Cedar river from Covington to Otis, Buffalo creek at Coggon and the Wapsipinicon from Troy Mills to Central City. The shattered Bertram beds are exposed along Indian and Big creeks, tributaries of the Cedar. The Coggon phase of the Otis is seen practically undisturbed at Otis, at Coggon and at Springville. The Cedar Rapids phase has suffered only a slight deformation marked by low undulations of the strata and crackling of the more brittle beds. The Independence is slightly folded but only partly brecciated at Kenwood, Otis and in the quarries about Cedar Rapids; but at the old cut of the Chicago, Milwaukee and Saint Paul Railway west of Linn it is intermingled with the higher terranes. The Lower Davenport is generally thoroughly brecciated, but at Kenwood beds only partly brecciated immediately overlie the Independence. The Upper Davenport appears west of Linn and along Felton creek, Cedar Rapids, in characteristic broken ledges carrying the First Fauna. The Linn section shows the soft buff limestones which hold the Second Fauna, shattered and intermingled with lower terranes. It is in the sections of Linn county that the sequence of the terranes of the Wapsipinicon is most clearly displayed and the effects of the major brecciation are most readily distinguished from those of the minor brecciations which preceded it.

SILURO-DEVONIAN CONTACTS

SECTION EAST OF CENTRAL CITY

(Northwest quarter of the southwest quarter of section 1, township 85 north, range VI west)

		FEET
5.	Otis limestone, Cedar Rapids phase, with much black flint..	6
4.	Slope, no rocks exposed................................	10
3.	Otis limestone, Coggon phase, abundantly fossiliferous, resting directly and apparently conformably on bed below..	16¼

2. Limestone, magnesian, compact, gray, crystalline-granular, made up of two layers in even courses four and five inches thick and a basal irregular layer about one foot thick which rests directly upon bed below............ 1¾
1. Dolomite, Hopkinton stage of Niagaran, with casts of corals and *Bronteus* cf. *B. laphami*........................... 4

SECTION SOUTH OF PARALTA ON BIG CREEK

(Northeast quarter of the southwest quarter of section 7, township 83 north, range V west)

FEET

5. Slope covered with imbedded fragments and blocks of Bertram limestone; near the base a ledge of same six feet thick; actual contact with No. 4 not observed although they are but a foot or so apart................28
4. Dolomite, or magnesian limestone, saccharoidal, light gray, weathering yellow, hard, compact, in obscure courses resembling rough masonry which become thinner and more distinct below................................19½
3. Dolomite, or magnesian limestone, dark gray, similar to No. 4 but evenly and distinctly stratified in layers one-half inch to three inches thick; weathering to quadrangular chipstone 3
2. Unexposed 1½
1. Limestone, Anamosa phase of Gower stage of Niagaran, finely granular, buff, finely laminated, with abundant casts of *Leperditia*.......................................12

COGGON SECTIONS

At Coggon, five miles due north of Central City, Buffalo creek cuts nearly to the base of the Wapsipinicon beds, and the Niagaran appears a mile east of the village at Nugent's quarry. Exposures in and about the town afford a general section reaching as high as the basal shaly beds of the Independence.

CUT OF ILLINOIS CENTRAL RAILWAY, ABOUT ONE-HALF MILE NORTH OF COGGON

FEET

9. Limestone, dark reddish 3
8. Limestone, buff or purplish, in layers from one inch to eight inches thick, containing nodules of quartz and calcite, and arenaceous with quartz sand and angular bits of chert 4
7. Shale, highly argillaceous, blue, thinly laminated; unfossiliferous 5

   The section is continued downward in the adjacent *Mains Quarry.*

6. Shale, greenish, and limestone, thin-layered, with imbedded limestone fragments 1½
5. Limestone, like No. 4 in the next section, but less variable 8

SECTION ADJOINING THE RAILWAY TRACK NORTH OF THE STATION

5.	Limestone, light yellow-gray calcilutite, in thin layers....	2
4.	Limestone, variable and lenticular, mottled, earthy-crystalline, in places composed of minute angular fragments of hard limestone with buff matrix. Siliceous, especially above, with black flint, in places becoming vesicular like pumice, probably from the removal of interstitial calcite	8
	With an interval of a few feet the section is continued in *Ashby's Quarry at the railway station.*	
3.	Limestone, gray, hard, compact subcrystalline magnesian layers from one inch to four inches thick, weathering into block chipstone	2
2.	Limestone, massive, pale buff, magnesian, moderately hard, granular, subcrystalline, porous and vesicular, with a few irregular cavities about an inch in diameter, in layers from eighteen to twenty-four inches thick, moulds of *Spirifer subumbonus* plentiful; lower two feet variable, in places brownish buff, semiearthy-semicrystalline	8
1.	Slope to water in river, elsewhere seen to be occupied by massive limestone similar to the above..........	6

In the above combined sections Nos. 6 and 7 are the Independence, and 1 to 5 inclusive belong to the Otis. Number 2 with No. 3 is the magnesian basal phase of the Otis designated as the Coggon beds by the writer before the identification of the prevalent fossil, *Spirifer subumbonus,* of both the magnesian lower and the nonmagnesian upper beds proved the identity of the Coggon with the Otis. While minor disturbances of sedimentation are to be noted, as in No. 4 and No. 6, no general brecciation is here displayed. The zone of the major brecciation, here as farther to the south, at Cedar Rapids, and west, as at Troy Mills, or north, at Quasqueton, no doubt lies above the basal Independence.

TROY MILLS SECTION

At Troy Mills, on the right bank of Wapsipinicon river below the dam, several square rods of the breccia of the major brecciation are exposed slightly above water level. The surface of this floor is hummocky, due to the relative resistances of different areas of breccia according to amount of matrix and degree of cementation.

The geological horizon is that of the Upper Davenport, and blocks of this hard, tough granular fossiliferous limestone, a foot and more in diameter are numerous. Some of these blocks show slickensides. The yellow fossiliferous fine-grained limestone immediately overlying the Upper Davenport beds also is involved and may be seen in undisturbed strata, in large fragments tilted and mingled with those of lower beds, and, under the bridge, in a ledge three or four yards long composed chiefly of shattered and partly brecciated rock of this horizon abutting at the west on a breccia of blocks of Upper Davenport.

An exceptional number of blocks show the juncture of the Lower Davenport calcilutite and the Upper Davenport coquina. Along the zone of juncture the laminæ of the former are flexed, broken, detached and imbedded in the paste of the latter rock. The brecciated beds from which such blocks were broken evidently were formed before the Upper Davenport was lithified. These blocks range from one foot to two and one-half feet in diameter, thus showing the firmness of their cementation and their ability to withstand without crush the stresses of the major brecciation which broke the bed into blocks and mingled them with fragments of other strata. Blocks are noted in which the contact is even and the calcilutite laminæ are undisturbed. But here a few small angular bits of the calcilutite occur sporadic in the Upper Davenport portion of the block. A block of two and a half feet diameter shows calcilutite laminæ mostly in place but partly bent and detached and imbedded in the granular fossiliferous paste. This block is also traversed by a half inch seam filled with the same paste and some calcite.

In one area of a yard square blocks chiefly of Upper Davenport are cemented with calcite which fills seams in places an inch and a half wide.

There are also areas of rubble breccia of calcilutite fragments set in interstitial yellow matrix of which but little is here arenaceous. The fragments when detached show no wear upon their edges, which remain as sharp as when first broken and show no corrosion upon their sides.

Two miles southeast of Troy Mills (southwest quarter of section 10, township 86 north, range 7 west) there is a noteworthy outcrop on the left bank of a small creek flowing into the river from the south and affording the following section:

FEET

3. Independence shale, buff and blue, weathering to clay, with some harder layers of crystalline-earthy limestone one or two inches thick, and dark brown earthy-granular limestone three to four inches thick, with some large siliceous

nodules. Slightly undulating in swells eight inches high and five feet long 13
2. Limestone, hard, brown and buff 2-3
1. Otis limestone, massive, crackled, seams healed with calcite, fossiliferous with *Spirifer subumbonus;* thickness to water level at east end 2¾

To the west a vertical fault, with a throw of about three feet, drops No. 1 just below water level.

On the hill overlooking this creek from the east the road gullies disclose about twenty-five feet of the Independence shale, overlain by five to ten feet of a breccia of small fragments of drab calcilutite—the Lower Davenport horizon.

Still farther down river on the right bank the following section is poorly exposed at the "Wolf's Den" (southeast quarter of the southeast quarter section 14, township 86 north, range VII west).

5. Upper Davenport horizon, seen in blocks of fossiliferous limestone on sloping hillside.
4. Lower Davenport horizon marked by a few poor outcrops of drab calcilutite breccia.
3. Lower Davenport breccia, in strongly cemented ledge, fragments of drab calcilutite up to one foot in diameter, set at all angles, matrix sparse 4
2. Limestone, rather hard, brown; mottled with masses of soft, light buff limestone whose upper surface is highly irregular and which is absent in places; maximum thickness 2½
1. Limestone, buff, earthy, fine-grained, evenly laminated, in beds up to five feet thick, to water's edge about.........15

About one mile down stream in the south half of section 24 a steep hillside fronting the Wapsipinicon on the right bank gives the following section:

FEET

8. Upper Davenport horizon, seen in blocks of fossiliferous limestone nine inches thick apparently in place eight feet above summit of No. 7.
7. Lower Davenport limestone, brown and gray calcilutite, in uneven, finely fragmental layers of two or three inches thickness 2
6. Independence limestone, in cliff, buff, soft, earthy, evenly laminated, beds undulating, in places brecciated, fragments and matrix alike but matrix more resistant. The removal of the angular and commonly quadrangular blocks by solution and other processes of weathering gives the surface of the brecciated beds where exposed in the cliff a peculiar reticulated appearance. The interstitial matrix is left in high relief as a network of thin limestone walls somewhat resembling those of septaria (figures 80 and 85). These matrix walls occamatrix walls occasionally are marked by close-set, low parallel linear ridges, giving them a finely laminated

appearance. The ridges, however, are not harder laminæ left in relief but are casts of the etched edges of the weaker laminæ of the formerly inclosed fragment. Hence a time sufficient for the etching of the sides of fragments elapsed after fragmentation before the completion of the filling with the matrix 18

5. Talus slope 18
4. Independence shale, argillo-calcareous, buff with blue cores, showing spheroidal weathering 2
3. Talus slope 3
2. Otis limestone, mottled brown and buff, in low gentle undulations, in places consists of drab calcilutite carrying *Spirifer subumbonus* and overlain with three inches of brown saccharoidal limestone .... ¾
1. Otis limestone, gray and browish gray, crystalline, in uneven layers about one inch thick; to level of the river... 2½

Number 6 of this section is apparently identical with No. 1 of the section at The Wolf's Den, and both strongly resemble the magnesian layers of Aungst's quarry of Vinton, which are referred to the lower beds of the Otis. But the presence of typical basal Independence in No. 4 of this section, thus closely paralleling the Kenwood section, and still more the presence of Otis limestone in No. 2, with the characteristic Otis fossil, *Spirifer subumbonus*—its most northerly known occurrence in Iowa—concur in identifying No. 6 with the Independence.

Down valley, as Wapsipinicon river cuts more and more deeply into the beds which bear its name, it reaches the base of the Otis limestone and enters the Niagaran dolomite at or near Central City. Two miles northwest of this village, at Granger's old quarry (southwest quarter of the southeast quarter of section 28, township 86 north, range 6 west), the Niagaran is still below water level, but the basal magnesian beds of the Otis are in force with characteristic fossils.[62]

CEDAR RIVER SECTIONS

THE LINN SECTION. ABANDONED CUT OF CHICAGO, MILWAUKEE AND SAINT PAUL RAILWAY. WEST OF LINN.

This cut, which scarps the bluffs on the left bank of Cedar river for the length of about three-quarters of a mile and offers a vertical section of about sixty feet, is one of the most extensive Wapsipinicon exposures in the state. The brecciated zone here involves all terranes of the Wapsipinicon except the Otis, whose

[62]Norton, W. H., Geology of Linn County: Iowa Geol. Surv., Vol. IV, pp. 149, 150.

calcilutites appear two miles to the southeast in old quarries along the Chicago, Rock Island and Pacific railway, but here have dipped beneath the level of the base of the outcrop. No exposure in the state shows more thoroughgoing and complete brecciation. Furthermore, this section is of exceptional importance in that it and the Brandon exposures recently discovered by Thomas offer the only outcrops of the fossiliferous Independence shales which are open to observation.

