GEOLOGY OF PAGE COUNTY.

BY

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CONTENTS.

INTRODUCTION.

SITUATION AND AREA.

Page county is situated well toward the southwest corner of Iowa. The state of Missouri forms its southern boundary, and the single county of Fremont on the west separates it from the Missouri river. It is bounded on the north by Montgomery and on the east by Taylor. It embraces part of the territory which was for some time in dispute between Missouri and Iowa. Its location is such as to make it one of the most important agricultural counties in the great state to

which it belongs. All the pasture and meadow grasses usually cultivated in this latitude flourish; small grains yield generously; bountiful crops of corn mature year by year without a single recorded failure; apples and the other fruits of the mid-temperate zone produce abundantly. In matters of soil and climate, in the fortunate location between the extremes of both north and south, Page county is exceptionally favored.

In area the county under consideration embraces somewhat less than sixteen congressional townships. The falling short is due to the fact that the Iowa-Missouri boundary does not follow the lines of the congressional surveys, but cuts through sections 31 to 36 of the southern tier of townships—the tier numbered 67 North—so as to leave not more than one-fourth of these sections on the Iowa side of the line. On the other hand the county loses in area by reason of the fact that the north line of the second row of townships north of the Missouri boundary is a correction line, and sections 1 to 6 in each of these townships is fractional. In place therefore of having an area of 576 square miles—the theoretical number in sixteen congressional townships—the number of square miles in Page county is approximately 530.

PREVIOUS GEOLOGICAL WORK.

Dr. C. A. White was the first geologist to give more than passing attention to the area which constitutes the subject of the present discussion. He visited Page county in 1866, and, in his report to the governor, at the beginning of 1867,* there is an interesting description of the region, in which the soils, forest lands, coal beds and limestone ledges receive especial notice. In White's final report of the Geological Survey of Iowa† the geological structure of the county is more fully described. In the volume referred to the limestones of the county—those along the east branch of the Tarkio being particularly mentioned—are assumed to be the equivalent of beds at Winterset,

*First and Second Ann. Rept. of Progress of the State Geologist, Etc., Des Moines, 1868.

†Report on the Geol. Surv. of the State of Iowa, by Charles A. White, M. D., Des Moines, 1870 vol. I, pp. 348-353.

near the base of the Upper Coal Measures. While recognizing the fact that the Upper Coal Measures (the Missourian stage of more recent writers on the geology of Iowa) attain a thickness of about 180 feet near Winterset, within ten miles of the attenuated eastern edge of the formation, Dr. White entertained the belief that beyond the margin of Madison county the strata of this stage have practically no dip to the west—at least the dip is not greater than the slope of the surface toward the Missouri river—and that there is little, if any, increment in the thickness of the beds in this direction. Two hundred feet is the maximum thickness assigned to this formation, a thickness but little in excess of that of the Winterset section. It was believed, therefore, that the members of the Winterset section recur at all the outcrops throughout the several counties of southwestern Iowa, and efforts were made to correlate the different exposures with recognized divisions of the assumed standard section in Madison county.

In volume II of the current series of reports on the Iowa Geological Survey, Keyes‡ gives a brief account of the coal deposits of Page county as they were known in 1894. On page 159 of the work cited the author reviews the different estimates which have been made by various observers respecting the thickness of the Upper Coal Measures—estimates ranging from 200 feet by White to more than 1,400 feet by Winslow. The latter estimate was made for the Upper Coal Measures of Missouri, but Keyes concludes that the actual figures, probably for Missouri as well as Iowa, lie between the two extremes. He assigns to the whole Coal Measure series in southwestern Iowa a thickness of about 800 feet.

In his work on "The Artesian Wells of Iowa," Norton has occasion to refer only briefly and incidentally to Page county. In a sentence or two he describes* a prospect hole bored near Clarinda in search for coal. While, however, no facts are given relating very directly to the details of geological struc-

‡Iowa Geol. Surv., vol. II. Coal Deposits of Iowa, by Charles Rollin Keyes, Des Moines, 1894.
*Iowa Geol. Surv., vol. VI, p. 339; Des Moines, 1897.

ture in the county under discussion, in connection with the records of borings in other counties he presents data which throw much light on the actual thickness of the Upper Coal Measures in this part of the state, and aid very materially in settling questions concerning the probability that the limestones of Page county are the equivalent of beds near the base of the Winterset section. The record of the Glenwood well† is particularly instructive in the fact that it shows clearly the division between the Upper and Lower Coal Measures, indicating for the former a thickness 670 of feet. The beds exposed in Page county are well up in the series and must be far above the top of the section described by White, in Madison county. The significance of the data collected since White's visit to this locality will be discussed on subsequent pages of this report.

Among the later attempts to fix the stratigraphic relations of the puzzling succession of limestones and shales to be found in the Missourian series is that of Keyes.* In his paper, in volume VII, of the Proceedings of the Iowa Academy of Sciences, Keyes reviews exhaustively the literature relating to the geology of southwestern Iowa and contiguous areas, and makes an effort to correlate the various typical exposures which geologists have described. While his work is the best that has yet been attempted in this line, it will doubtless require considerable revision before all the problems involved are satisfactorily settled. The difficulty experienced by geologists in correlating widely separated outcrops of beds belonging to the Missourian series arises from a number of facts. Shales are more common and are developed to a far greater thickness than was realized by the first observers. The shales alternate with comparatively thin beds of limestone. The fauna seems to have been very persistent, and the same species of fossils recur in successive beds of shales and limestones throughout practically the whole thickness of the

†Op. cit., pp. 343-347.

*Formational Synonymy of the Coal Measures of the Western Interior Basin, by Charles R. Keyes; Proceedings of the Iowa Acad. of Sc. for 1899; vol. VII, p. 82 et seq., Des Moines, 1900.

formation, for which reasons the paleontological method is not available in tracing beds from one locality to another. In preglacial time, as a result of erosion during the long period between the retreat of the sea and the advent of glacial conditions, the limestones formed escarpments and the thicker shales developed long, undulating slopes between the projecting limestone ridges. During the glacial epoch the region was covered with a thick mantle of drift, which effectually concealed all stratigraphic details. Subsequent erosion has cut through the drift in a comparatively few and completely detached localities, the greater portion of the rock surface being still hidden from view. The projecting limestone escarpments were the first to be uncovered,—they were practically the only portions of the formation that the first geologists saw—and since they contained essentially the same fossils, the conclusion was a natural one that the various outcrops were simply repetitions of the same beds. Later geologists, with a larger number of outcrops and the records of many borings available for study, are yet handicapped in the portions of the area covered with deep drift, by the inability to trace formations continuously over any great extent of country, and by the lithological and faunal resemblances of beds occupying different positions in the geological column. The problems of correlation are still farther complicated by strong dips and relatively sharp folds, which cause the same beds to appear at different levels within comparatively short distances. Near Henshaw, in Taylor county, there is a difference of thirty-five feet in the altitude of the Nodaway coal-seam in less than one-fourth of a mile, and the same coal dips sixty-five feet between the old Shambaugh mill, in Sec. 7, Tp. 68 N., R. XXXVI W., and the Ingraham coal mine, in Sec. 2, Tp. 68 N., R. XXXVII W., a distance less than two miles. Where so large a proportion of the area is effectually concealed by deep drift, it is impossible to reckon with the folds and erratic dips of the strata. And since in most cases no aid can be derived from paleontologic evidence, the relations

of the limestones outcropping in one stream valley to those in another can not be determined by ordinary surface observations. Furthermore, in the drift-covered regions there is nothing in the way of natural surface exposures to give any clue to the thickness of the shale beds between the different horizons of limestone. The records of some well borings, to be noted later, now put us in possession of facts which help to solve the problem of the relation and thickness of strata belonging to the Missourian series, a problem that otherwise could not well have been solved in a region as deeply covered with drift as southwestern Iowa.

PHYSIOGRAPHY.

TOPOGRAPHY.

The surface of Page county is a completely dissected and deeply eroded drift plain. The present topography is not modified or determined to any very large extent by erosion in the indurated rocks. The stream cutting which has brought about the present surface configuration of the region is limited almost entirely to the thick mantle of drift which overspreads this part of Iowa. The principal topographic features of the county are the deep, nearly parallel stream valleys which traverse the area with a direction a little west of south and alternate with a corresponding number of intricately carved ridges. The two most important valleys are those of the Nodaway and Nishnabotna.* The Nodaway river enters the county less than four miles from the northeast corner and following a direction in general almost due south, it crosses the state line less than six miles from the southeast corner. Throughout its whole length the valley is broad and deep. (Fig. 28.) Its walls rise on either side to heights

*Nishnabotany, Nishnabotny, Nishnabotony, Nishnabotane and Nishnabotena are some of various spellings for the name of this river which may be found on maps of Iowa, and in literature relating to Iowa when the river is mentioned. On January 9, 1901, the United States Board on Geographic Names decided that the correct spelling is Nishnabotna, and the decision is published in *The National Geographic Magazine* for Febuary, 1901, page 87.

ranging from 160 to nearly 200 feet. The bottom of the valley varies from two to three miles in width, and upon this broad plain the stream meanders freely, but within limits much narrower as a rule than the space between the bluffs. On the whole the stream flows nearer the eastern than the western side, and the slopes of the bluffs on the east are in general steeper than those on the west. The valley bears every indication of maturity, in some places approximating

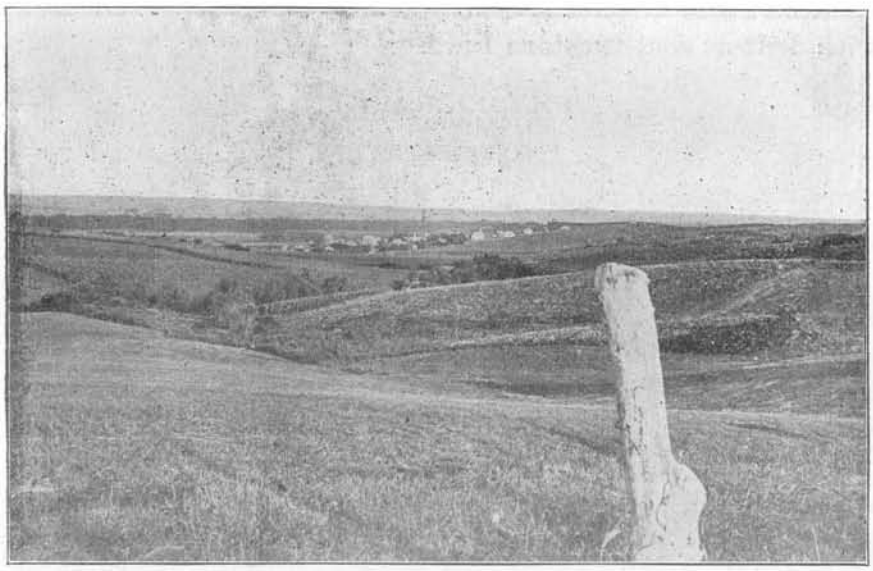

FIG. 28. View across the valley of the Nodaway from the highland northwest of Hepburn. The extent to which the side of the valley has been carved by erosion is shown in the foreground.

old age. It is well opened up. Not only have the walls receded so as to present the width of bottom land mentioned above; but the slopes, especially on the west side, are, in the main, long and gentle, mounting to the highland only at the greatly narrowed summit of the divides three or four or five miles back from the margin of the valley plain. At many points between Hepburn and Clarinda, for example, the long, gradual slopes of the bluffs blend almost imperceptibly into the gentle eastward slope of the bottom of the valley.