It is quite impossible to give any general vertical section of the chaotic brecciation displayed which will be applicable to it at all points. Here the breccia is composed largely of detritus of the buff Independence and there of Lower Davenport calcilutites. At one point fossiliferous limestones of the *Spirifer pennatus* beds are found commingled with blocks of the Upper Davenport and Lower Davenport at the bottom of the cut and at another the shaly Independence predominates to the summit.

The railway grade descends from fifty-nine feet above the river at the north end of the cut to twenty feet above it at the south end. The diagonal belt thus scarped has a total height of about sixty feet, but as the terrane dips southward the stratigraphic thickness of the section probably is considerably less.

It is possible to make out traces of a zonal arrangement of the material from the beds which have contributed to the breccia. Thus at the north end of the cut the highest beds are from a coral reef containing *Phillipsastrea billingsi, Acervularia,* numerous cyathophylloids and *Favosites.* In places along the top of the cut, but at a lower level than that of the coralline zone, the *Spirifer pennatus* beds are well-nigh continuous. Somewhat lower, the horizon of the Upper Davenport is marked in places by lines of huge blocks in which *Gypidula comis* is the common fossil. The Lower Davenport calcilutites are nowhere in place, but large areas of breccia are composed chiefly of the quadrangular fragments of these brittle, thinly laminated beds. The Independence is most conspicuous in tracts of exceptionally abundant buff, soft matrix.

Toward the south a wide, open valley tributary to the Cedar interrupts the section, dividing it into a south and a north cut, the latter being much the longer.

In the south cut, as in the north, the dip of ledges and the boundaries of areas of weak breccia trace obscure anticlines (figure 87). At the center of one of these upfolds, and four feet above the railway grade, occurs an interrupted ledge of massive soft saccharoidal limestone four feet thick, mottled white and brownish with some periphyral calcite crystals (A). Resting on this bed is a tract of buff sandy matrix of Independence facies with sporadic pebbles of white crystalline rock and of soft fine-grained buff limestone (B). Above this is a tract of rubble breccia of drab calcilutite fragments (C). It is surmounted by seven inches of buff soft limestone in part minutely

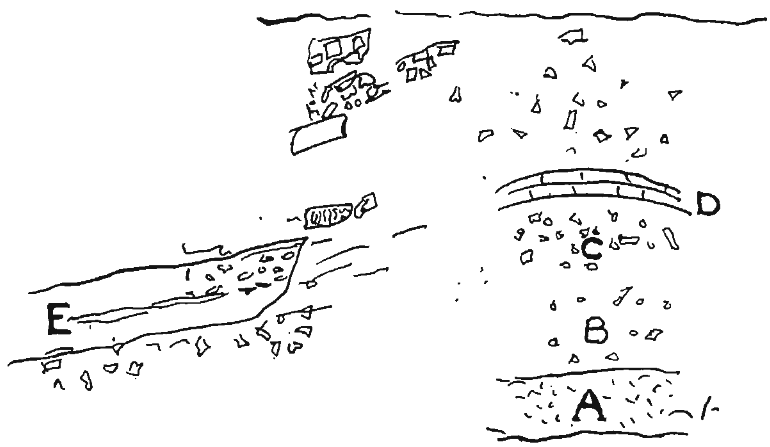


FIG. 87.—Section in the south part of the old railway cut west of Linn, Linn county.

fragmental, bent to an arch with a diameter of eight feet and a height of one foot (D). At the summit of this obscure anticline the breccia is somewhat fossiliferous (two specimens of *Atrypa reticularis* were observed), denoting a slight commingling of fossiliferous beds. The lowest ledge recalls the ledges of somewhat similar limestone seen at the base of the breccia of section E of Felton creek, Cedar Rapids.

A similar ledge occurs near the base of the northern limb of the arch. Here a ledge of limestone three feet thick is tilted northward at an angle of 10° (E). It consists of a layer two feet thick resting on a somewhat lenticular mass of brownish crystalline rock. The two-foot layer is composed above of whitish saccharoidal limestone inclosing small sparse fragments of a pinkish buff fine-grained limestone, with a few small calcilutite fragments. Within the same layer this whitish limestone passes downward into a four inch bed of pinkish buff rock identical with the fragments included in the whitish limestone. To the north the pinkish buff rock is little disturbed, except that calcite seams in relief show considerable crackling of the rock, but to the south it is much broken up and its fragments are imbedded in the matrix of the whitish rock above. At this end of the ledge the whitish rock also shows larger and more numerous fragments. The ledge thus records continuous but disturbed sedimentation. It rests upon a breccia of preponderant buff Independence matrix carrying near the top an elliptical six inch siliceous nodule. The ledge also abuts laterally on breccia of the same type. In juxtaposition at the south end are two large fragments each showing complex brecciation and parallelism of detached laminæ of calcilutite. The place of these whitish saccharoidal limestones seems to be the same as that of those seen in section A of the Felton creek exposures, that is at the base of the Lower Davenport.

A few rods from the lower end of the north cut and also at the northern base of a rude anticlinal structure there is seen a horizontal bed of breccia two feet thick whose unequiaxed fragments are set at all angles. These fragments range up to three inches in diameter and consist mostly of drab calcilutite with some small chips of light buff fine-grained limestone. The matrix is light buff and is little more than interstitial. In places it is slightly sandy. Upon this bed rests another layer of breccia one foot thick, whose close-set calcilutite fragments are smaller than those of the bed beneath. A little chert sand is visible but very little of the buff matrix rock is to be seen. There is considerable gray granular rock either as matrix, as fragments or as both.

The bedding of the layers indicates sedimentary deposition. In this case the high angles at which the unequiaxed fragments stand would point to flow en masse rather than to deposition of fragment after fragment by a slightly overloaded current. The fragments of the beds are similar to the fragments throughout these breccias in their angular unworn condition. The position of this ledge as well as its structure suggests comparison with the basal ledges in the south cut, and the fragmental structure of both seems to be due to minor brecciations during Lower Davenport time while the breaking up of the ledges is referred to the major brecciation.

Independence Areas of Breccia.—These are not areas in which the Independence has been preserved intact. They are areas of breccia characterized by the abundance of material which is referable to that formation. The large admixture of Independence detritus renders the breccia argillaceous and soft, so that these areas weather back to slopes. In comparison with the fragments of other and harder beds the soft buff Independence detritus appears as matrix. It is not a sediment in which the foreign fragments of hard rock have been imbedded; no lamination lines are seen within it as a rule; it is the fine detritus to which weak rock has been crushed in a brecciation involving harder beds. Other outcrops, however, show that sedimentary breccias were formed in Independence time, and a few probable relicts of such breccia are to be found in this section.

The larger of the Independence areas rise in the centers of rude and obscure upfolds with steeply outward-dipping areas of strong breccia on either hand, but smaller areas occur at several places in the section. Where it is most abundant, the material referred to the Independence weathers to flattened irregular lumps two inches and more in horizontal diameter, a structure similar to that seen in No. 7 of the Chicago, Rock Island and Pacific Railway cut at Cedar Rapids, where the shales are practically undisturbed. Much of the material is sparingly arenaceous, with disseminated bits of chert easily recognizable on weathered surfaces. These grains are not assembled into laminæ in the matrix rock but are sporadic like the larger fragments. They are not gathered around the base of larger fragments as if swept and lodged there by currents of water. Siliceous nodules of intercrystallized quartz and calcite, elliptical or ovate in shape and as much as a foot in longest diameter, occur sparingly. Some of these are set at high angles in the breccia.

FIG. 88.—An area of predominant Independence shale strongly bent and much broken with some included fragments. Strong Davenport breccia at left. Summit of arch, Linn section, Linn county.

Certain fragments of impure limestone in the breccia which probably belong to the Independence are a dingy buff color. Some of these are themselves sporadically fragmental, and in this case a disturbance of sedimentation in Independence time is inferred. At a few points some of the beds seem to have been preserved. At the lower end of the north cut a buttress of strong well-cemented limestone breccia rises abruptly from the tracks and forms natural ledges on the valley sides. Immediately beyond, an area of Independence, forty-five feet wide, gives rise to talus which rises within twelve feet of the summit of the cut. At three points the Independence breaks through to the top of the section in chimneys of weak shaly breccia and talus parted by towers of breccia of the upper limestones. At the north of this area of Independence, blocks of the higher formations descend steeply to the railway grade in well-nigh vertical cliffs. Along the summit of this Independence area one may find in places a fine gritless calcareous shale closely laminated and bent to strong convex curves to conform to the curves of the lower surface of the limestone breccia above or at either side. It is clearly impossible that the laminæ were deposited in their present attitude, and their deformation is attributed to the major brecciation (figure 88).

Some rods north of this area there appears midway the section a ledge of massive bluish limestone two feet thick, weathering to buff, soft, fine-grained, earthy, of Independence facies, dipping 20° to the north (figure 89, B). The bed contains very rare minute sporadic fragments of drab and buff limestone and some quartz nodules. It graduates above along an undulating line into light grayish buff clayey rock of about the same thickness, which weathers into minute chipstone and irregular lenticular lumps (C). This bed contains areas of finely laminated calcareous shale and weathers back beyond both the ledge below and a cornice above. The bed contains fragments of drab limestones more numerous than those of the ledge on which it rests but still small and sparse. The cornice which overhangs it is of breccia (D) whose fragments are larger and more numerous and better cemented than those of the beds beneath. The aspect of these beds is that of continuous deposition and recalls the bed of breccia intercalated in the little disturbed layers of the Independence in Section C of Felton creek, Cedar Rapids.

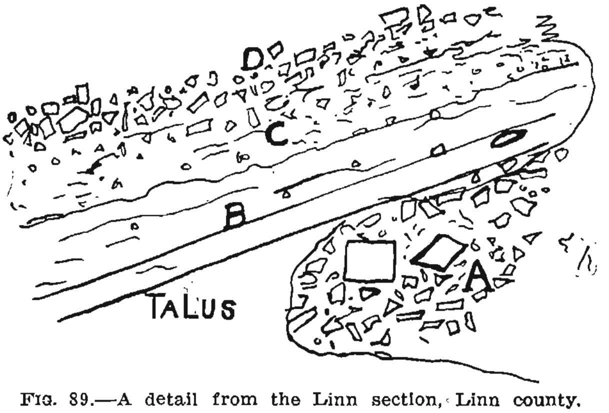


FIG. 89.—A detail from the Linn section, Linn county.

For ten feet this ledge of Independence facies overlies a tract of well-cemented rubble breccia (A) of Upper Davenport with an occasional fossiliferous fragment and Lower Davenport calcilutite fragments with sparse matrix, just as in the Vinton Railway cut a similar ledge, the lower part of which is laminated shale in place, rests upon a breccia carrying fossils of higher beds. For the reasons mentioned in the discussion of the Vinton section the ledge is referred to the Independence, and its fragmentation is referred to an Independence brecciation. The fossiliferous breccia underneath it is assumed to have been underthrust from the south, thus tilting it to a moderately high angle.

The Lower Davenport Zone of Brecciation.—The tracts to which calcilutites referable to the Lower Davenport have contributed the mass of the fragments do not offer any features different from those seen in other sections. The fragments are well cemented by a sparse calcareous matrix in some places gray and in others buff and slightly arenaceous. Here the stresses were sufficient to intermix fragments of the higher fossiliferous beds, and more than sufficient to destroy any ledges of mosaic breccia such as those seen at Quasqueton. But a few fragments, themselves of crackle or mosaic breccia, lead to the inference of a brecciation during Lower Davenport time or at its close, when such ledges were produced.

The Upper Davenport Zone of Brecciation.—The tough, hard beds of fossiliferous gray limestone (the *Gyroceras* beds of Calvin) are here more broken and displaced than in several other sections (Plate X). Yet in places they appear in interrupted ledges, the blocks tilted but retaining something of their initial attitude (Plate XI). The large size of a few of the blocks is noteworthy. One measures eleven feet in length with a thickness of two and one-half feet. The fracture planes are commonly smoothed and grooved with slickensides on a few of which calcite crusts have formed. These surfaces cut across bedding planes and transect the thick shells of *Gypidula* and other fossils. Besides these ledges near the summit of the section, large blocks and irregular masses of breccia of this type occur down to the level of the railway grade. Thus at the lower end of the north cut, blocks two to three feet in diameter are common and one

In Upper Davenport zone of brecciation, Linn section, Linn county.

block five feet long is seen. In this strong breccia blocks of Upper Davenport, Lower Davenport, and the *Spirifer pennatus* beds are mingled pell-mell without the slightest zonal arrangement except near the top where the *Spirifer pennatus* beds prevail. The matrix here is scant and of the sandy buff Independence material.