Just at Hepburn there is an unusual bit of topography which, seen from the bottom of the valley, presents the form of bluffs high and steep, in which short, rapidly-ascending gullies have been carved by lateral drainage. The lateral ravines are steep-sided and narrow. Within a small area in this vicinity the topographic forms are surprisingly young (Fig. 29), and in marked contrast with those which characterize nearly all the rest of the county. The river in this

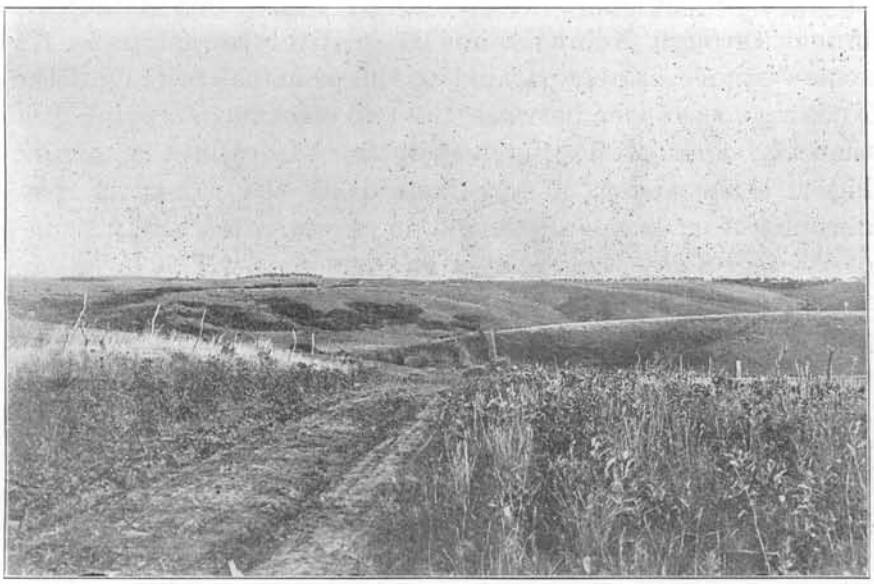

FIG. 29. The steep slopes and narrow ravines indicative of youthful topography, west of Hepburn.

locality is now three-fourths of a mile or more east of Hepburn, but the topography referred to clearly indicates beyond very much question that in times comparatively recent the stream washed the foot of these western bluffs, undercutting what had been a salient, eastward projecting ridge and causing the recession in the lower part of the bluff to keep pace with that at the summit. Since then the stream has swung back toward the east, and the bluffs at this point are now suffering modification only by the wash and wear of the

ordinary storm waters. Between Hepburn and Clarinda, as already noted, the sides of the valley fade away into gentle slopes, but farther south, at a number of points along the east side of Harlan and Amity townships, the bluffs on the west side of the stream, incised more or less by lateral erosion, become comparatively steep.

The east branch of the Nodaway enters Page from Taylor county, in section 1 of Nebraska township. It, too, flows in an old valley—a valley wide, deep and flat-bottomed like that of the main stream described above. The course of the east branch through Nebraska and East River townships is, for some distance, nearly parallel to the principal branch of the Nodaway, the space between the two streams averaging less than two miles. The ridge separating the valleys is narrow, high, rather sharp, deeply incised on the sides; it rises abruptly from both valleys and, in places, attains an altitude of 200 feet above the water in the channels. This is one of the most prominent ridges, one of the most conspicuous topographic features in the county. Its base is narrower than either of the adjacent valleys.

The valley of the Nishnabotna is of the same character as the valleys already described. Its great width—greater even than that of the Nodaway, or any of its branches—and the long, gentle slopes of the sides, are all indicative of a long period of erosion. Near Essex the west side of the valley is the steeper, but this feature of steeper bluffs shifts from side to side, appearing west of the stream in one place and east of it in another. The valleys occupied by the branches of the Tarkio are, in the main, repetitions of those of the Nodaway and the Nishnabotna. The streams have cut deep trenches, and the valleys have been widened by the recession of their walls under the influence of weathering and storm-water erosion. Even the smaller, more or less intermittent streams have valleys disproportionately wide and deep.

A topographic feature, rather common throughout the county, is well illustrated in the southwest corner of section

15, Colfax township. It is evident that for a time deposition took place in the branches of some of the smaller valleys, which partly filled them with a heavy body of black loam eight or ten feet or more in depth. Lately, erosion has begun anew, and has cut fresh, deep, narrow, ragged-sided trenches in the loam (Fig. 30). Some readjustment of relations, some disturbance of the previous balance of forces acting on the surface, has started a new erosion cycle in a great number of

FIG. 30. Deep, narrow trench cut by recent erosion in the bottom of one of the broad depressions in the surface. The deep, black loam in which the trench is cut indicates aggradation of the small valley for a long period before the recent trench cutting began.

individually limited areas. Disturbances quite sufficient to result in the erosion of these new, deep, V-shaped, annoying trenches, now so commonly found along the principal lines of surface drainage in every part of the county, are not infrequently produced by the artificial cutting of drainage ditches along roadsides or for the passage of water under road culverts. Indeed, any interference with the natural surface of the ground in the lower part of the small valleys is almost

certain to start the process, and, once started, the trench backs up into the adjacent fields and meadows with surprising rapidity. The trench does not fade out, but terminates abruptly with practically its full depth, at the upper end; and so miniature waterfalls are formed where the storm waters pass from the uneroded portion of the field to the new made channel. The upper end, however, does not remain stationary for any considerable length of time. It rapidly advances up the sloping area which it drains, its rate of progress depending on the frequency of storms and the volume of water which discharges into it. The trenches in question, ruinous sometimes to the fields, annoying always to the farmer, afford illustrations of what is known as "headward erosion," a geological phenomenon which follows a law as unfailing and inexorable as the law of gravitation, an effect which owners of land should be able to foresee and against which they should take every reasonable precaution to guard.

All that part of southwestern Iowa which is drained by affluents of the Missouri river exhibits an older and maturer type of topography than regions in the same latitude east of the great water-shed. The main topographic features in both areas are due to water sculpture in the superficial sheet of drift; but west of the water-shed the surface is much more deeply trenched by erosion, the stream valleys are wider, with more gradually sloping sides, the whole area is dissected back to the divides between the major valleys, there being no uninvaded flat spaces or plateaus such as are commonly found in the regions occupied by Kansan drift farther to the northeast. At a distance from the stream valleys profiles of the surface in any direction would show a series of convex curves sweeping through arcs of such extent as to indicate a very considerable relief. (Fig. 31.) In passing from the western to the eastern side of the water-shed, between Osceola and Chariton for example, the change in topographic type is very striking. On the one side is the deeply trenched and thoroughly carved surface with the elevations between the

drainage courses exhibiting full rounded maturity; on the other, an area trenched to a much less extent, the details of sculpturing less numerous and complete, and the convex profile curves in many cases flattened at the top. The observer gets the impression of having passed suddenly into an area of younger and flatter topographic detail. The region east of the water-shed is covered with what has become established by usage in the literature of geology as the Kansan drift.

FIG 31. The sweeping, convex curves characteristic of mature, erosional topography on the highlands between the stream valleys. View taken four miles west of Clarinda.

Can it be that the older topography west of the divide is developed on the pre-Kansan drift? The answer must await more extended investigations in the field. It is certainly a fact, however, that the topography of Page county belongs to a fully mature erosional type, a type in which sculpturing of the original drift plain has been carried much farther than in average areas of the recognized Kansan drift in southeastern Iowa.

Over a large portion of Iowa the present topography is controlled to a greater or less extent by the configuration of the preglacial surface. The old rock cut valleys and intervening hills were only partly disguised by the sheets of drift which were subsequently spread over the area. In many cases the present drainage follows preglacial valleys, a result which would necessarily follow from the fact that, even if the entire surface had been levelled by the ground moraine of the latest ice sheet that overflowed any given area, the glacial detritus where it filled the valleys, owing to its greater thickness, would settle more than in the areas of thinner drift over the hill tops. Thus sags in the surface of the drift plain were frequently formed, conforming in direction and windings to the old valleys; and these, wherever they were developed, determined the lines of subsequent drainage. Page county was covered with a very thick mantle of drift which probably levelled the surface and obliterated for a time even the larger details of the preglacial topography. But in the settling of the drift and readjustment of the drainage after the retreat of the ice the new streams were directed by depressions in the drift plain along the courses of the old valleys. The work of the streams since the disappearance of the ice has been only partly successful in re-excavating these valleys. At Clarinda the Nodaway river has not yet reached the original rock surface, for wells at the level of the city water works go down from forty-five to fifty feet in the superficial detritus. That the old valley was wider than the present one is indicated by the record of the well at the Clarinda hospital where, starting part way up the side of the valley, the drill penetrated to a depth of seventy-two feet without reaching the bottom of the loose materials with which the ancient water course was filled. The depth of the glacial detritus in the valley of the Nishnabotna at Shenandoah was not ascertained; but the wells at the water works, on the low bottom-land toward the river, end in a bed of blue clay, probably glacial till, at a depth of forty-five feet from the surface.