The stresses which broke the Upper Davenport into blocks seem to have been sufficient as a rule to detach from it the Lower Davenport laminæ. In one case only were the two lithologic types found conjoined in a single block. In this case the contact phenomena showed that there had been undisturbed continuous deposition without fracturing of the laminæ of the lower rock. Several blocks appear, however, which show calcilutite fragments imbedded in the Upper Davenport. Thus one seen near the base of the section at the lower end of the north cut contains twenty-two small angular sporadic calcilutite fragments in an area six inches square. All these were under one inch in diameter except a fragment three inches in size which itself was brecciated. Such crowding is quite exceptional. No lenticles of calcilutite arranged in lines parallel to the bedding have been observed.

Zone of the Spirifer pennatus beds.—A soft, yellow shaly highly fossiliferous limestone lies along the summit of the north cut. The beds are shattered and in places blocks are set on edge. Of these beds distinctive fragments also have been mingled with the rubble breccia beneath to the bottom of the cut.

An interesting block at the base of the north cut near the upper end consists of a large mass of *Diphyphyllum* coral between whose slender branches hundreds of the young of various species of brachiopods had found a sheltering home.

ELLIS PARK QUARRY, CEDAR RAPIDS

Figures 46 and 47, pages 380 and 381

This quarry, operated by the city for crushed stone, is situated at the northeastern edge of the park on the side of a bluff facing Cedar river. Beneath a shallow and here negligible cover of drift, the Independence appears as a buff calcareous shale.

The juncture of the shale with the Otis limestone beneath is particularly well marked. The upper zone of the limestone is characterized by the development of gigantic lenses. Beneath these the main body of the Otis consists of brown limestone, laminated in places, which passes downward into brown magnesian limestone vesicular at the base. The Otis has been thrown into low undulations and the beds are traversed with narrow vertical and oblique seams filled with calcite. The base of the section is nine feet above water level in the Cedar. Many of the layers are irregularly bedded, with brownish or black films covering rugose surfaces.

INDEPENDENCE.

		FEET
17.	Shale, buff, calcareous, weathering to clay, stratification shows in horizonal lines of cores of weathering and in harder thin beds. Easily cut down anywhere with spade. Small elliptical nodules of black flint occur and larger masses of intercrystallized quartz and calcite.........	8

OTIS.

16.	Limestone, lenticular or massive mottled buff and dark brown, or light gray and dark drab, fragmental in structure. Lenses up to nine feet in diameter and from three to five feet thick form the base of the stratum. These are overlain by massive limestone of the same structure or in places by thin overwrapping layers of hard drab limestone, whose laminæ are flexed and in places broken.	7
15.	Limestone, hard, brown, fine-grained with disseminated crystalline particles, some layers saccharoidal, in layers from three to eight inches thick, laminated conspicuously with narrow bands of alternating lighter and darker stone which may be as numerous as ten to the inch, and in places are slightly undulating. Overhanging layers show a mesh-work of projecting fissure casts. Some layers show narrow stylolitic surfaces. Closely filled nests of calcite, a few inches in diameter, occur. The stratum is flexed beneath lenses of No. 16..............	6
14.	Limestone, brown, finely crystalline, subconchoidal fracture, compact, rapid effervescence, crackled.............	2-3
13.	Limestone, brown, in irregular courses from one-half foot to two feet thick, parted by blackish films along rugose surfaces. Some layers affected throughout with lustrous cleavages of calcite. Some layers of calcilutite. One or two feet at base is massive, light brown crystalline or granular limestone with disseminated subangular or rounded darker masses a fraction of an inch in diameter. In the finely granular matrix rock these masses are of coarse saccharoidal limestone; in the more crystalline matrix they are in part or wholly of black flint......	4
12.	Limestone, calcilutite, light gray, moderately brisk effervescence, crackled with vertical and oblique calcite-filled seams, the fine hair-line seams grouped half a dozen to the inch, the larger three to four inches apart..........	1

Large blocks of Upper Davenport limestone in alignment, Linn section, Linn county.

11.	Limestone, brown, massive, rapid effervescence, in places traversed by calcite cleavages, in places mottled or minutely fragmental as is No. 13, but not so conspicuously, surface hummocky and minutely rough, parted from No. 12 by brownish crust	2
10.	Limestone, light gray calcilutite similar to No. 12, small calcite nests with diameters of one to three inches; massive, and parted from No. 9 along irregular surface	1 1-6
9.	Limestone, brown, crystalline, lenticular, slow effervescence, rather obscurely laminated with undulating lines and bands of more earthy and lighter colored rock, with elliptical calcite nests up to one foot in diameter	3½
8.	Limestone, crystalline, slow effervescence, buff and coarsely and highly vesicular above, brown, coarsely saccharoidal and more compact below	1 1-6
7.	Limestone, brown or black, macrocrystalline, rapid effervescence, passing into soft impure ochreous limestone with stretches of elongate cavities filled with calcite crystals mingled with ochreous-calcareous clay, upper surface parted from No. 8 by black crust	1-3
6.	Limestone, brown, hard, cryptocrystalline, crackled, slow effervescence, laminated, overwrapping in three layers the lenticular surface of No. 5	1 1-3
5.	Limestone, rough, buff, vesicular, lenticular, with elliptical calcite nests up to a foot in horizontal diameter; rather slow effervescence	1
4.	Limestone, hard, brown, cryptocrystalline, obscurely laminated, with lines of minute cavities resembling molds of short flexuous rods of less than a millimeter in diameter; effervescence varying from slow to moderately rapid	5
3.	Limestone, brown, laminated	½
2.	Limestone, brownish buff, massive, cryptocrystalline, vesicular, slow effervescence, upper surface irregular and stained reddish	¾
1.	Concealed to level of river	9

SNOUFFER'S QUARRY, CEDAR RAPIDS

Right Bank of Cedar River, Near Chicago, Rock Island and Pacific Railway Bridge (figure 51, page 400).

Pleistocene.

		FEET
19.	Loess, brown, weathered	5
18.	Sand, light yellow, in horizontal layers, graduating by interbanding into loess above	10
17.	Till, reddish	6

Independence.

16. Shale, calcareous, soft, buff, weathering to detached laminæ a fraction of an inch thick and to brittle flakes a millimeter in thickness. Harder layers of buff argillaceous limestone an inch or more thick are seen, also thin lenticles, which coalesce into layers an inch or so thick. These lenticles consist of saccharoidal calcite and some silica with interlaminated areas of soft impure buff

limestone. Lenses of silica up to three inches in thickness occur 6

15. Shale, calcareous, blue, weathering to buff 6

14. Shale, blue, thin-layered, fissile in flakes a fraction of an inch thick, unctuous on wet surfaces, spheroidal, weathering to lenticular surfaces 4

13. Shale, calcareous, blue, with close flexuous dark lines of lamination which knot into nodules in places. Layers up to five inches in thickness 2 1-3

12. Shale, calcareous, buff, with narrow blue cores, in layers from two to eight inches in thickness, wavy laminæ, lenticular partings 2

11. Limestone, blue, argillaceous, obscurely laminated, with small nests of dog-tooth spar horizontally arranged. Laminæ in places marked by close-set wavy lines. In two layers both of which thicken down the sides of the lenses of No. 9.. 2

OTIS.

10. Limestone, brown, weathering light gray, a calcilutite below becoming more or less crystalline-granular in texture above. Upper three inches laminated. Upper surface rugose and covered with thin clayey parting, and with hollows filled with calcite. This layer partly evens the depressions in the lenticular layer beneath and thus differs in thickness within a horizontal distance of four feet from four inches at the crown of the lens to one foot eight inches in the hollows..................... 1 2-3

9. Limestone, massive, lenticular, brown, saccharoidal, mottled buff or gray. Upper surface hummocky and rugose, parted from No. 10 by a thin selvage of brownish clay. Lower surface irregular with a clayey selvage and purplish decayed fragmental limestone four inches or less in thickness. Containing *Spirifer subumbonus*.

Fantastic mottlings (figure 50) affect particularly the upper two feet of this layer. A vertical arrangement in the mottling is marked, the buff earthy areas having the appearance of narrow irregular and discontinuous pipes in the mass of brown crystalline rock. The areas of differently colored rock meet on irregularly and minutely curved surfaces. In places small imbedded fragments of the buff rock are bounded by straight lines. The buff areas in places are replaced by gray rock. Both buff and gray areas are composed of soft argillaceous limestone or calcareous shale which is earthy but effervesces briskly in cold dilute HCl. Occasionally the gray is found to be somewhat granular-crystalline. The brown saccharoidal rock is in places shot through with calcite cleavages and a number of small rhombs of clear calcite occur. Small nodules of black flint with buff smooth surfaces are rarely found. At one point an area of one or two square feet contains numerous sporadic quadrangular fragments of whitish fine-grained laminated limestone less than one-half inch in size...............3 to 5

8. Limestone, massive, gray or light brown, parted from No. 9 by clayey selvage, conforms to lower surface of No. 9, rising between its lenses. Upper surfaces rugose with protuberances an inch and less in height and three inches wide but with a few three or four times as large.

The upper one to three inches fragmental with numerous small rounded fragments of soft light yellow limestone. The lower surface bends downward beneath the lenses of No. 9, but with a diminished curve 1

7. Limestone, light brown, weathering light gray, closely laminated with laminæ of different shades, somewhat wavy, but generally parallel and even. Small cavities with linear horizontal arrangement common. In places a little disturbed sedimentation is seen in broken inset laminæ. Some thin horizontal calcite seams............ 4
6. Limestone, calcilutite, light brown weathering to gray, massive, with some irregular half-inch cavities with horizontal arrangement. In parts of the quarry the stone is subcrystalline 2
5. Limestone, light brown, crystalline, laminæ gently undulated, of lighter and darker shades. At the west end of the quarry the lower two feet of this layer is massive and the basal part of this massive layer is broken and the fractures are filled with brown calcite. Some parts are mottled with black flint in sporadic irregular areas a fraction of an inch in diameter or with gray chert.... 3
4. Limestone, calcilutite, light yellow-gray, massive. The basal portion between the lenses of No. 3 is darker and minutely crystalline. Upper surface horizontal, lower surface conforming to curved surfaces of lenses of No. 3 2
3. Limestone, brown, crystalline, brisk effervescence; in places laminated with close set slightly wavy laminæ; nests of white calcite. This layer in places is lenticular and macrocrystalline with brown calcite crystals; its hummocky rugose upper surface is covered with a brownish or blackish crust of clay. Horizontal seams, one five feet long, of brown calcite crystals ....1 to 2
2. Limestone, calcilutite, light gray, laminated above, massive below 2 2-3
1. Limestone, brown, crystalline 1¼

The bedding of the quarry is fairly even and horizontal except where affected by the lenticular structures noted. The Independence, however, shows slight undulations of the strata. The beds of the Otis are quite generally traversed by vertical and oblique narrow cracks healed with calcite. These are more marked in the massive and brittle calcilutites.

CUT OF CHICAGO, ROCK ISLAND & PACIFIC RAILWAY.

Two and a quarter miles southeast of First Avenue, Cedar Rapids

This cut exhibits twenty feet of the Independence resting at the southeast end on ledges of the Otis. The entire body of the Independence is argillaceous and much of it is a fissile shale. Some more calcareous layers standing in relief on the weathered slope show a slight dip to the northwest. All layers are slightly undulating, and shaly beds show strong folds within narrow horizontal and vertical limits.