The best evidence of a modern stream following an ancient, filled, and only partly re-excavated water course is found at Blanchard in the valley of the Tarkio. Here a well, partly bored, partly dug, was made to supply the railway tank with water, and it is said that rock was reached at a depth of 178 feet. The rock mentioned seems to have been limestone, and it is possible that some shale was penetrated without being differentiated from the superficial materials. But, according to the testimony of persons on the ground when the well was made, pieces of bark and wood were brought up from a depth of ninety or ninety-five feet, large bones which, judging from the descriptions given, must have belonged to the mammoth or the Mastodon, were found fifty-four feet beneath the surface; and beds of sand and gravel were reported to occur at various depths. There is clear evidence that the bottom of the preglacial valley which the Tarkio has partly reopened, was many feet lower than the level of the present stream.

DRAINAGE.

The drainage of Page county is fully mature. Practically every part of the surface is thoroughly drained. With the exception of a few small and unimportant areas in the flood plains of the streams where shifting of the meanders has left temporary wet places, there are no marsh lands in the county. There is one rather striking characteristic which the drainage of our area shares in common with all southwestern Iowa: the drainage basins of all the streams are remarkably long and narrow, the valleys are parallel or practically so for long distances, and the intervening spaces are disproportionately long in comparison with their width. The eastern third of the county is drained by the Nodaway and its branches; the various forks and branches of the Tarkio drain all the central and southwestern part; a relatively small area in the northwestern part of the county is drained by the Nishnabotna; and Walnut creek, whose drainage basin lies

almost entirely west of the county, receives the drainage of a square mile or two in the extreme northwest corner.

Elevations.—In Gannett's Dictionary of Altitudes the elevation of Villisca, a short distance north of the Page county line, is placed at 1050 feet above tide, Clarinda 1009 feet, Essex 992 feet, and Shenandoah 975 feet. These figures refer in each case to the surface of the road bed at the railway station. Hawleyville has an elevation about the same as Clarinda. The high points of the divide between the two branches of the Nodaway reach a height of about 1200 feet, and this may be taken as an approximate average for the higher eminences in the eastern and northern parts of the county. The figures given indicate a general slope of the whole county towards the west and south.

STRATIGRAPHY.

The geological formations of Page county are not very numerous. They belong at most to three different series, the series being separated from each other by long periods of time. The oldest of the formations in the county, occurring at the surface, belongs to the later part of the Carboniferous system; the next in order of age is a member of the Upper Cretaceous series; and lastly there are Pleistocene beds consisting of the loose deposits of drift, loess and alluvium which cover by far the greater part of the surface. The Carboniferous and Cretaceous are marine deposits; the Pleistocene beds owe their origin to the action, first, of glacial ice, and, second, of winds and surface drainage waters. The two marine deposits are separated by an interval equal to the Permian, Triassic, Jurassic and Lower Cretaceous combined; the Upper Cretaceous is separated from the Pleistocene by the whole length of the Tertiary. The taxonomic relations of the strata are shown in the following:

SYNOPTICAL TABLE OF THE GEOLOGICAL FORMATIONS OF PAGE COUNTY.

GROUP.	SYSTEM.	SERIES.	STAGE.
Cenozoic.	Pleistocene.	Recent.	Alluvial Deposits.
		Glacial	Kansan Drift?
Mesozoic.	Cretaceous.	Upper Cretaceous.	Dakota Sandstone.
Paleozoic	Carboniferous.	Upper Carboniferous or Pennsylvanian.	Missourian Limestones and Shales.

The Carboniferous System.

MISSOURIAN STAGE.

General Discussion on Relations of the Strata.—The deposits of the Missourian stage are made up of alternating beds of shales and limestones, the shales predominating so that much the greater part of the entire formation is composed of argillaceous strata. To appreciate the conditions under which these deposits are exposed in Page county, and generally in southwestern Iowa, it is necessary to have in mind some facts relating to the geological history of the region as well as to the characteristics of the indurated rocks. This region, with its relatively thin beds of limestone alternating with much thicker beds of shale, was subject to erosion for long periods before the beginning of the glacial epoch. Valleys were cut, and on their sides, as noted on a preceding page, the shale beds formed long gentle slopes, while the limestones gave rise to more or less prominent offsets or escarpments. During the glacial epoch this surface was deeply covered with drift, the depth of the till sheet averaging probably not less than 200 feet. All the indurated rocks were thus effectually concealed; and were it not for subsequent erosion, our knowledge of the preglacial geology of this portion of the state would now be very imperfect, since any knowledge of the subject

could have been gained only at the expense of deep borings. Since the glacial epoch the streams, in the main following the old water courses, have cut in places down to the level of the walls of the ancient valleys. Where limestones occurred the beds now project more or less, owing to their greater power of resisting the processes of weathering. On the other hand any shales which may have been exposed by late erosion, have broken down as rapidly as the streams cut into them and so have been reduced to gentle slopes which were at once concealed by their own waste or the wash from higher levels. Such surfaces are now, in general, sodded over and blend indistinguishably into the slopes produced by erosion of the drift. It thus comes about that while the shale beds are much thicker than the limestones in the Missourian stage, the limestones are much the more conspicuous. By far the greater part of Page county, however, is yet covered with its mantle of drift; it is only in a few places that the limestone strata with some associated shaly layers are available for study; and an examination of these natural exposures tends to create the erroneous impression, so generally entertained by the earlier observers who visited the region, that the formation is made up largely of limestones.

There seem to be two distinct limestone horizons in Page county, the first being exposed at intervals along the two branches of the Nodaway, while the second is typically developed in the valley of the east Tarkio. The limestones on the Tarkio were correlated by White with certain members of the Winterset section, but he is less explicit in correlating the calcareous beds exposed at Braddyville, Hawleyville and other localities in the eastern part of the county.* It now seems certain, however, that the Page county limestones lie some hundreds of feet above the top of the Winterset section.

*In the report of the Geological Survey of the State of Iowa, by Dr. Charles A. White, published in 1870, in discussing the Geology of Page county, on page 349, the general statement is made that "The strata thus far discovered [in the county] are all referred to the horizon of the lower half of the series of limestones and shales of the Winterset section." In speaking of the limestones on the Tarkio, page 352, certain layers are definitely and explicitly regarded as "equivalent with No. 2 and No. 3 of the Winterset section, in Madison county."

Near Clarinda, in the Sw. ¼ of Section 36, Tp. 69 N., R. XXXVII W., a prospect hole was bored for coal. The drilling was carried to a depth of 1002 feet, and the part of the record which seems to relate to shales and limestones of the Missourian stage, is as follows:

		THICKNESS.	DEPTH.
9.	Clay and gravel (Pleistocene)	50	50
8.	Shale, partly marly, varying in color	100	150
7.	Limestone	5	155
6.	Light shale	20	175
5.	Very hard limestone	20	195
4.	Shale	105	300
3.	Limestone	20	320
2.	Shale, partly marly, black, blue and red	180	500
1.	Limestone	20	520

Only thin beds of limestone, and these separated by thick shales, are reported from a depth greater than 520 feet. No. 1 in the preceding table seems therefore to be the base of the Missourian, and to correspond to the Winterset limestones described by White and Bain in Madison and Decatur counties. No. 8 evidently lies below the level of the Braddyville and Hawleyville limestones, and the limestones of the East Tarkio are yet 125 feet higher than those exposed on the Nodaways. The total thickness of the Missourian in Page county is at least 625 feet. This agrees well, so far as thickness is concerned, with determinations made by Professor Norton, in his study of drillings from the deep well at Glenwood, a locality about forty-five miles in a straight line northwest of Clarinda. According to his interpretation the equivalents of the Winterset section are found in alternating beds of shale and limestone from 740 to 815 feet below the surface; and, subtracting the 175 feet of loose surface materials, the base of the Winterset section is 640 feet below the stratum which, at Glenwood, constitutes the top of the Missourian. The rocks immediately beneath the drift at Glenwood are limestones which, as will at once be noted, occupy essentially the position in the series that would be assigned

to the limestone ledges outcropping in the valley of the East Tarkio. Beyond the mere matter of thickness, however, the parallelism between the Glenwood and Page county sections of the Missourian does not seem to extend; for the reported beds of limestone in the Clarinda boring are thin, few in number, and far apart as compared with the limestone layers penetrated at Glenwood. For example, in that portion of the Glenwood section which should correspond to the part of the section at Clarinda referred to the Missourian, there are sixteen limestone layers recorded in place of four; and their aggregate thickness is 240 feet, against the sixty-five feet at Clarinda. It must be said, however, that samples of drillings from the test hole at Clarinda were not examined by anyone connected with the Survey. The person who kindly furnished a copy of the record, as it was preserved, reports that "a man took the layers passed through, but it is not very perfect." The object of the boring was to find coal, the depth of the hole at different stages was determined with reliable accuracy, but it is possible that the limestones were not always carefully discriminated from the shales, and that a part of the discrepancy between the two records referred to may be thus accounted for.

In the Iowa Academy paper of Keyes, already cited, the Missourian formation is divided as in the following table. The thickness assigned by Keyes to the several beds, from a study of the whole field, is given in the first column of figures; while in the second column is given the thickness of what seem to be the corresponding members as they appear in the drill hole at Clarinda. The difference between the minimum and maximum thickness of the several portions of the Missourian, while seemingly large, is probably not greater than occurs in other sedimentary deposits which extend over large geographical areas:

Missourian Formations.