		FEET
10.	Shale, buff, calcareous, with large siliceous nodules......	4
9.	Limestone, argillaceous, brown, coarsely saccharoidal, weathering to dingy crystalline sand	2
8.	Limestone, whitish, fine-grained, brittle	1-3
7.	Shale, calcareous, with lumpy structure due to flattish irregular cakes which are traceable on vertical surfaces. Weathering to clay	5
6.	Limestone, argillaceous, brown, weathered parts crumbling under the fingers into sand	½
5.	Shale, blue, fissile, weathering to brittle flakes. In the midst of this bed there may be traced for ten feet a layer of slate colored earthy limestone from four to six inches thick made of lumpy fragments. At one point it forms a tiny lens whose interior is fissured like septaria and whose surface also is crackled....................	6
4.	Limestone, argillaceous, buff, with blue cores, with wavy laminæ, in layers up to nine inches thick..............	1½
3.	Shale	2
2.	Limestone, fine-grained, compact, blue weathering to grayish buff, earthy, fine-grained, in three layers, the lower crystalline, finely laminated, upper layer inconspicuously arenaceous with sporadic sand much of which consists of grains of black flint. These layers are wrapped evenly over the gently arching lenticular surfaces of No. 1, and in places thicken down the lens and thus even up the surface	1½
1.	Limestone, brown, saccharoidal, lenticular, with curved structure lines which have been opened by weathering directed outward and downward; mottled with buff or gray areas having a vertical arrangement. On the weathered edges of the beds these elongate splotches resemble buff stains left by a liquid trickling down the side of the brown rock. The buff areas are of a fine-grained earthy limestone on which weathering has etched out exceedingly fine lines of lamination. These lines are commonly concave and abut on the vertical sides of the area, where they are somewhat crumpled. In some a fragmental structure is indicated. As in other outcrops the boundaries of these mottlings are irregular, and some of them are rather intricately curved. The bluish gray mottlings are entirely similar to the buff except in color. At one point the buff finely laminated rock appears in an irregular band more than an inch wide and inclined at an angle of 30° above a parallel structure line in the lens. The band is finely laminated and the undulating laminæ are parallel with the edges of the band. In places laminæ of the brown crystalline rock are inclosed in the laminæ of the buff earthy rock. We have here contemporaneous deposition of the two while the dip of the band and the flexing of the laminæ indicate some distortion before the sediments became hard. The rock carries *Spirifer subumbonus*	5

CHICAGO AND NORTH WESTERN RAILWAY QUARRY, CEDAR RAPIDS.

This large quarry has been opened along the left bank of Cedar river southeast of the city. The section reaches from near the summit of the Independence to the lower magnesian beds of the Otis.

THE INDEPENDENCE

About thirty-five feet of the Independence have been preserved at the north end of the quarry, but over the larger part of the area most of the formation had been removed by erosion, and Pleistocene deposits rest upon the Otis limestone. A section near the north end along a north-south face is as follows (figure 90).

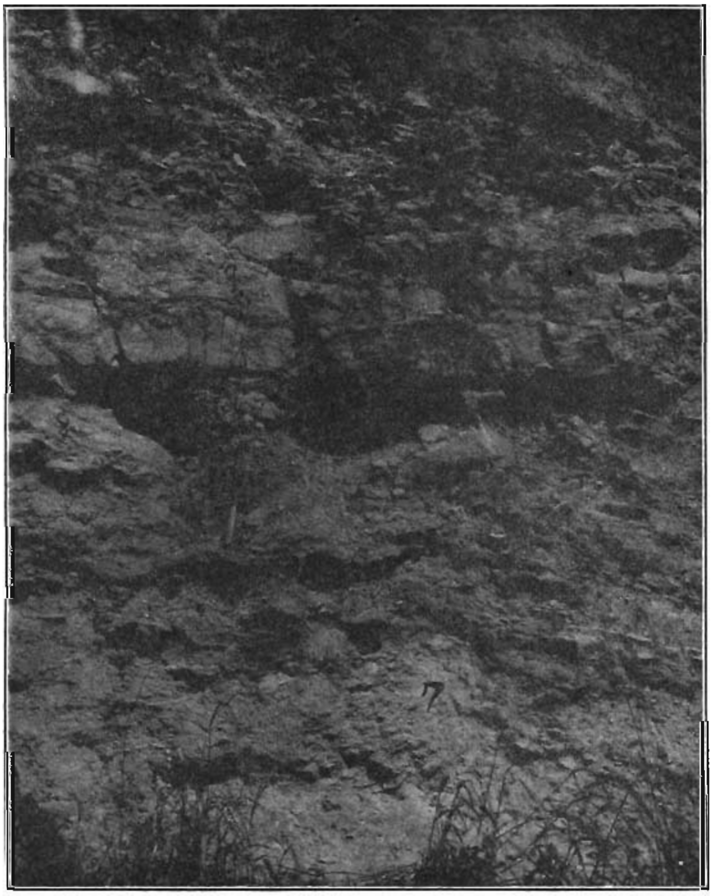


FIG. 90.—Independence limestone and shale. Quarry of the Chicago and North Western Railway Company, Cedar Rapids, Linn county.

FEET

9. Limestone, buff, earthy, weathering in places to thin plates, in even layers up to one foot thick, upper portion split to thin beds, slightly undulating and much shattered. In places the rock is speckled with disseminated darker crystals set in lighter granular rock. Commonly laminated with close-set wavy narrow lighter bands and darker more crystalline lines. In places the laminæ are bent to gentle folds less than a foot in width...........12

8. Limestone, fragmental, a rubble breccia, fragments small, usually a fraction of an inch in size, but some three and four inches long, angular, brown, finely crystalline, laminated, weathering to dark drab, finely granular surfaces. Matrix interstitial or somewhat larger in amount, soft, buff, in places weathers back leaving fragments in high relief. One larger fragment is seen to be shattered into quadrangular matching pieces. Upper surface hummocky. In places depressions are filled by the basal layer of No. 9, in places No. 8 graduates into No. 9 as its sporadic fragments are fewer and fewer upward within the limits of the same bed. Stratum continuous over most of outcrop, but in places gives way for two or three feet to masses of broken fragments of buff granular limestone similar to that of No. 9, half a foot or a foot in diameter. At one point the stratum graduates laterally into buff limestone with few sporadic fragments which graduates beneath into buff calcareous shale.

   This layer may be seen along a road leading into the quarry from the east and here it is less disturbed and is made up of clearly defined layers about two inches thick. These layers are themselves laminated, and the laminæ are more or less shattered and recemented within the limits of the layer. Some of the laminæ are merely broken without displacement and all degrees of rotation and displacement may be observed from this shatter-breccia to the condition where the entire bed is converted into a rubble breccia................................ 1

7. Shale, buff, calcareous, with some limestone, largely brecciated, fragments easily detached; in places flexed to narrow anticlines and synclines. At top is a bed in places two feet thick in which siliceous nodules, for the most part broken to a rubble of sharp-edged fragments, are specially conspicuous. There are also many buff fragments and some fragments of brown finely crystalline limestone with diameters as much as three inches. The matrix is abundant and clayey, and fragments are easily detached. The rock in places is minutely fragmental and here fragments and matrix are nearly alike. At one point a bed of fragmental limestone, strongly cemented, is arched, one limb descending three feet within a horizontal distance of five feet.

   On the section along the road leading into the quarry from the east there may be seen undulating strings of quadrangular pieces of flint, parallel with the undulating surface of the layer in which they lie. The brittle flint deposited in a continuous thin bed was broken into bits while the still plastic limy muds with which it was intercalated yielded to the stress by bending. In places the flint chips are so sporadically scattered in the midst of well defined layers that a contemporaneous breaking and deposition is implied.

Below these beds characterized by the abundance of siliceous fragments the breccia is softer, with the buff detritus as matrix or fragments more abundant, Siliceous nodules and fragments are found here. In places the matrix is highly arenaceous with angular grains of black and white flint and rounded grains of clear quartz sand. The lower part of these beds weathers to clay with cores of disintegration and fragments of shattered limestone layers largely in place. Much of lower part concealed by talus. Total thickness of No. 7............15

6. Limestone, buff, argillaceous, irregularly bedded, passing above into buff thin layers and arenaceous shales....... 3
5. Shale, buff, calcareous, weathering to clay............... 2
4. Limestone, blue, argillaceous, weathering to buff for an inch or so from bedding planes and joints, arenaceous in certain thin layers with sand of angular black and gray flint and rounded grains of crystalline quartz...... 2

Otis

3. Limestone, light gray, horizontally bedded, in thin irregular layers, fine of grain, fracture subconchoidal, seamed, contains some sporadic fragments of same rock........ 1
2. Limestone, brown, weathering gray, fine of grain, in uneven layers from a fraction of an inch to one foot thick, wrapping about lenticular masses of No. 1 with steep dips on the sides of the lenses and broken in places into breccia at their bases. In places sporadically fragmental with fragments the same as the matrix rock. Rock closely crackled, and seams passing through fragments as well as matrix. Sparingly fossiliferous with *Spirifer subumbonus.* Lenses of macrocrystalline brown limestone and of other types up to three feet in vertical diameter..................................... 4
1. Limestone of same general character as in Ellis Park and Snouffer's quarry 20

SECTIONS ALONG FELTON CREEK, CEDAR RAPIDS

SECTION A

A steep-sided narrow ravine takes its rise a few rods east of the Catholic cemetery, Cedar Rapids, and, continuing eastward a short distance, falls into Felton creek. This ravine gives the following section on the left bank near its mouth.

FEET

9. Breccia, fragments small, some six inches in diameter, dark drab weathering light gray, fine-grained, conchoidal fracture, some laminated, laminæ coherent and undulating, matrix buff, slight in amount. Along a path five feet below top of outcrop *Atrypa reticularis* and fragments of *Orthis* and *Spirifer* were found weathered out. Exposed in scattered bowlderets over slope of hillside in vertical distance of... 8

8. Breccia, matrix buff, abundant, fragments of calcilutite sparse, some with wavy laminæ some of which are two millemeters thick.................................... 4
7. Small outcrops of white saccharoidal limestone in places containing sporadic drab fragments, in places mottled white and buff.................................... 3
6. Limestone, buff, soft, vesicular, in layers about one foot thick. Obscure undulating lamination................ 7
5. Limestone, reddish buff, weathering to thin layers, closely laminated, laminæ etched out on weathered surfaces; darker, more vesicular buff laminæ alternating with lighter colored and more compact................. 8
4. Limestone in thicker layers and lighter color than above with thin, brownish irregular laminæ................. 3
3. Limestone, brown, in thin layers........................ 2
2. Limestone, buff, soft, earthy, fine-grained, massive, containing sparse small quadrangular fragments of hard dark drab limestone, edges mostly angular but not splintery, in places numerous but not in apposition, also fragments of thin laminæ of soft dark limestone; rare small nodules of dark gray flint 3
1. Limestone, buff, weathering to marl, with ledges of buff argillaceous rock with blue earthy-crystalline cores, speckled, the darker crystalline grains being set in a lighter earthy matrix, the crystalline grains left in relief on weathered surfaces. Sporadic fragments of dark bluish drab and of brownish crystalline limestone. The most characteristic feature is the abundant angular siliceous fragments and elliptical nodules some of which are as large as four inches in diameter. Small nodules of dark gray flint appear in places in the blue cores. In places the buff rock is thickly set with small quadrangular fragments of white chert as from broken laminæ a fraction of an inch thick, but for the most part the siliceous inclusions are crystalline............10

The base of this section lies about twelve feet above the level of the creek. About fifteen rods up the valley of the creek the summit of the Otis appears. In the above section Nos. 1 to 6 inclusive are referred to the Independence, while the higher beds are of the Lower Davenport, for the most part brecciated and including fragments from the fossiliferous horizons which overlie it.

SECTION B

This outcrop is that of the Otis limestone referred to in the preceding paragraph. The outcrop occurs in the bed of the creek in low domes of drab calcilutite. The one fully exposed measures twelve feet in diameter and exposes a foot and a half of its upper layers. Two other domes of about the same dimensions are partly exposed on the left bank where they are covered by the buff Independence. The limestone lies in convex layers from one-half inch to one foot thick, which are in part composed of tests of a minute spiral foraminifer (?). The surfaces are crackled with a close mesh as small as one-half inch in diameter.

SECTION C

A few rods north of this exposure of the summit of the Otis the creek bends to the east and extends about parallel with the Mount Vernon Road which lies on the divide to the north. Along the steeply rising creek floor there are exposed a number of sections from the base of the Independence to the fossiliferous beds of the Upper Davenport. A short distance above the turn to the east the bed and the banks of the creek offer the different members of section C, all of which belong to the Independence.

		FEET
5.	Limestone, buff and gray, compact, finely laminated, approximately horizontal, in weathered spalls from a small fraction of an inch to 2-3 inch thick..................	5½
4.	Limestone, dark buff, of same texture as above but less finely laminated, in three layers. Undulating in swells eighteen feet in length and one or two feet high. At the bottom of a syncline these layers are broken into a mass of blocks, some a foot and more in length, forming a coarse breccia	2½
3.	Breccia, buff or blue in color, soft, so that fragments stand in relief on weathered surfaces and can be easily detached with the fingers. Matrix abundant, buff, soft, argillaceous, or in places blue, harder, more calcareous; in places irregular masses of a clay shale dark brown or blackish. Fragments less in bulk than matrix, not in apposition, angular and unrolled, set at all angles, mostly small, commonly less than two inches in diameter, rarely as large as four inches, of lithologically various types, including:	
	A soft buff rock like matrix except that it is thinly laminated and laminæ have dark argillaceous surfaces like No. 4 of section A.	
	Shale in small fissile blocks.	
	Limestone, dark drab, compact, hard, subcrystalline.	
	Limestone, brown, hard, fine-grained, conchoidal fracture, with small disseminated crystals of calcite.	
	Limestone, hard, blue, obscurely laminated, subcrystalline.	
	Limestone, hard, buff, compact, laminated, contains black flint in discontinuous laminæ.	
	Limestone, blue, gray, saccharoidal.	
	Nodules and fragments of crystalline silica.	
	Sand, siliceous, in matrix consisting of angular siliceous grains, blackish white and gray, and well rounded grains of clear quartz the largest of which are one-half millimeter in diameter.	
	All of these types are found in the Independence, and some occur also in the Otis.	
	Total thickness of this bed.........................	6

2.	Limestone, gray weathering buff, soft, upper surface smooth, unscored, overlain in places with an inch or two of drab or blackish shale slightly undulating............	½
1.	Limestone, blue weathering buff, argillaceous, saccharoidal and earthy, in irregularly bedded rough surfaced layers six and eight inches in thickness, lower two feet more massive and containing elliptical siliceous nodules......	3

SECTION D

About thirty-five rods up valley there is exposed on the left bank five feet of brown crystalline limestone weathering light gray, in irregularly bedded layers with a maximum thickness of six inches. The strata run approximately horizontal but with slight noticeable undulations. The lower layers are laminated and resemble the upper layers of the preceding section.

SECTION E

Figure 91, page 523

A few rods north and across the valley an old quarry gives a section of about twenty feet whose base is not far from the top of section D.

Zonal arrangement.—While the strata of the exposure are brecciated from top to bottom, it is possible to make out zones characterized by the predominance of certain types of rock referable to different terranes. Thus an upper zone, particularly at the west, is characterized by prevalence of blocks of the gray fossiliferous rock of the Upper Davenport. In a middle zone crackled blocks and mosaic and rubble breccia of the Lower Davenport gray calcilutites prevail. A basal zone presents large blocks of crystalline fragmental limestone. There are also areas affecting the centers of the archings to be mentioned which are characterized by a large amount of a soft buff argillo-calcareous material. These areas are found also intercepting the blocks of the basal zone and in some cases immediately above it.

The boundaries of these zones are by no means well defined. Fragments of the fossiliferous Upper Davenport may be found sporadically intermingled with fine rubble breccia, near the base of the middle zone. Fragments of the characteristic limestones of the basal zone and of the Lower Davenport calcilutite occur in places at the summit of the section and the detritus of the soft buff earthy beds ranges from top to bottom.

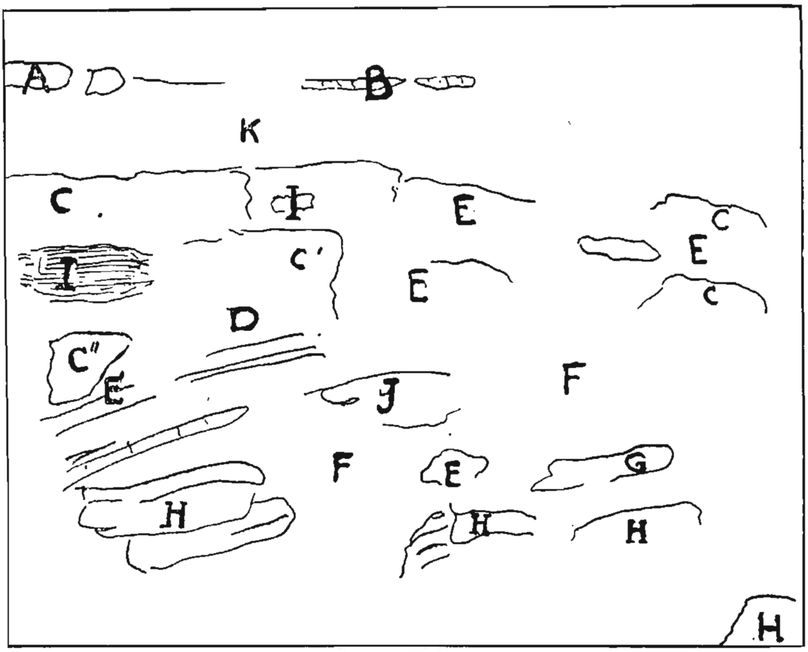


FIG. 91.—Outline sketch of the eastern end of section E, Felton creek, Cedar Rapids, Linn county. A, Upper Davenport with inclosed sporadic fragments of calcilutite. B, Crackled layers of Lower Davenport calcilutite. C, Mosaic breccia of Lower Davenport fragments. (C" crackled block of Lower Davenport). D, Rubble breccia of Lower Davenport fragments. E, Large buff Independence detritus with much Lower Davenport rubble. F, Predominant buff detritus. G, Limestone, buff, Independence facies. H, Crystalline limestone. Basal Lower Davenport type. Commonly with sporadic fragments. I, Mass of buff limestone with a few sporadic gray crystalline fragments. J, Mass of buff crystalline limestone with sporadic white fragments. K, Slope with fossiliferous fragments among others.

Structure Lines.—In the midst of the general chaos accordantly dipping blocks and ledges of the same rock and the boundaries between different belts of breccia trace ill-defined lines of structure. Thus near the east end of the quarry certain ledges have a dip of 13° and 16° W., while ledges of crackle and rubble breccia of the Lower Davenport zone have a still sharper descent (figure 91). Here too in the center of the anticline whose western limb is traced by the ledges mentioned the areas of buff shaly rock rise to near the summit. Structure lines are to be seen in certain archings in the basal zone, where a stratum eleven feet long and more than a foot thick has been bent upward and broken into three faulted blocks.

Zone of the Upper Davenport.—Along the summit from the center of the outcrop toward the west and especially at the west end down the sides of an ill-defined syncline are found numerous blocks of the Upper Davenport limestone. Weathered outcrops along the summit yield the following fossils: *Gypidula comis, Schizophoria macfarlanei, S. iowensis, Atrypa reticularis, A. aspera* var. *occidentalis, Pholidostrophia nacrea, Spirifer bimesialis* and *S. pennatus;* but under the conditions of strong brecciation prevailing here, it can not be certain that none of these are weathered from fragments of higher beds.

The size of the blocks is not so large as in some other sections of this horizon although blocks a foot or so in diameter are common. An unusual number of blocks include both Lower Davenport calcilutite and the Upper Davenport limestones. In some of these the Lower Davenport is shattered or brecciated and the Upper Davenport paste descends into the interstices of the calcilutite fragments or these fragments are found sporadic in the paste (figure 72). Still more common are blocks of Upper Davenport with small quadrangular fragments of calcilutite imbedded, in some cases rather thickly. At the summit of the section on the east end are rather large thin slabs of greatly crackled calcilutite whose interstices are filled with a granular gray paste which apparently is Upper Davenport, although it is not fossiliferous (figure 66, figure 91).

Lower Davenport Zone.—(Figure 91 C, C′, C″, D; figure 70). This is characterized by the prevalence of the calcilutites referred to the Lower Davenport. The rock weathers to a light blue-gray, and the interiors of fragments are yellowish or light brownish in color. It is of lithographic fineness of grain, brittle, and breaks with conchoidal fracture. Much of it is finely laminated. Fragments occur with pustulose surfaces. In certain ledges the rock is a crackle breccia and the narrow ruptures are filled with calcite. This graduates into mosaic and close-set rubble breccia with fragments of various sizes down to finest chinkstone and all of the same rock and set at all angles. Farther on in the ledge fragments of other types intermingle. Blocks of Upper Davenport are found at the bottom as well as at the top of the zone, and a similar range obtains for the fragments of the well marked limestones from the ledges of the lower zone.

In small irregular areas the rubble breccia is composed of fragments of all kinds commingled, and a fraction of an inch in size, but these areas do not resemble in outline layers deposited by water, as no bedding planes are seen within them, nor are the fragments waterworn. In places fragments of buff soft limestone and its detritus prevail and here the breccia is weak and weathers back under cornices of the stronger breccia of the prevailing Lower Davenport calcilutite.

The Lower Zone (figure 91, H).—This zone, which extends upward for seven or eight feet from the base of the section, is characterized by heavily or irregularly bedded crystalline fragmental limestones in large blocks which are arched, faulted, and widely interrupted. In some cases these are of hard brown crystalline granular rock, weathering to drab, with nests of calcite, and very sparse small fragments and with lenticular structure more or less developed. In other cases the rock is conspicuously fragmental and is composed of fragments of whitish fine saccharoidal limestone, and fine-grained light buff limestone which is very sparingly arenaceous with small angular grains of white chert. In all the basal blocks of either type, a few small rectangular fragments of drab laminated calcilutite occur. While these beds are fragmental there can be no doubt of their deposition under water. Thus the faulted stratum of figure 73 shows in the upper three or four inches distinct lines of lamination which are parallel with the surface of the block though they are somewhat broken and displaced. Strings of dislocated laminæ still retain their parallelism with the bedding planes of the block.

Especially in the cores of the anticlines we have buff, finely granular earthy limestone (figure 91, E. F). It occurs in strongly inclined beds a foot thick which are continuous for a yard or so and thence merge into a rubble derived from its own fragmentation and from that of similar beds. It is found in fragments, some of which are of considerable size, which are mingled with the fragments of the calcilutite rubble breccia, and apparently it is its finer detritus that forms so much of the interstitial matrix of this rubble. In places the rock has a pronounced lumpy lenticular structure as if it were composed of small flattish irregular lenses. Angular sand of flint and rounded grains of quartz are in places noticeable while in others they are nearly or entirely absent. This buff earthy and somewhat arenaceous constituent of the breccia is referred to the Independence. Its horizon seems to lie beneath that of the crystalline limestones of the basal zone, which then may be assigned to the Lower Davenport, although it is a question not easily determined and one of no special importance on which side of the division line between the two terranes these limestones should be placed.

SECTION F

A few rods up valley from section E a small quarry shows at top about four feet of the Upper Davenport in ledges little disturbed and in slickensided blocks. Weathered chipstone on the surface of the ledges yielded the following numbers of different fossils, which probably is some indication of their relative proportions in the rock.

Atrypa reticularis	39
A. aspera var. occidentalis	16
Gypidula comis	11
Schizophoria iowensis (?)[63]	8
Stropheodonta plicata	7
Pholidostrophia nacrea	6
Schizophoria macfarlanei	3
Stropheodonta demissa	1
Gyroceras sp.	3

The Upper Davenport exhibits small angular imbedded fragments of calcilutite as is the case at other outcrops.

At a lower level the stripping of the quarry shows the whitish Lower Davenport calcilutite in crackled shattered masses which appear to be largely in place, but which graduate into areas of rubble breccia of the same material but mingled with fragments of other horizons, such as slickensided blocks of the Upper Davenport. The lower part of the quarry face shows rubble breccia which is blue at bottom and buff above, the line of oxidation passing through imbedded fragments.