	DIVISIONS OF THE MISSOURIAN, KEYES.	THICKNESS.	
		General Section.	At Clarinda.
11	Cottonwood limestone	10	
10	Atchison shales	500	
9	Forbes limestone	30	
8	Platte shales	150	100
7	Plattsmouth limestones	30	5
6	Lawrence shales	300	20
5	Stanton limestones	35	20
4	Parkville shales	100	105
3	Iola limestone	50	20
2	Thayer shales	75	180
1	Bethany limestones	100	20

Correlations.—The Bethany limestones of the general section of Keyes are practically identical with the alternating beds of shale and limestone in White's Winterset section. In the record of the Clarinda well it is probable that the upper portion of the Bethany or Winterset division was counted as shales and appears in the greatly increased thickness of No. 2. Nos. 1 to 5, inclusive, have about the same aggregate thickness in both columns and it would require very little adjustment to bring about practical agreement; but the great discrepancy in No. 6 can only be harmonized on the hypothesis of local differences in the rate of sedimentation. Whatever may be said, however, about the accuracy of the assumed correlations between the members of the general section and the section penetrated by the drill at Clarinda, there is no question that the limestones on the Nodaways, at Hawleyville and Braddyville, are the exact equivalent of what has been called by Keyes the Forbes limestone. This limestone is overlain by shales—the Atchison shales of Keyes, the Wabaunsee of Prosser—which attain a great thickness in Nodaway and Atchison counties, Missouri. A section of these shales 125 feet in thickness is exposed near Burlington Junction, in Missouri, and at the base of the section occurs the Nodaway coal seam which is recognized as marking a definite horizon near

the junction of the Forbes and Atchison divisions of the Missourian formation. It is the basal portion of the Atchison or Wabaunsee shales that is penetrated by the shafts of the coal mines in the neighborhood of Clarinda and Shambaugh. At the Ingraham coal mine, in the northeast quarter of section 11, Tp. 68 N., R. XXXVII W., there is a thickness of seventy-five feet of this shale between the limestone cap rock and the base of the drift, and near Shambaugh the cap rock is overlain by sixty or seventy feet of the same formation. Between six and seven miles southwest of Shambaugh, in the northwest quarter of section 29, Amity township, Mr. G. H. Lowrey passed through more than 100 feet of shale without reaching the cap-rock overlying the Nodaway coal. On the farm of Mr. H. Larrabee, in the southwest quarter of section 22, Tarkio township, an 18 inch seam of coal was found in boring a well, at a depth of 180 feet from the surface. There can be little doubt that this is the Nodaway coal; and yet if the dip between the old Shambaugh mill, in section 7 of East River township, and the Ingraham coal mine two miles to the west, were constant, the coal seam in the Larrabee well should be more than 300 feet from the surface. Sixty feet below the mouth of the Larrabee well, and about sixty feet above the level of the water in the east Tarkio, there are numerous outcrops of the limestones for which the Tarkio valley has long been noted. These limestones lie about 125 feet above the Nodaway coal seam and constitute the second and last assemblage of limestones in Page county. Furthermore these limestones are evidently the southward extension of the beds which are quarried on a comparatively large scale near Stennett in Montgomery county; and these, on the other hand, are the equivalent of the limestones near Macedonia in Pottawattamie. At Stennett some of the beds are unusually rich in the small grain-like fossil called Fusulina, and Fusulina is the most common and characteristic form in certain beds along the Tarkio and near Macedonia. While it is not possible to attach much importance to the presence of Fusulina,

since it occurs in all the Missourian limestones from the Bethany upwards, the species—*Fusulina cylindrica*—attains an unusual development at this horizon. Now the Cottonwood limestone of Kansas and Nebraska is rich in Fusulina, so much so that it has been referred to in the literature of geology as the "Fusulina limestone." The Cottonwood beds have been traced from Kansas into Nebraska, up opposite Iowa, along the high land forming the rim of the Missouri river valley; and it need occasion no surprise if they should be found at essentially the same level on the east side of the river. The occurrence of this uppermost limestone of the Missourian stage in Page, Montgomery and Pottawattamie counties in Iowa would be all the more probable if, as seems to be the case, the body of shales which attains such great thickness in Atchison county, Missouri, and the adjacent parts of Kansas and Nebraska, thins rapidly towards the northeast.

It must be said, however, that the discussion of this problem, in the present state of knowledge, is not likely to lead to definite conclusions. For example, it is difficult to reconcile the great amount of limestone reported from the Glenwood well* with the results of observations in other localities. The great number and thickness of the calcareous layers so reported may mean that the development of limestones is different in different parts of the Missourian area; that beds occur in one place, which, by thinning out in certain directions, are not found in other places; and that it is not possible to correlate all the limestones known in Page, Pottawattamie and neighboring counties with the members of the general section studied by Broadhead, Prosser. Haworth, and Keyes, in regions farther south and west, However the facts may be interpreted or explained, it is certain that the great body of shale which overlies the Nodaway coal in Page county and which is exposed in natural section near Burlington Junction, Missouri, appears not to be

*Iowa Geol. Surv., vol VI, pp. 343-345.

represented in the Glenwood well. The coal shafts of Page county go through a thickness of 100 feet of these shales in which there is not a trace of limestone; and in the Burlington Junction section of fully 125 feet, there are only occasional impure calcareous bands which at most attain a thickness of a few inches, but there is nothing that would be regarded as limestone. On the other hand, in the Glenwood record, the thickest of the non-calcareous beds which could correspond to the Atchison shales of Keyes, does not exceed

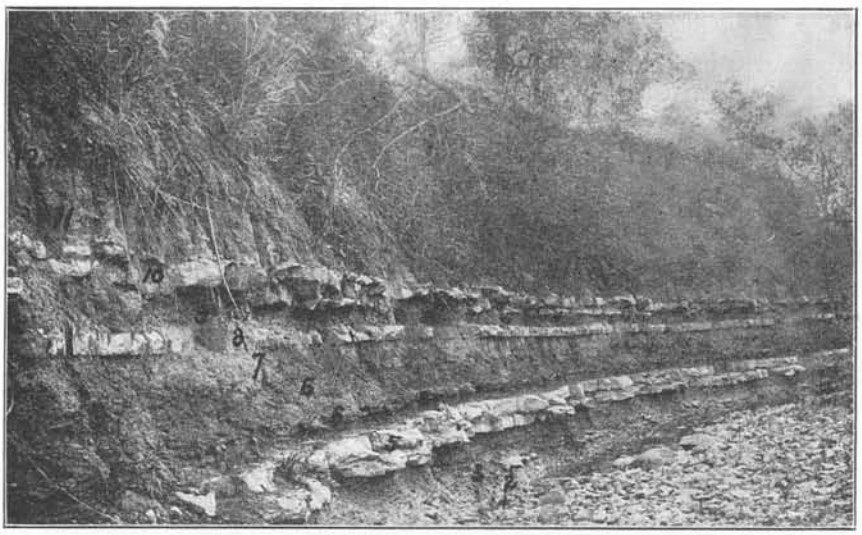

FIG. 32. Exposure of the Forbes limestone near Hawleyville.

twenty feet. Whether, therefore, the limestones on the Tarkio are to be correlated with the Cottonwood limestone of Kansas and Nebraska, or whether they are beds that feather out before reaching the states mentioned, is a problem which must be left to future investigation.

Typical Sections of the Missourian in Page County.—The limestones exposed along the Nodaways constitute the lowest member of the Missourian seen in Page county. As already noted, they may be correlated with the Forbes limestone of Keyes; and according to this author they are the fifth of the

series of calcareous beds occurring in the Missourian stage. One of the best exposures of the beds in question is seen near Hawleyville, in the southeast quarter of the southeast quarter of section 12, Nebraska township. The land is owned by Mr. J. M. Molnux, and it is traversed by a small ravine which enters Page from Taylor county. The small valley is occupied by an intermittent stream which carries the surplus storm waters from a rather limited area to the East Nodaway. At the point where the ravine crosses the county line, and for a few rods down the valley towards the west, layers of limestone alternating with shale occur in the steep bank on the south side of the valley (Fig. 32). The following detailed section may be noted:

		FEET.	INCHES.
14.	An aqueous loess-like silt with occasional pebbles and small pockets of red sand near the base	10–15	
13.	Gravel composed of crystalline pebbles	0	3–10
12.	Drift with pebbles and small cobblestones	1	
11.	Yellow marly fossiliferous shale	1	8
10.	Limestone somewhat decayed and broken into irregularly shaped fragments; nodular in places, sometimes apparently made up of a single layer, in some places double	0	6–11
9.	Dark, carbonaceous, fossiliferous shale containing such forms as *Rhombopora lepidodendroides*, *Chonetes granulifera*, *Chonetes verneuiliana* *Derbya crassa*, *Ambocœlia planoconvexa*, *Athyris subtilita*, *Bellerophon carbonarius*, and the small Straparollus described by Hall in his report on the Geology of Iowa as *Euomphalus rugosus*,—the *Straparollus catilloides* (Conrad) of Keyes	0	6
8.	Dark colored, earthy or clayey limestone with many of the species of fossils found in No. 9.	0	6
7.	Shale gray in color, but otherwise similar to No. 9 and containing the same fossils	0	8
6.	Dark, carbonaceous, slaty or fissile shale.	2	
5.	Limestone separated into two layers by a thin band which is very rich in a species of Derbya differing slightly from the normal average form of *Derbya crassa*. The same form		

		FEET.	INCHES.
	of Derbya occurs in the overlying portion of the limestone	1	
4.	Gray, lean shale	1	
3.	Limestone in the form of nodules a few inches in thickness, nodules disconnected, not forming a continuous layer	0	6
2.	Light colored shale	0	8
1.	Limestone in the bottom of the creek, thickness not measured.		

One-fourth of a mile farther up the small valley, in Taylor county, there are a number of exposures which show that the yellow shale, No. 11 of the section described, has a thickness of four feet, and that the upper part of this layer contains disconnected slabs of an impure but very fossiliferous limestone. *Chonetes granulifera* is the most abundant species, but *Productus cora*, *Myalina subquadrata* and a species of Pinna also occur. A number of small slabs containing *Fusulina cylindrica* were found on the weathered slopes, but the bed from which they came was not seen in place.