KENWOOD SECTION

At Kenwood, on the right bank of Indian creek, a cliff about fifty feet in height displays at top the Lower Davenport lime-

[63]Some fragments included are not distinguishable from *S. macfarlanei.*

Cliff at Kenwood, Linn county.

stone in part but little disturbed and in part thoroughly brecciated with the Upper Davenport. The full thickness of the Independence is shown in the center of the section, while at the base appear the upper beds of the Otis calcilutites carrying *Spirifer subumbonus.*

FEET

6. Breccia (Plate XII, E), rubble of well cemented small fragments of Lower Davenport drab calcilutite, weathering whitish, many of them crackled, with some included blocks of gray granular fossiliferous Upper Davenport limestone, some of which are a foot in diameter. Some of these blocks include sporadic fragments of drab calcilutite, a fraction of an inch in diameter. Matrix small in amount, interstitial, yellowish. This mass of breccia occupies the center of a low syncline. It thins to the left and apparently is here less well cemented, since it weathers back. Fossiliferous fragments carrying the First Fauna are found to the base of the mass..........11
5. Limestone, Lower Davenport (D, Plate XII); at east end (left of Plate XII) is a light pinkish gray limestone weathering whitish, bedding irregular or obscure, in places distinct and even, partly brecciated. Laminated areas are seen where the laminæ are bent in short flexures and in some instances are brecciated at the axes of the synclines. In places masses of thin calcareous plates four inches thick, are set on edge. A brecciated bed six inches thick is seen to be covered by a layer four inches thick which is closely laminated and crackled, with vertical and oblique seams which are filled with calcite. This crackled layer graduates upward into a brecciated bed to the base of which it furnishes fragments which lie approximately parallel to the bedding. Matrix similar to fragments but of yellowish tinge. No buff sandy Independence matrix observed. At base of No. 5 lies a layer of crystalline lenticular rock one foot four inches thick whose laminæ are coherent. Number 5 descends gently to the west forming a cornice above the weaker rock of No. 4........ 7

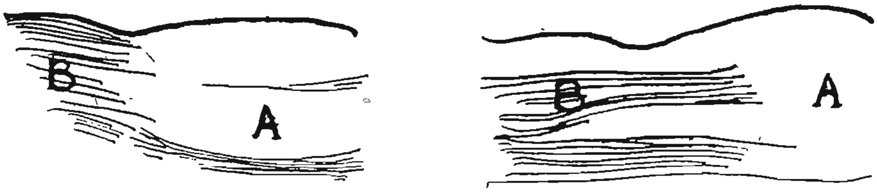


FIG. 92.—Passage of massive vesicular buff Independence limestone (A) into laminated limestone (B); thickness of bed about one foot, Kenwood, Linn county.

4. Limestones, Independence, brownish and buff, dingy, earthy, in places massive, in places graduating laterally or passing abruptly into thin reddish calcareous plates (figure 92). Along the eastern part of the outcrop (left of Plate XII) undulating laminated shaly beds predominate for some eight feet vertically beneath the

cornice of No. 5. Here occur small lenticles of massive rock. To the west of the mass of breccia of No. 6 (E, Plate XII) these shaly beds merge into massive dingy limestone which forms the apparent downfold on the right of the area shown in Plate XII. This lenticular mass at base passes to the right into calcareous plates which dip 20° E. parallel with the lower surface of the lens. These calcareous plates are themselves brecciated in places and the massive limestone of the lens also shows in places included angular blocks which are now standing on edge and which consist of the same dingy limestone as the rest of the lens. Siliceous angular fragments and broken elliptical siliceous nodules are common at this horizon..15

3. Shales. (B, Plate XII) blue weathering buff, calcareous, weathering to slopes of marly clay. Toward the top they contain siliceous nodules and fragments of flint. Some beds show spheroidal weathering. In places fissile 15
2. Shaly parting, fissile, greenish .... ½
1. Limestone, Otis (A, Plate XII) drab, dense, in layers four or five inches thick carrying *Spirifer subumbonus*. Smoothly bedded, layers parallel, in long gentle undulations, in places slightly fragmental; fragments a fraction of an inch in diameter and of same texture as the matrix rock, but slightly darker................ 8¼

Johnson County

The Devonian-Silurian frontier passes diagonally across the northeastern township of Johnson county, parallel with the course of Cedar river. The only exposures of the Silurian are found in the cliffs sixty feet high along the river bluffs. These show the LeClaire phase of the Gower stage of the Niagaran. A belt several miles in width intervenes in which no outcrops occur. Near Elmira and Solon the Devonian appears in a breccia whose place is near the summit of the brecciated zone of the Wapsipinicon. As Calvin[64] states on the evidence of deep wells over the belt of drift, "This region, or at least a part of it, seems therefore to be occupied by a preglacial valley over which the limestones and shales were cut away." The strata thus removed include the Bertram and Otis limestones and the Independence.

SOLON SECTION

About forty rods north of Solon the road cuts through ledges of breccia in some of which the Independence predominates, although for the most part the breccia is made up of "angular

[64]Calvin, S., Iowa Geol. Surv., Vol. 7, p. 58, Des Moines, 1897.

fragments of very fine-grained gray or drab limestone lying in all possible positions in a softer lighter colored gray matrix.''[65] At the northern edge of Solon an exposure shows small areas of the dingy buff argillaceous Independence underneath the rubble of Lower Davenport. Elsewhere in the northern part of the town the breccia beds involve the fossiliferous beds and fragments contain *Atrypa reticularis, A. aspera* var. *occidentalis, Schizophoria iowensis* and *Gypidula comis.*

On the western edge of the town occur partly brecciated beds belonging to the Upper Davenport. The brachiopod fauna as given by Calvin includes *Gypidula comis, Schizophoria macfarlanei, Hypothyridina cuboides, Spirifer pennatus,* and the Atrypas. ''The strata at this point are very much shattered, the bedding planes are obliterated, oblique joints intersect the beds and divide the mass into numberless shapeless pieces from a few inches to a foot or more in diameter,[66] the texture is coarse and granular.''

ELMIRA SECTION

A mile north of Elmira Calvin found an exposure of fossiliferous limestone, in some of whose beds, he states, ''the brecciation is more complete than any seen at the corresponding horizon at Solon.''[67] As in other counties, brecciation is associated with low foldings of the strata. Thus down the valley of Rapid creek from the outcrop noted, the rocks lie in a series of low arches, and at some points the axes of the anticlines are found brecciated. An example given by Calvin is in Graham township (southeast quarter of the northeast quarter of section 20). ''Here the fold is quite sharp, the strata dipping from the axis on either side at an angle of fifteen degrees.'' The axis of the fold shows the following section:

		FEET
3.	*Megistocrinus* beds evenly bedded	6
2.	*Phillipsastrea billingsi* beds, not shattered or brecciated	8
1.	Limestone, imperfectly bedded, very much shattered and divided into small angular pieces by oblique joints; fauna contains *Schizophoria iowensis, Atrypa reticularis, A. aspera* var. *occidentalis* and *Gypidula comis*	12

[65]Calvin, ibid. p. 58.
[66]Calvin, ibid, p. 59.
[67]Ibid. p. 60.

The line separating the Wapsipinicon and the Cedar Valley is drawn by Calvin between Nos. 1 and 2.

Cedar County

Cedar county exhibits some of the clearest contacts between the Devonian and the Silurian to be found within the state. Owing to the large quarries at Cedar Valley and at Lime City the basal magnesian beds of the Otis, which here lie above the quarry rock of the Niagaran, are exceptionally well displayed. The Otis calcilutites are seen in typical facies and relations, but in only a few outcrops and in no great force. Sections of Independence are very rare. A deep railway cut, such as that of the Chicago, Milwaukee and St. Paul at Fayette or west of Linn, or that of the Chicago, Rock Island and Pacific north of Vinton would be very welcome to the geologist in any township of Cedar county where it would trench the Independence and its inclosing strong terranes. For lack of good natural or artificial sections of the Independence it is difficult to refer certain ledges of calcitutite definitely to either the Otis or the Lower Davenport. Where the Lower Davenport horizon is defined by the presence of the Upper Davenport the lower formation is found to be brecciated. In the absence of any deep or extensive sections of the upper terranes of the Wapsipinicon it is difficult also to speak with certainty as to the intensity of brecciation. It seems safe to say that brecciation is less pronounced than in Linn county to the northwest and more pronounced than in Scott county to the southeast.

The Otis exhibits in force the lower magnesian, or Coggon phase, which embraces here not only soft vesicular and fossiliferous earthy limestone but also saccharoidal limestones weathering to crystalline sand. The upper horizons also embrace a variety of lithologic types—the lenticular masses and reefs of calcilutite carrying *Spirifer subumbonus,* and the brown limestone shot through with cleavage planes of calcite, all characteristic of the horizon immediately beneath the Independence.

The Independence shows a typical dingy impure buff limestone which in places is speckled. A seam of black shale underlain with thin brown sandstone outcrops at one point in a road section. There also occur saccharoidal limestones of various colors, some of which are mottled with argillaceous material. These are probably of chemical deposition—an inference confirmed in one instance by the inclusion of minute perfect hexagonal crystals of clear quartz. No outcrops of blue calcareous shale, or of fossiliferous shale have come under observation. Nodules of silica intercrystallized with calcite are characteristic. As they decay these nodules leave curiously carious surfaces.

The Lower Davenport shows massive ledges of calcilutite, which at places graduate laterally into thin plates and the usual breccia of drab calcilutite fragments. The Upper Davenport follows the Scott county and Linn county type of a tough granular fossiliferous limestone with *Gypidula comis* as its most common fossil.

Zones of brecciation of the Wapsipinicon terranes are visible only in road cuttings and a few other very imperfect sections. Little can be expected from such data except scraps of evidence confirming or casting doubt on conclusions reached by the study of more complete sections in other counties.

The Lower Davenport exhibits the usual intense brecciation which formed a rubble of angular calcilutite fragments, but in places crackle and mosaic breccia bring us nearer to the initial condition of the beds. Complex brecciation obtains in fragments which show broken and detached laminæ imbedded in a paste and with their parallelism in part preserved, indicating that the first brecciation was contemporaneous with the deposit of the beds. The Independence also shows in places local and contemporaneous brecciation. Sporadic fragments in some beds of the Otis also show disturbed sedimentation. The basal magnesian beds of the Otis show no evidences of stress or of interruptions to the normal course of sedimentary deposit. It is probably owing in part to lack of good sections that archings and flexures of the strata are so seldom seen. The best example noted is that described in the section given on page 538 (southeast quarter of section 8, township 79, range II west), where the beds below the Lower Davenport breccia have been thrown into a series of low arches.

SILURO-DEVONIAN CONTACTS

In Cedar county the Devonian rests on the Gower limestone, which is quite free from siliceous inclusions, instead of on the cherty Hopkinton as in the northern counties of the Devonian area. The basal conglomerate, or rather the beach breccia, of cherty angular fragments, which is present in the lowest Otis in Fayette and Bremer counties, is here absent. Where the Otis rests upon the hard crystalline LeClaire lime rock of the Gower the latter was able in at least one instance to supply limestone fragments to the lower two feet of the Otis to form a beach breccia which has the characteristics of a basal conglomerate. But where the Otis was laid upon the soft Anamosa rock of the Gower its basal layers are free from inclusions of the older stone. In places the magnesian beds of the Otis are absent and the nonmagnesian saccharoidal limestone rests upon the Niagaran.

ROCK CREEK SECTION

(Section 25, Township 80 North, Range III West)

		FEET
3.	Limestone, soft, buff, vesicular, in layers about eighteen inches thick of Coggon facies and fossils, exposed at two horizons within a vertical distance of............	8
2.	Limestone, buff, horizontally bedded, finely granular, in layers from one-half inch to six inches thick. The horizontal face exposed in the bed of the draw shows interlacing seams along which weathering has taken place and *imbedded angular bowlders of the underlying LeClaire, some of which are two feet in diameter, also small imbedded fragments of the same rock*............	2
1.	Limestone, hard, gray, crystalline, of typical LeClaire facies, fossiliferous, in heavy beds dipping as high as 30°, in recurring ledges to water in creek............	20

At the head of the ravines which here descend to Rock creek there outcrops at the height of about fifty feet above the creek, a dark brown macrocrystalline nonmagnesian limestone characteristic of the higher beds of the Otis as these may be seen at the station of the same name and at Cedar Rapids. This well marked horizon, considered in connection with the summit of the LeClaire below would indicate a thickness for the Otis of not far from thirty feet.