In the west bank of the river, south of the mill at Braddyville, a very interesting section was formerly exposed; but the surface has more recently been covered with riprap to protect the bed of the railway which is here located near the edge of the slope. It is still possible to make out the succession of beds described in the following section:

		FEET.	INCHES.
10.	Thin band of impure limestone	0	6
9.	Yellowish, fossiliferous shale	1	3
8.	Black, slaty, carbonaceous shale splitting up into thin, brittle laminæ	2	
7.	Impure limestone with many shells of Derbya embedded in the lower part of the layer; in the upper part the fossils are comminuted and indistinguishable	0	8
6.	Thin band of shale crowded with the same form of Derbya occurring in No. 5 of the Hawleyville section. This form is intermediate between *Derbya crassa* and *Derbya robusta*	0	2

		FEET.	INCHES.
5.	Thin bed of limestone like No. 7 containing shells of Derbya and Myalina.....	0	2
4.	Dark shale varying somewhat in thickness, about	1	
3.	Hard, impure, nodular limestone, breaking into fragments on exposure to the weather.....	0	8
2.	Light drab shale, imperfectly laminated and containing concretionary nodules	2	
1.	Limestone beneath the level of the water in the river.		

This section is essentially the same as the preceding one. The equivalent of No. 5 of the Hawleyville exposure is divided into its three constituent parts in the notes of the Braddyville section and numbered 5, 6 and 7. Numbers 8 and 10 above represent 6 and 8 respectively at Hawleyville; the two foot band of black, brittle shale and the six inch layer of limestone being identical in the two localities. Above number 10 the section at Braddyville is so much altered by weathering and creep that the succession of beds is rather obscure. Some of the shale beds, especially numbers 2 and 9, are at Braddyville much thicker than their equivalents farther to the northeast.

Before the advent of the railway and the application of riprap to the bank, the beds at this point were much better exposed; and certain layers above the level of those now accessible to observation furnished a large number of species of fossils unusually well preserved. The region was visited by the writer in 1875, and the following partial list of species is based on collections made at that time:

Fusulina cylindrica Fischer,
Derbya robusta Hall,
Chonetes verneuiliana Norwood&Pratten,
Productus semireticulatus Martin,
Productus cora D'Orbigny,
Orthis pecosi Marcou,
Spirifer cameratus Morton,
Athyris (Seminula) subtilita Hall,
Fistulipora nodulifera Meek,
Chonetes granulifera Owen,
Productus costatus Sowerby,
Productus longispinus Sowerby,
Productus symmetricus McChesney,
Dielasma bovidens Morton,
Spiriferina kentuckiensis Shumard,
Hustedia mormoni Marcou.

At the site of the old Shambaugh mill (Fig. 33), in the Sw. ¼ of the Nw. ¼ of section 7, East River township, there is an exposure which shows:

		FEET.	INCHES.
9.	Yellow, weathered shale	4	
8.	Black shale	1	
7.	Yellow shale	1	3
6.	Yellowish, impure limestone which at the north end of the exposure is in two layers—the upper 14, and the lower 18 inches in thickness. The lower bed thins and runs out in a few yards toward the south. Average thickness	2	

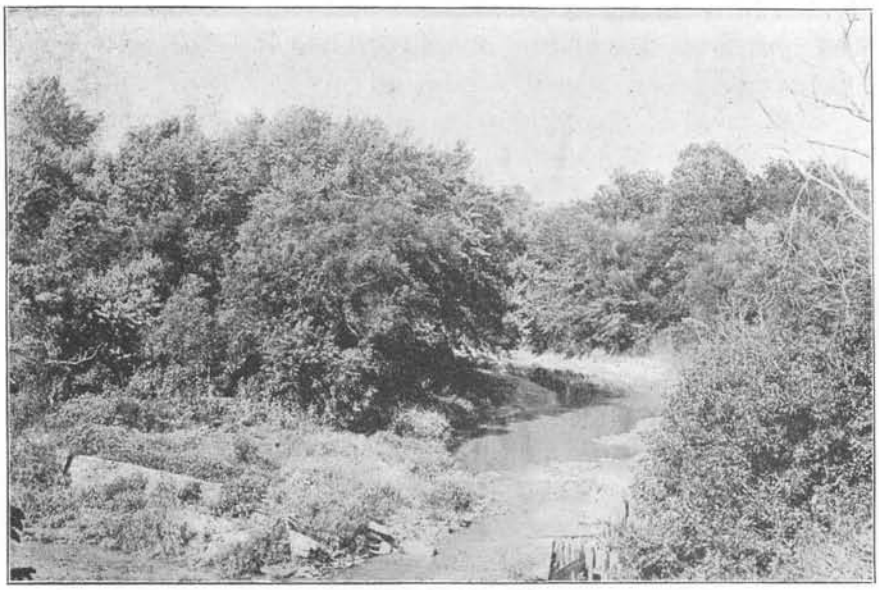

FIG. 33. The site of the old Shambaugh mill near Clarinda.

5.	Yellowish shale, present in some parts of the exposure and not in others	0	6
4.	Black slaty shale	0	6
3.	Grayish, fossiliferous, non-laminated shale which disappears and re-appears in distances of a few yards. Among the fossil species noted are: *Lophophyllum proliferum*, plates and spines of Zeacrinus, *Rhombopora lepidodendroides*, *Chonetes granulifera*,		

		FEET.	INCHES.
	Productus longispinus, *Productus pertenuis*, *Derbya crassa* represented by numerous small, fragile individuals, *Spiriferina kentuckiensis*, *Ambocœlia planoconvexa*, represented chiefly by detached valves, but very abundant, *Athyris subtilita*, *Straparollus catilloides*, *Bellorophon percarinatus*, *Bellerophon carbonarius*, and a small Pleurotomaria.	2	
2.	Coal	1	6
1.	Drab shale down to river	8	

The members of this section above No. 2 are all very variable in thickness. At the north end of the exposure the fossiliferous bed, No. 3, thins out, and bed No. 4 rests directly on the coal. The fossiliferous bed, however, is quite generally present at this horizon. The dull gray, non-fissile clay of which it is composed, crowded with its characteristic and characteristically preserved fossils, is readily recognized in the waste dumps from the coal mines of the region. Its presence is thus detected at all the old coal mines on the east side of the river south of the exposure described. It is recognized in the Howard mine and other mines near the village of Shambaugh, and it appears with all its characteristic features in the mines at Henshaw in Taylor county. The coal, No. 2, is the Nodaway coal, which is the basis of all the coal mining in the neighborhood of Clarinda and Shambaugh.

The foregoing section lies above the beds exposed at Hawleyville and Braddyville. The exposure at Braddyville seems to be the summit of a small anticlinal fold as suggested by White, for the coal is about at the level of the river at Shambaugh, and at Burlington Junction it has descended until it lies thirty feet below the water level. Eight or nine miles north of Villisca, on the east branch of the Nodaway in Montgomery county, there is a small mine in which the coal is found about thirty feet above the water in the stream. It appears, therefore, that the average dip of the strata is a little greater than the descent of the valley. The top of the

limestone, No. 6, which forms the cap-rock of the coal throughout all this region may be regarded as forming the division between the Forbes limestone and the Atchison shales. It is part of the system of limestone beds alternating with shales, seen at Hawleyville and Braddyville, and no other limestone layer of any consequence occurs above it for a distance of more than 100 feet.

The lower part of the heavy body of shale which lies above the cap-rock limestone is penetrated by the shafts of the Howard and Fulk mines in the Nw. ¼ of section 36, Harlan township, by the shaft of the Ingraham mine near Clarinda, and by all the other coal shafts in the eastern part of the county. But these shafts are now timbered so as to hide the section, the only facts now obtainable being that they passed through beds of variously colored shale. A good natural section of these shales is exposed near Burlington Junction, Missouri, and a brief description of it will help to illustrate the character of the beds overlying the Nodaway coal and the cap-rock limestone. The colors of the exposed beds, it will be remembered, have been modified by weathering, and are not those which would be found in sinking a shaft through fresh strata.

		FEET.	INCHES.
20.	Blue shale	10	
19.	Yellowish green, calcareous shale	0	3
18.	Concretionary marly shale	2	
17.	Bluish green shale, not calcareous	3	
16.	Yellowish, calcareous concretionary shale	1	6
15.	Greenish blue shale	1	
14.	Calcareous, ferruginous sandstone	0	6
13.	Sandy shale with concretionary nodules in the upper part; the nodules showing the structure of septaria	10	
12.	Band of impure limestone with obscure impressions of fossils		2
11.	Sandy shale	2	
10.	Thin bands of fossiliferous limestone, with *Productus cora* and other species, alternating with sandy shale which carries septarian nodules near the bottom	5	

		FEET.	INCHES.
9.	Gray shale	3	
8.	Thin layer showing cone-in-cone at top and bottom, structureless in the middle	0	7
7.	Gray shale with occasional large septarian nodules	25	
6.	Calcareous band with plates of Zeacrinus, Fustulipora and Rhombopora, *Productus longispinus*, *P. nebrascensis*, *P. semireticulatus*, *Spiriferina kentuckiensis*, *Ambocœlia planoconvexa* and *Straparollus catilloides*	0	4
5.	Dark shale, with some calcareous bands, fossiliferous near top, down to level of water in the river	25	
4.	Shale in shaft of coal mine a short distance from where the section was taken, below level of river	30	
3.	Cap-rock	2	
2.	Shale above coal	4	
1.	Coal	1	6

The Burlington Junction section shows the beds immediately above the coal, but it evidently includes only a part of the whole thickness of the Atchison shales. To these shales, as already noted, Keyes assigns a thickness in northwestern Missouri of 500 feet. At all events, at the Burlington Junction exposures there are no indications of the next limestone—the Cottonwood limestone—which should follow the shales in ascending order.

It must be said, however, that the Atchison shales either thin out rapidly toward the northeast, or they are divided by a limestone which does not extend into Missouri, Nebraska and Kansas, where the Missourian formations have been most carefully studied; for in the valley of the Tarkio in Page county there is a very conspicuous limestone which seems to hold a position only about 125 feet above the sections exposed on the Nodaways. Beginning at Coin and extending up the valley, especially along the east branch of the Tarkio, heavy limestone ledges are quarried, the quarries occurring at intervals up to the north line of the county.

Near Coin there is a quarry of this limestone on the land of Mr. J. H. Palmer, on the Sw. ¼ of the Se. ¼ of section 29, Lincoln township. Owing to weathering and decay the ledges are here somewhat displaced, and the detached blocks occur in clayey, residual materials. The true relations of the beds cannot be made out; but weathered bowlders of the limestone indicate that the upper layer is rich in Fusulina; while beds that seem to have been displaced but little, and show only slight effects of weathering, furnish very excellent building stone in the form of a blue, fine-grained layer, sixteen inches thick, which breaks readily at right angles to the bedding planes into blocks suitable for use in all kinds of substantial masonry. A few rods southwest of the point where the building stone is taken out, and at a lower level, there is an exposure, in place, of another bed of limestone, which, however, is soft and easily decomposed. This limestone crops out for some distance in the hillside, between the Palmer homestead and the river.

More satisfactory sections of the Tarkio limestone are found farther up the valley. In sections 22 and 27 of Tarkio township there are a number of quarries and natural exposures from which it is possible to make out the following succession of the beds belonging to this horizon:

		FEET.	INCHES.
8.	Fusulina limestone	1	
7.	Shale	3 to 5	
6.	Limestone, rather soft	0	8
5.	Blue, fine-grained, hard limestone, breaking at right angles to the bedding planes into excellent blocks for building purposes. The most important quarry stone of the county	1	4
4.	Shale	12	
3.	Limestone rather softer than No. 5, but of fair quality	1	6
2.	Shale	3	6
1.	Limestone	2	

The quarry ledge has been worked quite extensively on the land of Mr. Geers, on the Nw. ¼ of section 27. The work has

been carried on lengthwise along the slope of the west side of the valley, so that operations have not been carried very far into the hill. Near the surface the shale No. 7 has suffered by decay and weathering, and allowed the Fusulina bed, No. 8, to come down upon No. 6; but where a fresher part of the section is exposed the shale attains the thickness reported above. On the farm of Mr. Wolf Miller, in the Se. ¼ of the same section, a large quantity of stone has been taken out; but since the one ledge, No. 5, is all that is sought for, there has been no effort made to maintain a quarry face which would show a section of the beds. At a few points the Fusulina layer is seen resting on No. 6, the intervening shale having been wasted and removed by weathering.

The beds below No. 5 are shown in a well on the Geers place. No. 3 is seen naturally exposed near the barn of Mr. Harlan in the Sw. ¼ of the Se. ¼ of section 22; while the blue ledge, No. 5, is quarried a little farther up on the hillside. There are several small quarries on the land of Mr. Barrabee, in the Sw. ¼ of section 22. In the Ne. ¼ of section 15, Mr. O. Erickson has a a quarry which uses the ledges numbered 1 and 3. These beds, each separable into two or three distinct layers, are thicker and firmer here than they are farther south, and the intervening shale is much reduced. A good quality of stone is taken out, and it is obtained with greater ease than the products of some of the other quarries noted. *Myalina subquadrata* is a common fossil in the Erickson quarry. On the north side of the road from Erickson's, in the Se. ¼ of section 10, stone has been taken from the same beds worked in the Erickson quarry and also from the characteristic "blue ledge" of this region, No. 5. There are many other openings furnishing stone along this branch of the Tarkio. Mr. C. Apple has a quarry in section 14, of Tarkio township; and farther north, in Fremont township, there are quarries in sections 24, 25, 35, and 36. There are also some openings on the smaller branches of the stream in Douglas township.

Some of the best natural exposures of the limestone of the Tarkio are seen in the bed of a small stream near the southwest corner of section 18, and the adjoining part of 19, in Douglas township. On the south side of the road running between these sections there is an exposure due to undercutting of the stream, which shows:

		FEET.	INCHES.
5.	The limestone cap above the quarry ledge.....	0	8
4.	The "blue ledge" of the quarries farther south.	1	2
3.	Calcareous shale containing numerous fossils, such as *Fusulina cylindrica*, *Rhombopora lepidodendroides*, *Derbya crassa*, *Meekella striatocostata*, *Enteletes hemiplicata*, *Chonetes granulifera*, *Productus nebrascensis*, *P. semireticulatus*, *P. cora*, *Pugnax uta*, *Spirifer cameratus*, *Ambocœlia planoconvexa*, *Athyris subtilita*, together with numerous stem segments of Zeacrinus.....	7	
2.	Calcareous, yellow, marly clay	0	4
1.	Limestone with fossil fragments, generally barren, soft and yellow when weathered, but harder and bluer when fresh.....	1	2

No. 1 comes down to the level of the bottom of the creek and is the equivalent of No. 3 of the preceding section. No. 2 of this section was not recognized farther south. The other members will be easily correlated. No. 3 is somewhat variable in its characteristics. The fossils are not distributed uniformly in any of the layers, but seem to have formed local colonies. East of the point where the section was made, ledges 4 and 5 are exposed continuously for some distance along the sides of the small valley. On the north side of the road there is a bed of limestone in the bed of the creek, which lies below No. 1. At all of the quarries visited, with the exception of those mentioned at Erickson's, the "blue ledge" is the only bed that is regarded with favor. In Fremont township the eight inch layer, No. 6, affords servicable quarry stone for some purposes.

The limestones exposed in the Tarkio valley have an inclination southward a little greater than the grade of the

stream. In sections 22 and 27, Tarkio township, they have an elevation about fifty feet above the water in the channel, while at Coin they are less than twenty-five feet above the water level. As a whole the calcareous beds, particularly 1, 3 and 6, increase in thickness and firmness toward the north, while the alternating shale beds become correspondingly thinner. Near Stennett, in Montgomery county, what are evidently the equivalents of the limestones under considera-

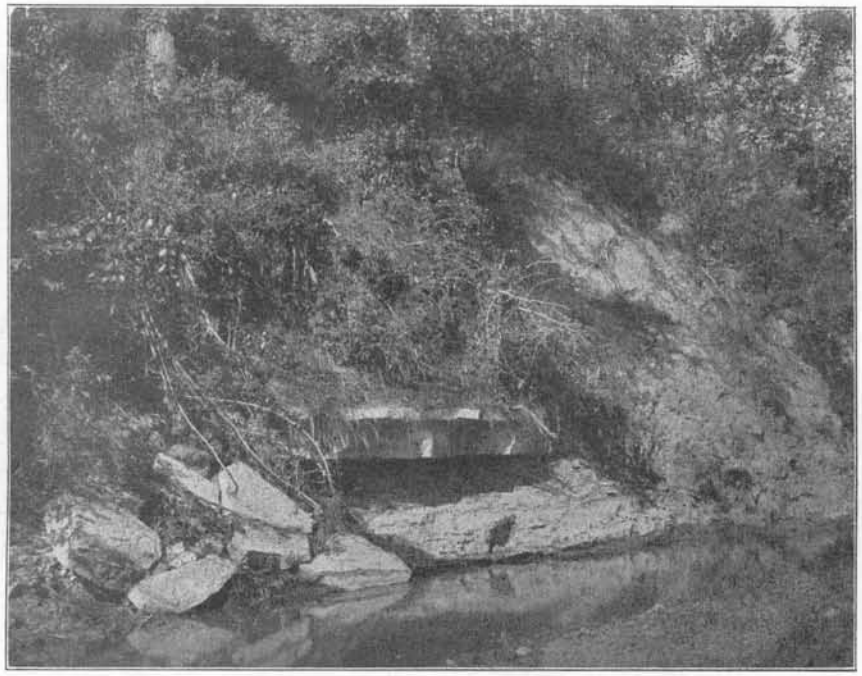

FIG. 34. Exposure of the "blue ledge" and associated strata southeast of Essex.

tion have become much thicker at the expense of the intervening shales, and a greater number of the layers are crowded with the small grain-like shells of Fusulina.

One of the few exposures of the indurated rocks occurring in the western part of the county is seen in the valley of a small creek in section 31 Fremont township, and section 36 of Pierce, a mile and a half or two miles southeast of Essex.

The beds are the equivalent of those seen on the Tarkio. The eight-inch cap and the sixteen-inch blue ledge, underlain by shale, are shown in figure 34. The blue ledge is the same fine-grained, compact stone that it is farther east, and it breaks into blocks at right angles to the bedding planes the same as elsewhere. The eight-inch layer is here separated from the blue ledge by a thin bed of shale. The Fusulina limestone, No. 8 of the Tarkio section, is not quite so rich in the small shells which give character to this bed farther east, and which are so exceedingly common at Stennett. While certain parts of the bed are crowded with the small fossils in question, other parts are quite barren. This bed carries other species of fossils to a somewhat greater extent than elsewhere. *Enteletes hemiplicata*, *Productus semireticulatus*, *P. longispinus* and *Ambocœlia planoconvexa* are among the forms noted. At this point many Fusulina occur in the blue ledge. This exposure near Essex illustrates the fact that, except in a general way and in the case of a very few persistent layers, the strata of the Missourian stage are exceedingly inconstant in thickness and lithological characters. There is here a strong dip to the west, but the grade of the stream channel is greater in this direction than the dip. On this account lower and lower beds appear successively when the exposure, which continues some two or three hundred yards west of the township line, is followed down the valley. The most variable beds are those which lie below the level of the blue ledge. A certain layer, for example, when first seen in the bed of the stream, is calcareous, hard, firm, and breaks off at right angles to form a miniature fall. Traced farther down as it appears in the bank, it grades into a soft shale. Other layers show the same transition from a limestone in one place to shale in another. The limestone does not feather out, but it grades out, the layer persisting, but becoming more and more argillaceous until it grades into a true shale. Even the blue ledge, the most persistent of

all, varies in thickness and in fossil contents, certain parts being rich in Fusulina, while others show none.

The relations of the Tarkio limestones to the Nodaway limestones have not been very satisfactorily determined. The Nodaway beds dip to the west quite rapidly as shown by the difference in altitude between the coal seam at the site of the old Shambaugh mill near Clarinda, and at the Ingraham mine a mile or two to the west. The dip, if constant, would carry the coal about 300 feet below the level of the limestone in the Tarkio valley. The dips, however, are not constant. The strata are folded more or less; and the deep mantle of drift precludes the possibility of following the beds from one locality to another. A well bored on the farm of Mr. H. Larrabee, in the Sw. ¼ of section 22, Tarkio township, was carried down to a depth of 300 feet; and an eighteen inch bed of coal is reported at a depth of 180 feet from the surface. This is beyond much question the Nodaway coal, lying much nearer the surface than would be expected if the strata had a uniform dip. From the position of the well mouth the depth of the coal below the Tarkio limestone is found to be about 125 feet.