SECTION AT BEALER'S QUARRY, CEDAR VALLEY

OTIS LIMESTONE, COGGON PHASE

		FEET
6.	Limestone, hard, dense, yellow-gray, breaking into large rhombic chipstone by diagonal cracks about six inches apart	1
5.	Limestone, laminated of similar texture as No. 6, in spalls one to four inches thick	1
4.	Limestone, soft, granular, laminated, with minute moulds of brachiopods	1
3.	Limestone, soft, light buff, with occasional lenses of dark flint, fossiliferous with minute moulds, in layers up to one foot in thickness	2½
2.	Limestone, in massive layers about three feet thick, soft, earthy, buff, with some flint nodules, and with many characteristic specimens of Coggon fossils, *Spirifer subumbonus*, and trilobite pygidia	7
	NIAGARAN LIMESTONE, ANAMOSA PHASE	
1.	Limestone, horizontally bedded, with apparently conformable contact with No. 2, light buff, granular, even-bedded, quarried for building stone	100

The Otis is seen to rest on the tilted layers of the LeClaire phase of the Gower or on its equally characteristic calcareous massifs at the lime quarries at Cedar Valley and at Lime City. Another contact between the LeClaire and Coggon may be seen on Rock creek, in the northeast quarter of section four of township 80, range 3 west.[68]

The Coggon magnesian phase of the Otis is not everywhere present. Thus at the crossing of Rock creek on the Tipton-Rochester road, southeast quarter of the southwest quarter of section 23, township 80 N., range II W., the following section may be observed below the bridge:

		FEET
4.	Limestone, briskly effervescent in cold dilute HCl, irregularly bedded, in part massive, in bed five feet thick, without trace of stratification, but with imbedded sporadic fragments of fine-grained yellow magnesian limestone. Abutting on this in places is drab dense limestone weathering to layers an inch thick. Elsewhere the rock appears in courses two feet thick, highly crystalline, pink and yellowish green, with lines of lamination indicated by different tints. Upper layers brownish, macrocrystalline	11
3.	Limestone, reddish, crystalline, saccharoidal, approximately horizontal, briskly effervescent, in two layers	2
2.	Contact of Nos. 3 and 1 not observed.	
1.	Dolomite, Gower, dipping 30° SSE	20

Above the bridge the macrocrystalline nonmagnesian limestone of the Wapsipinicon comes again within four feet of the Gower dolomite, which here dips at angles exceeding 45°.

[68]Norton, W. H., Iowa Geol. Surv., Vol. XI, p. 329. Des Moines, 1901.

THE OTIS, INDEPENDENCE AND LOWER DAVENPORT

In Cedar county as in Linn the Otis exhibits quite a variety of lithologic types. The following section shows a larger amount of crystalline limestones than is common. All these layers of the Otis from No. 2 up, are magnesian, are useless for building stone, and because of their crystalline-granular texture are called "sand rock" by the workmen. All are practically horizontal.

BUILDING STONE QUARRY, LIME CITY

OTIS

	FEET
7. Limestone, saccharoidal, slightly pinkish, laminæ up to four inches thick	1
6. Limestone, white, saccharoidal, with close coherent laminæ	2
5. Limestone, yellow-gray, soft, earthy luster, weathering to layers two to four inches thick	2½
4. Limestone, saccharoidal, pink and yellowish gray, decaying into crystalline limestone sand. This layer changes both laterally and vertically into brittle, gray, dense fine-grained rock in layers one to four inches thick which breaks into rhombic chipstone of dull earthy luster	6
3. Limestone, light buff, saccharoidal, in heavy laminated courses, weathering to fine crystalline sand	5
2. Limestone, massive, highly vesicular, with moulds of fossils of Coggon phase	3¾
GOWER	
1. Dolomite, hard, crystalline	22

The only locality where the Otis calcilutite upper beds are found to be fossiliferous is that of the following section, which shows also the Coggon magnesian phase beneath and the Independence above. The presence of black shale in the Independence suggests the coal found in the formation in Linn county. The streak of sandstone is exceptional.

SUGAR CREEK SECTION

On Sugar creek and in the road to the west at the bridge between section 3, township 79, and section 34, township 80, is exposed the following section:

INDEPENDENCE	FEET
12. Limestone, buff, argillaceous, weathering to calcareous clay with some harder layers of buff dense dark speckled limestone, some finely laminated, all briskly effervescent in cold dilute HCl., with lenticular nodules of silica having carious surfaces from the solution of intercrystallized calcite	18

11.	Limestone, buff, earthy, breaking into rhombic chipstone, at base a layer of green clay one-half inch thick	2½
10.	Limestone, buff, soft, more or less crackled	2
9.	Shale, black, argillaceous	1-6
8.	Sandstone, brown	½
7.	Limestone, buff, earthy, crossed with parallel cracks about three inches apart, dipping about 10° N. Briskly effervescent	5
6.	Limestone, soft, buff, dark-speckled, earthy, dipping as above	1

OTIS

5.	Limestone, brown, crystalline, nonmagnesian, in thin plates; with *Spirifer subumbonus*	¾
4.	Limestone, gray, earthy, dipping 10° N.	½
3.	Concealed	4
2.	Limestone, Coggon facies	1½
1.	Concealed, to water in creek	8

An interesting contact between the Otis calcilutite and the Independence is opened to view by the narrow trench of a small run entering Rock creek from the east north of Rochester (northwest quarter section 6, township 79 north, range II west). The bottom of the trench, which is about twelve feet deep, is floored a few rods upstream from the road bridge with extremely irregular ledges of calcilutite in lenses up to ten feet in length quite similar to those which form the summit of the Otis along Felton creek in the eastern edge of Cedar Rapids (p. 520). About three feet of this layer is exposed to view. It is fissured to a crackle breccia, and the seams are filled with calcite. A layer of bluish clay three to six inches thick, with some white saccharoidal limestone intermixed, immediately overlies the calcilutite. Arching over these lenticular masses, and forming the main body of rock exposed in the section is a soft dingy brown speckled argillaceous limestone of Independence facies. In places it is formed of laminæ which are an inch and less in thickness and are more or less flexed. In places the rock forms a pudding breccia with small sporadic fragments generally of brownish rock of the same texture as the matrix limestone. But near the ledges of calcilutite there occur also fragments of drab laminated calcilutite set at all angles. One noted was one foot long and five inches broad.

At the top of the section lies a pinkish saccharoidal limestone forming a lenticular mass twelve feet long and five feet thick and extending half a rod upstream in a layer one foot thick. A thin selvage of bluish plastic clay parts this lens from the impure limestone underneath.

The brecciation of the Independence here is taken to be contemporaneous. The brown fragments, like the matrix, are supplied by the laminæ in process of deposition and the calcilutites are derived from the adjacent reefs. The crackling of the Otis calcilutite may be due to later stresses, since the fissures and seams thus opened were inaccessible to the sediments of the Independence. Later than the deposition and brecciation of the shaly limestone came the deposition of the pink crystalline limestone, probably by evaporation of calcium-saturated water in a shallow depression on the shoal.

CROOKED CREEK SECTION

At the crossing of Crooked creek (southeast quarter of section 8, township 79 north, range II west) and on a hill a few rods west there is exposed in the road a section showing the following succession:

		FEET
3.	Limestone, calcilutite, closely laminated, gray, more or less brecciated. Some layers, especially those toward the base, are massive and finely fragmental, the fragments remaining in juxtaposition and being disclosed only on weathered surfaces. There is also considerable rubble breccia with sparse interstitial lighter gray matrix. In certain layers the closely set coherent laminæ are sharply flexed within the limits of a hand specimen. Here and there are large fragments set at all angles. There is seen also the type of fragment where the laminæ are separated but retain within the matrix considerable of their initial parallelism. Lenticles of silica occur. At base a foot or so of light colored saccharoidal limestone is seen	25
2.	Unexposed	10
1.	Limestone, white, saccharoidal at top, brownish buff and earthy at base. Considerable difference in appearance of strata, but all briskly effervescent. Among types noted are light gray earthy limestone, dark drab cryptocrystalline limestone, and a saccharoidal white limestone mottled with irregular greenish yellow argillaceous laminæ, the white portions containing considerable clear quartz in minute detached perfect crystals. Siliceous nodules with carious surfaces are present	8

The upper stratum is assigned to the Lower Davenport zone of brecciation. A part of Number 1 of the section is probably Independence.

ROCHESTER SECTION

A mile northwest of Rochester on the right bank of the Cedar a little above the mouth of Rock creek (southeast quarter of the northwest quarter of section 3, township 79 north, range III west) a ledge of calcilutite, probably referable to the Lower Davenport, overlooks the river:

		FEET
3.	Limestone, drab weathering to lighter tints, calcilutite, in places crackled and fragmental, in massive layers two feet thick and more, which here and there graduate laterally into thin plates a fraction of an inch thick	10
2.	Limestone, nonmagnesian, gray, semicrystalline, weak, retreating under No. 3	2
1.	Unexposed to flood plain of Cedar river	25

Directly across the river from Rochester the same ledge appears at nearly the same height. A miner's shaft which was sunk here some years ago, shows to a certain extent the nature of the underlying strata.

		FEET
8.	Upper portion of shaft not observed	7
7.	Limestone, rough, brown, crystalline	2
6.	Limestone, brown, soft, earthy luster, ferruginous and argillaceous, briskly effervescent in cold dilute HCl	6
5.	Limestone, buff, earthy, speckled with darker spots, thin layered	1
4.	Limestone, bluish, nonmagnesian, in part crystalline, in part earthy	4
3.	Limestone, pale buff, argillaceous, weathering to chipstone	3
2.	Limestone, buff, dull earthy luster, laminated, in even layers two to six inches in thickness	1
1.	Limestone, white, saccharoidal	½

Lithologically these layers may be referred to the Independence, with the exception of No. 1, which resembles the saccharoidal Otis, and thus the calcilutite ledge of the preceding sections falls in with the Lower Davenport. This inference is to a degree corroborated by the appearance of the Lower Davenport three miles south of Rochester in association with the Upper Davenport at the level of the higher river terraces (p. 540), the position to which a normal moderate dip would carry the strata.

UPPER DAVENPORT OUTCROPS

The highest bed of the Wapsipinicon within the limits of the county may be seen in going down the Cedar about three miles south of Rochester where it appears at the level of the upper terraces of the river. The following section, taken in an abandoned road in the southwest quarter of the southeast quarter of section 23, township 79 north, range III west, is wholly characteristic of the Upper Davenport and its relations over several counties. Unfortunately so slight is the exposed thickness of this bed that its brecciation is not well made out.

	Feet.
Upper Davenport.	
3. Limestone, hard, tough, gray, a coquina of minute fragments of shells, valves of *Gypidula comis* very abundant, ten individuals being counted on a surface six inches square	½
Lower Davenport.	
2. Breccia, fragments large, nonfossiliferous, of Lower Davenport type, some of them nearly three feet long. Some fragments crackled. In places matrix abundant and fragments small	6
1. Breccia, fragments dark drab calcilutite, mostly small, matrix abundant, light yellowish in color, of coarser grain than fragments	2½

One mile south of this exposure an old quarry in the southwest quarter of the southeast quarter of township 79 north, range III west shows ten feet of tough, hard, gray, irregularly bedded limestone, in part a coquina. The following brachiopods were collected here: *Gypidula comis, Stropheodonta demissa* var. *plicata. Atrypa reticularis* winged, *A. aspera* var. *occidentalis, Hypothyridina cuboides* (?) immature, *Spirifer pennatus.* At the base of the hill the Lower Davenport appears in three feet of finely laminated calcilutite with many of the laminæ curved.

Scott County

Scott county contains the type exposures of the Upper and the Lower Davenport beds of the Wapsipinicon, which occur in contact in the quarries of the city from which they take their name. At Bettendorf and along Duck creek northeast of the city the Lower Davenport beds display a thickness not elsewhere attained within the state. Farther to the northeast along Crow and Pigeon creeks, the Independence shale and the upper Cedar Rapids phase of the Otis limestone outcrop in contact.

The Upper Davenport, as exposed in the quarries of West Davenport, is a tough hard gray crystalline-granular limestone, lying in irregular and rough surfaced layers varying in thickness up to two feet. Under the sledge it breaks unevenly. The rock is highly fossiliferous as a rule, and certain layers form a coquina, but so firmly are the shell fragments cemented, and so tough and hard is the rock, and so resistant to decay, that fossils are disengaged with difficulty and perfect forms are rarely obtained. The entire thickness of the beds is probably compassed within fifteen feet. Stylolites are common and many joints show slickensides. Small angular imbedded fragments of the Lower Davenport calcilutite are sometimes seen.