On land belonging to C. A. Linquist in the Nw. ¼ of section 24, Fremont township, a thin bed of coal lying above the limestones of the Tarkio valley has been worked on a small scale. The shaft is located on the hill top overlooking the deep valley of the east branch of the stream. The section as reported by persons who had opened and worked the mine, is:

		FEET.	INCHES.
6.	Black soil	1	
5.	Red soil, with pebbles (drift)	40	
4.	Bluish clay (may be shale, possibly drift)	10	
3.	Limestone, roof over coal	3	
2.	Coal		6 to 14
1.	Fire clay		

One of the earlier attempts to work the mine was by means of a drift on the east side of the hill, starting in at the level of the coal. The beds here, as usual, dip slightly to the west

so that the drainage was toward the breast of coal instead of toward the pit mouth. Another effort was made to open the mine on the west side of the hill so as to take advantage of the slope in keeping the mine dry; but the roof limestone proved to be shattered and broken, and gave so much trouble that the shaft was finally located on the summit of the ridge. The level of the coal on the east slope of the ridge is thirty-five feet above the blue ledge of limestone, which has been somewhat extensively quarried for half a mile or more along the hillside. With the horizon of the Linquist coal may be correlated the coal seam found on the land of Mr. O. H. Brewer, in the Nw. ¼ of section 20, Tarkio township. The information is furnished by Dr. George L. Smith that at a depth of fifty feet, commencing about fifteen feet above the bottom of West Tarkio creek, Mr. Brewer found a layer of limestone one foot in thickness, beneath which occurred four feet of shale and one foot of coal.

Dr. George L. Smith, to whose extensive and accurate knowledge of the geology of the county, the Survey is indebted for much of the information relative to the region about Shenandoah, writes that he has found a natural exposure of the indurated rocks on the West Tarkio, and the only one in Grant township. It occurs in the Se. ¼ of the Se. ¼ of section 25. On the east side of the creek, in a gully, there is an exposure of "blue slate" two and one-half feet in thickness. It lies about ten feet above the level of the water in the creek, and in the opinion of Dr. Smith it lies above the horizon of the Linquist coal. Dr. Smith's views relative to the stratigraphic position of the exposure seem to be well founded, and the "blue slate" of this locality may be looked upon as the highest of the Missourian strata observed in Page county. The entire section of this formation, so far as developed in the county, may be generalized as follows:

	FEET.
6. The "blue slate" in section 25, Grant township, thickness unknown.....	

		FEET.
5.	Linquist coal with overlying beds	14
4.	Shale between Linquist coal and the limestones of the Tarkio valley	35
3.	Limestones of the Tarkio valley and associated shales	27
2.	Shales between Tarkio valley limestones and the Nodaway coal	125
1.	Nodaway coal with the limestones and shales at Hawleyville and Braddyville	20

Deep Drill Holes.—There are very few deep drill holes in the county which throw any light on the Missourian section. The most important boring was put down near Clarinda, and to this reference has already been made. The location was chosen in the Nodaway valley, and the first rock encountered lies below the level of the Hawleyville and Braddyville sections. The deep well on the Larrabee farm is important as showing the relations of the limestones of the Tarkio valley to the Nodaway coal. Some years ago a hole was bored to a depth of 700 feet, near the southwest corner of the Nw. ¼ of section 21, Grant township; but the only record obtainable was the statement that the drill passed through two coal beds, each from one foot to eighteen inches in thickness. The depth to the coal, or the distance of the seams apart, could not be obtained. It is possible, however, that the boring passed through both the Linquist and the Nodaway seams. Even allowing for more than the normal dip toward the south and west, the depth of the well was sufficient to pass beyond the lowest of the two coal horizons.

Another deep drill hole in Grant township is located in the Nw. ¼ of section 14. The record as reported shows that the drift here is 180 feet in depth ; that underneath the drift is a body of sandstone sixteen feet in thickness ; that at a depth of 310 feet a fourteen-inch seam of coal was encountered ; and that the drill continued down through shales and limestones to a depth of 400 feet. All other details are lacking. The sandstone beneath the drift is probably of Cretaceous age

and belongs with the formation to be noted under a subsequent heading. The fourteen-inch coal is very probably the Nodaway seam, as the depth is approximately that at which this vein should be found, if present at all. The upper, thinner coal of the Linquist horizon may be locally absent, or it might easily be overlooked. On land belonging to Mr. Falk, a few rods southeast of the opening in the side of the valley to the Linquist coal mine, a test hole was made in search for coal. The boring began below the level of the limestones. No samples were kept, but the record as preserved in manuscript by Mr. Falk is as follows:

		FEET.
16.	Clay	15
15.	Limestone	1½
14.	Blue shale	3
13.	Brown soapstone	6
12.	Blue soapstone	13
11.	Soft slate	16
10.	Two ledges of "stone"	3
9.	Light clay	8
8.	Soft slate	25
7.	"Stone"	1
6.	Dark slate	2
5.	"Stone"	3
4.	Fire clay	2
3.	Dark slate	1
2.	Fire clay	1
1.	Limestone	16

This gives a depth of 116 feet, almost enough, according to the record of the Larrabee well, to reach the Nodaway coal. If the shale beds, as seems in some instances to be the case, thin toward the north, it may be possible that the coal horizon is represented in the dark slate, No. 3, and that the limestone, No. 1, is equivalent to the beds beneath the coal, exposed at Hawleyville and Braddyville. The log of the boring, as it stands, is believed to be worthy of permanent record; but carefully preserved samples from other borings should be submitted to careful study and examination before final interpretations or correlations respecting this part of the Missourian section are made.

The Cretaceous System.

DAKOTA STAGE.

Sandstones of the Cretaceous system are indicated at a few localities in Page county. They are usually found in wells and borings which have penetrated the drift. As a rule they are completely concealed by the heavy mantle of Pleistocene deposits which everywhere overspread the surface. Neither the extent nor the outlines of the areas in which these sandstones occur can at present be known; and for this reason the areas on the accompanying map, which are colored to indicate the presence of the Cretaceous, must be regarded as only a provisional attempt to map this formation. Along Buchanan creek, on the land of Mr. J. D. Maxwell, in the Sw. $\frac{1}{4}$ of section 15, Buchanan township, there are some very unsatisfactory outcrops of a micaceous sandstone which is probably Cretaceous. This sandstone has been penetrated at a few points where small pits have been dug in search for coal. It overlies shales and shaly limestones of the Carboniferous. It is not very thick, and the area it covers is probably quite limited. Well diggers report a sandstone, twenty feet below the surface, in the northern part of the town of College Springs. From the best information obtainable, the sandstone dips toward the north, and disappears abruptly south of the college. No samples were seen. Nothing is known as to the character or thickness of the sandstone at this locality. The facts reported by persons familiar with the locality are placed on record in the hope that the attention of those who have opportunities to collect data may be stimulated and more precise information obtained for use in completing the final geological map of the state.

The most satisfactory evidence of the presence of Cretaceous sandstones in Page county is found in the vicinity of Shenandoah. The bed of sandstone already noted beneath 180 feet of drift, in section 14 of Grant township, may be referred to the Cretaceous without much question. A similar sandstone

is found in wells, beneath the drift, at a number of points in sections 15, 16, and 17; and the same sandstone is known to occur as far south as the Se. ¼ of section 16 in Morton township. At the point last named the drift is seventy-six feet in thickness. In sections 15, 16, and 17, of Grant township, the sandstone lies under from twenty to forty-five feet of drift. The upper surface of the sandstone is very irregular, as if it had suffered a great deal of erosion before being covered with the superficial till. So far as learned the sandstone was passed through at one point only—the wells in other cases getting water before reaching the bottom of the formation—and the thickness reported is fifteen feet. The difference in level between the upper surface at the point where the stone was penetrated and the upper surface at some lower points in the neighborhood, is more than fifteen feet—a fact which would indicate an unconformity between the sandstone and the underlying shale. The deposit in question varies greatly in hardness, some beds being almost quartzitic while others are loose and practically unconsolidated.

The Pleistocene System.

KANSAN DRIFT.

The surface of Page county is very generally covered to a great depth with glacial deposits. The drift is unusually heavy, attaining a thickness in places of 200 feet. The topography of the county, as previously noted, is due almost wholly to erosion of the superficial materials. The amount of rock cutting is comparatively small. Valleys walled with drift have a depth of 200 feet, and wells on the divides not infrequently reach depths below the level of the water in the streams before encountering the indurated rocks. The drift of Page county in this report is referred provisionally to the Kansan, though it possesses many characteristics which suggest the age of the older pre-Kansan till.

The materials forming the drift are here very variable. They lack the constancy exhibited by the blue Kansan clay of south-central and southeastern Iowa. The best artificial section of the glacial deposits in the county is found in the great railway cut in the south half of section 33, Tp. 69 N., R. XXXVI W. (Fig. 35.) The fresh unaltered clay first breaks down, on exposure to the weather, into a crumbling, powdery product altogether unlike the tough, persistent blocks which weather off the fresh blue Kansan when it is exposed in the eastern

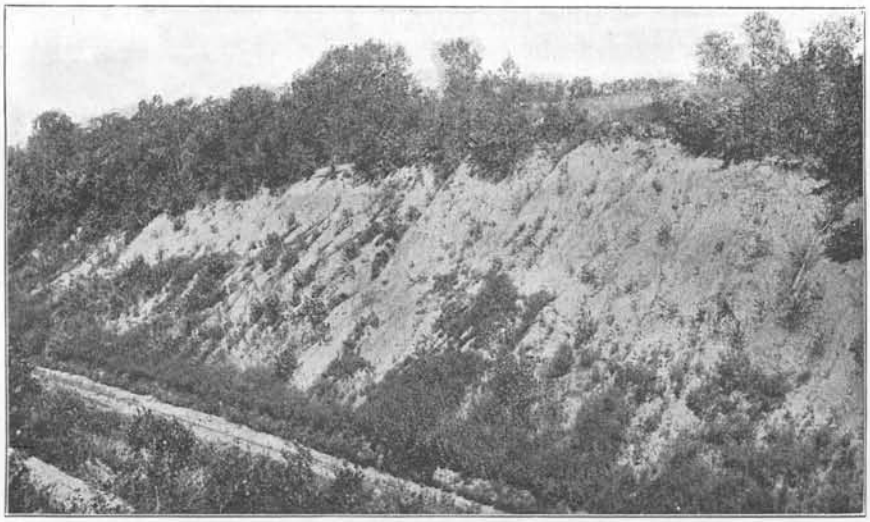

FIG. 35. The deep railway cut near Clarinda.

part of Iowa. Leaching and oxidation have descended to a depth of twelve or fifteen feet from the surface. In the fresh till in the lower part of the cut, limestone pebbles are numerous, but in the weathered zone the calcareous fragments have been completely dissolved out; the granites are wholly decayed, and nothing but hard, fine-grained greenstones remain. The limestone pebbles below the zone of weathering are very frequently enlarged by deposition of the calcareous matter held in solution by descending ground waters; and calcareous concretions representing the dissolved pebbles and limestone flour

carried down from the leached zone, are sprinkled over the surface of the slope in the lower part of the cut. Greenstoen cobbles and pebbles are common throughout the whole thickness of the exposure, and a very large proportion of these are planed and scored on one or more sides.