It is fortunate that the fossils of these beds were collected with great pains for many years by members of the Davenport Academy of Natural Sciences. In the publications of this Academy are recorded lists of fossils and descriptions of new species for which science is indebted chiefly to the indefatigable labors of Barris. Mr. A. S. Tiffany also collected largely from these beds, and after his death the writer secured for the museum of Cornell College a number of rare specimens labelled in Mr. Tiffany's handwriting as coming from the "Corniferous" of Davenport. The rock texture of these specimens corroborates the reference and shows that if they are from Davenport they could have come only from the Upper Davenport beds, called by the Davenport geologists "the Corniferous." The following list comprises the fauna of the Upper Davenport beds of the county so far as these have been specifically identified.

Acervularia profunda
Phillipsastrea billingsi
Stromatopora expansa
Favosites placenta
Calceocrinus barrisi
Megistocrinus nodosus
Stereocrinus triangulatus
Atrypa reticularis
Gypidula comis
Newberria johannis
Hypothyridina cuboides
Pentamerella arata
Pentamerella dubia
Pentameralla micula
Productella spinulicosta
Reticularia fimbriata
Reticularia subundifera
Schizophoria iowensis
Schizophoria macfarlanei
Spirifer bimesialis
Spirifer asper
Actinoptera decussata
Conocardium cuneus
Paracyclas elliptica
Capulus echinatum
Capulus erectum
Platystoma lineatum
Straparollus lativolvis
Gyroceras pratti
Phragmoceras walshi
Proetus clarus
Proetus crassimarginatus
Proetus prouti
Proetus rowei
Phacops rana
Ptyctodus calceolus

The following additional species are reported by Ekblaw[69] from the same beds in Rock Island county, Illinois. *Astreospongia hamiltonensis, Alveolites goldfussi, Acervularia davidsoni, Cladopora palmata, Craspedophyllum archiaci, Cystiphyllum americanum, Favosites hamiltonensis, Favosites alpinensis, Heliophyllum halli, Streptelasma simplex, Hemitrypa tenera, Orbignyella monticula, Athyris fultonensis, Atrypa hystrix, Cranaena romingeri, Cranaena iowensis, Nucleospira ventricosa, Productella subalata, Pholidostrophia iowensis, Spirifer subvaricosus, Spirifer euryteines, Bellerophon pelops, Pleurotomaria lucina, Gomphoceros.*

The Lower Davenport beds as seen in the Davenport quarries and along Duck creek immediately underlie the Upper Davenport limestone and are composed largely of a calcilutite of finest grain and conchoidal and even splintery fracture. The rock is light brownish gray or medium dark drab color weathering to whitish, in irregular layers few of which reach a thickness of more than nine inches. In the quarries about Bettendorf, much of the calcilutite is evenly bedded and is composed of laminæ an eighth of an inch to an inch in thickness. The laminæ weather to separable plates. Gray mottled and finely saccharoidal limestones also occur. Siliceous elliptical nodules with curiously carious surfaces and with diameters as large as six inches are rarely seen.

The upper surface of the Lower Davenport in some places is uneven, and a thin band of greenish clay, not exceeding two inches in thickness, intervenes between it and the Upper Davenport. In the Schmidt quarry the Lower Davenport rises at the east end and pinches the Upper Davenport beds to a thickness of about five feet.

Deformation is seen both in the low archings in which the strata are commonly disposed, and in local brecciation more or less complete. The ledges about Rock Island show low synclinal and anticlinal flexures. On the Iowa side along the river

[69]Ekblaw, W. E., Correlation of the Devonian System of the Rock Island region: Trans. Ill. Acad. of Sci., 1912.

the strata show low arches from twenty to one hundred feet in length. Brecciation, while locally intense enough to shatter the laminated rocks and leave the fragments set at all angles, has left the larger part of the strata unaffected. On Rock Island few of the brecciated areas are more than a rod or so in width. Ledges along the river on the Iowa side opposite the Island show local brecciation in the hollows of the synclines. In places in the quarries of West Davenport brecciation is complete. In such areas we have a mosaic and rubble breccia of small fragments which retain their sharpest flint-like edges intact. The matrix is interstitial and consists of limestone of the same general nature as the fragments, of calcite and in a few places of clay. The thinly laminated upper beds along Duck creek show extensive crackle breccias; in places the vertical calcite-filled seams are an inch and less apart. Here some of the laminæ are arched in little folds of three or four inches diameter, which may pass into breccia at the axes of the synclines or throughout. Crackle breccia passes into rubble, and while a shattered layer retains its bedding planes, its upper surface becomes irregular. At one point there was observed a layer of minute rubble which was included between two layers of crackled rock. Contemporary brecciation is inferred also from the small angular fragments of Lower Davenport calcilutite which are sporadically scattered through the lowest layer of Upper Davenport in places along Duck creek.

The Independence beds are found at two outcrops on Crow creek, resting directly on the fossiliferous calcilutites of the Otis. Their contact with the overlying Lower Davenport has not been observed. Lithologically the formation at these outcrops is a rough brown earthy and ferruginous limestone in layers from two to four inches thick containing lenticular nodules of silica and weathering to a stiff clay. The total thickness observed is seven feet.

The Otis beds outcrop along Crow and Pigeon creeks in several ledges, one of which is twelve feet high. The total thickness of these exposures may aggregate twenty feet. The limestone is identical lithologically with the same horizon in Linn county, that is, a drab calcilutite in beds for the most part about one foot thick and somewhat lenticular. In places they are crackled and fragmental and thus present surfaces and fractures which are highly irregular. At one point the beds are thin and here also they are more or less fragmental. These outcrops of the Otis, like those along Cedar and Wapsipinicon rivers in Linn county, are indentified by the presence of *Spirifer subumbonus*.

The magnesian lower beds of the Otis which have been designated as the Coggon phase have not been identified with certainty in Scott county. Vesicular magnesian limestones found in conjunction with the Otis calcilutite, in a road cutting in Pleasant Valley township (northwest quarter of the southeast quarter of section 13) and in Hanna's and Dodd's quarries (southwest quarter of the southeast quarter of section 12 of the same township) probably belong to this formation, but in the absence of fossils they can not be assigned to either the Devonian, or the Gower stage of the Silurian.

WAPSIPINICON SECTIONS IN SCOTT COUNTY

MEUMANN QUARRY, FIRST WARD, DAVENPORT

		FEET
2.	Limestone, Upper Davenport, gray, granular, crystalline, close textured, tough, hard, in rough-surfaced irregular layers varying in thickness from fourteen inches to four inches. Many blocks show slickensides. Rarely there may be seen a small angular imbedded fragment of Lower Davenport calcilutite. Most abundant fossils are *Phillipsastrea billingsi* and *Gypidula comis*	6
1.	Limestone, Lower Davenport, calcilutite, brownish drab, in irregular layers nine inches and less in thickness, unfossiliferous, now under water	5

SCHMIDT QUARRY, FIRST WARD, DAVENPORT

3.	Shale, Cedar Valley, calcareous, yellow, highly fossiliferous	1¼
2.	Limestone, Upper Davenport, of color and texture as described in the above section, layers six to ten inches thick, joints oblique. A coquina of *Newberria* and other shells two feet thick forms the upper surface in places. *Acervularia* six inches from top of bed	12
1.	Limestone, Lower Davenport, calcilutite, light brownish gray or medium dark drab, in obscure, irregular, undulating layers, in places three feet thick, elsewhere thinner, more or less brecciated into a mosaic-rubble breccia of small angular fragments of sharpest edges, matrix slight, partly of calcite, partly of limestone of same general nature as fragments but slightly more earthy and of a lighter color, in places of clay	8

The quarries of the First Ward (West Davenport) have been abandoned for some years and their floors are deeply covered with water. Their side walls, of which only a few feet emerge, are largely concealed beneath the dumps of city and factory waste. Only the Upper Davenport is now to be seen except at the eastern end of the Schmidt quarry.

In both the Meumann and the Schmidt quarries the surface of the Upper Davenport ledge shows a coquina of brachiopods, in which valves of *Newberria johannis* are conspicuous. Beneath this layer is a coral reef, about two feet thick, in which *Phillipsastrea billingsi* occurs in fine heads usually set in the position of growth, associated with numerous other corals. *Phillipsastrea billingsi* extends down beneath this coral layer to a distance of six feet from the surface of the bed. *Acervularia profunda* occurs in the same zone.

The only contact now to be seen between the Upper and the Lower Davenport limestones is at the east end of the Schmidt quarry where the Lower Davenport rises from the water in a pure whitish massive calcilutite. The rock is intimately crackled and the upper inch or so is shattered to a mosaic or rubble breccia. The upper surface is hummocky. The Upper Davenport arches over these hummocks in irregular courses and a space of about an inch is now left between the two formations, a parting probably filled with clay when the quarry was opened. Here the Upper Davenport limestone does not fill the cracks in the Lower Davenport nor do fragments of the Lower Davenport calcilutite occur in the upper rock.

Immediately above the Upper Davenport limestone the fossiliferous shale may still be seen and the following fossils were collected: *Cyrtina umbonata, Cyrtina hamiltonensis, Stropheodonta perplana, Spirifer pennatus.*

QUARRY OF THE BETTENDORF STONE COMPANY, BETTENDORF

This extensive quarry offers one of the deepest sections of the Lower Davenport to be found within the state.

		FEET
5.	Limestone, calcilutite, whitish, in thin plates, gently arched accordantly with the arches of the underlying beds	6
4.	Limestone, light brownish gray, finely mottled, upper four feet massive, but traversed by irregular planes of stylolites at vertical intervals of six inches to one foot; upper surface somewhat hummocky and rugose, with deep stylolites. Lower two and one-half feet in rather even layers one foot and less in thickness	6½
3.	Limestone, lithographic calcilutite, light brownish gray, massive	1¾
2.	Limestone, finely saccharoidal, light gray and whitish, in irregularly bedded layers two to six inches thick. In places contains sparse small angular drab fragments. In places are conspicuous partings of plastic blue clay an inch thick	3
1.	Limestone, granular, earthy, light brownish buff	1

"DEVIL'S DEN," DUCK CREEK

Pleasant Valley Township, Section 27, Northwest Quarter

12.	Limestone, gray, granular, highly fossiliferous, Upper Davenport	1
11.	Limestone, Lower Davenport, whitish calcilutite, laminated, crackled, laminæ minutely folded in places and in places brecciated to mosaic and rubble	8
10.	Limestone, crystalline, purplish brown, irregularly bedded, containing a few angular fragments of whitish calcilutite	1
9.	Limestone, light gray, hard, compact, fine-grained, in layers three to four inches thick, composed of laminæ two to six millimeters thick, with distinct alternations of shades of color	4½
8.	Limestone, as above, laminæ in places flexed, broken and brecciated within the layer	1 2-3
7.	Limestone, as No. 9	1-3
6.	Shale, reddish brown, highly calcareous, brittle, finely laminated	½
5.	Limestone, dove-gray, hard, finely laminated	1-3
4.	Limestone, light gray, calcilutite	1 1-3
3.	Limestone, coarse-grained. laminated, laminæ coherent	4 1-3
2.	Limestone, drab weathering to white, compact, semi-crystalline, in two layers, breaking in places into small irregular chipstone	5¼
1.	Limestone, finely crystalline, white or light gray, weathering to thin plates, passing downward, and in places laterally, into mottled vesicular darker gray limestone, which merges into a basal massive light yellow-gray finely crystalline rock which is briskly effervescent in cold dilute HCl	8

Muscatine County

The exposures of the Wapsipinicon in this county are very limited. The lowest beds outcropping, according to Udden[75], are on the west bank of Cedar river south of the county line. Here there are exposed twenty-five feet of a very pure grayish or white compact unfossiliferous limestone much of which is brecciated. In their stratigraphic position and in their facies these beds appear to correspond with the beds of the Lower Davenport in the counties to the north and northeast. This inference is confirmed by Udden's observation of overlying beds of tough gray limestone carrying *Phillipsastrea billingsi* and other fossils found in the Upper Davenport of Scott county.

[75]Udden, J. A., Geology of Muscatine County, Ia. Geol. Surv., Vol. IX, pp. 269 et seq.

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