The indications of age in the drift of Page county are found in a number of its characteristics. In the first place the extent to which the surface is eroded bears evidence of a long lapse of time. The stream valleys are all deep and wide; the great width, rather than the depth, affording some measure of the length of time the work of valley making has been in progress. The whole surface of the country over the divides, from one stream valley to another, has been carved into a system of completely rounded ridges, separated by wide and deep-cut ravines, as shown in Figures 28, 29, 30, and 31. In the second place the processes of weathering and oxidation have affected the surface so as completely to change the character of the original materials, to a depth, in places, of at least fifteen feet. The iron constituent of the till is completely oxidized. The calcareous material is all leached out and carried away, part of it being removed from the region and carried by drainage waters to the sea, part having been carried downward by descending ground waters, to be redeposited in the form of concretions. Not only have all the limestone fragments of all sizes up to ten or twelve inches in diameter, been dissolved, but most of the granites are completely disintegrated into non-coherent granules, now scarcely distinguishable from the original fine constituents of the till. In the third place, there is in Page county one evidence of age which is not presented by the Kansan drift in the eastern part of the state. Thoughout a large portion of the county the loess overlying the drift is thin, and the gulches carved by erosion along the roadsides cut down through it and expose the pebbly till. Between the loess and the till there is a sheet of gravel (Fig. 36) conforming to the contact between the two deposits. The loess is young as compared with the drift.

Before it was laid down the surface had been eroded to practically the same extent as now; all the present topographic features had been developed; the surface in all its contours and inequalities was covered with the sheet of gravel referred to; and it was on this surface that the loess was deposited. The gravel is made up of pebbles, which were at first distributed through that part of the drift which has been removed by erosion. The finer portion of the till was easily trans-

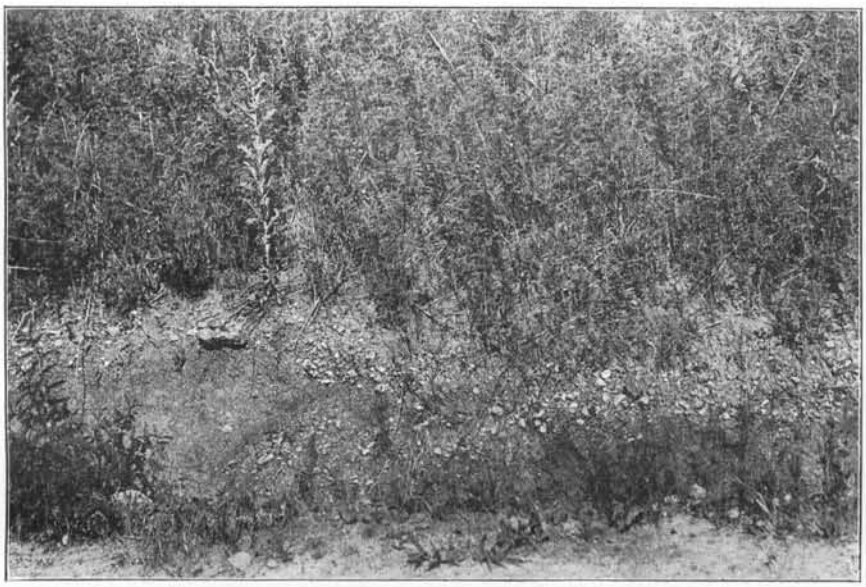

FIG. 36. Thin sheet of residual gravel between loess and Kansan till, north of the center of section 17, Lincoln township.

ported by the sheet-water which drained the general surface, while the pebbles from quite a thickness of the drift—too heavy to be carried along—were concentrated by the transportation of the fine clay in which they were embedded, and left as a sheet of residual material, from which finer constituents had been sorted and removed. The residual gravel indicates two things: First, the erosion of a considerable thickness of drift from the surface, and, second, the consummation of the process by currents of sheet-water too weak,

even on slopes quite steep, to transport rounded pebbles an inch or more in diameter. The process, so carried on, was one requiring time. It is worthy of note that, although the till was originally rich in limestone pebbles, no pebbles of this composition are found in the residual gravels, nor are there pebbles of any kind except those of the hardest and most resistent of the crystalline rocks. Quartzites are very common.

The Loess.—The surface of the county is very generally covered with loess. As a rule this material is not very thick, yet there are places where it reaches a depth of twenty feet or more. The average thickness does not exceed two or three feet. The loess is much younger than the till upon which it lies. All the changes in the character of the drift surface, which have been referred to as indicating a long period of erosion and weathering, had taken place before the loess was deposited. Along the north line of the Se. ¼ of section 33, east of the river, in Nodaway township, a road cut through the summit of the ridge shows the loess at that point to be about twenty feet thick, and yet underneath this thick mantle the weathering of the surface of the drift is as complete as in places where the loess is thinner. It is conceivable that where the loess is thin the weather may continue to affect the underlying till, but the thicker deposits of loess would protect the surface beneath it from any change. The changes now apparent were accomplished before the deposition of the loess. In the deep railway cut in this same section, the thickness of the loess above the weathered, ferretto zone, is thirteen feet, and this weathered zone is at least twelve feet in thickness. In some instances there are indications of two distinct beds of loess. For example, on the top of the hill east of the Crabill brickyard, the freshly cut surface showed :

	FEET.	INCHES.
4. Light colored loess, not very ferruginous.....	6	
3. Yellowish sand, the upper 10 inches clay colored, the lower part showing cross bedding. The laminæ in the cross bedded portion are		

		FEET.	INCHES.
	inclined toward the east, away from the river valley	2	6
2.	Dark colored, ferruginous, weather stained loess, quite different in appearance from No. 4	5	
1.	Very much weathered drift, ferruginous, leached, the cobbles and pebbles much decayed, the whole stained with organic matter; exposed.	7	

A part of the foregoing section is illustrated in figure 37. The two beds of loess are very distinct in color, No. 2 show-

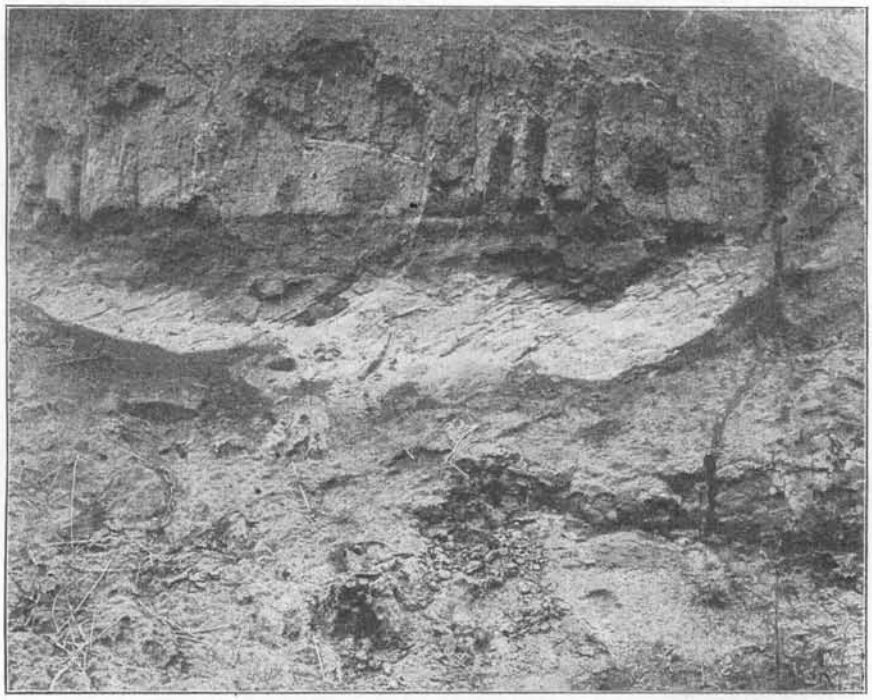

FIG. 37. View showing sand, partly cross-bedded, separating an old, weather-stained loess from an overlying, fresher body of the same material. View taken on hill east of Clarinda.

ing signs of much greater age than No. 4. The obliquely bedded sand, No. 3, may probably be of eolian origin. The altitude is 160 feet above the present flood plain of the river, and it is scarcely conceivable that this material could have been deposited by currents of water flowing toward the east.

The prevailing dry winds, however, are from west to east, and the cross bedded sand may represent readjustments which took place during a period when winds blew with more than usual force.

Flooded Valley Deposits.—In nearly all the valleys of Page county there is a formation which in some of its phases resembles loess; but in other of its aspects it is clearly an aqueous deposit. It has evidently been laid down since the valleys reached approximately their present depth. North branch near Clarinda has its channel cut in this material. It is yellowish in color, tough, jointed and obscurely stratified. Unlike loess it contains occasional pebbles and pockets of sand. A small greenstone, two inches long and showing glacial planing on two sides, was taken from this silt in the bank of North branch. No. 14 of the Hawleyville section illustrates the character of the deposit. Above the section described at Braddyville, west of the railway track, there is a body of this clay, twenty feet thick and forming a distinct terrace fifty yards or more in width at the top. The hard, enamelled scales of the gar pike, Lepidosteus, were found in this bed at Braddyville, the scales retaining their proper relations to each other as if the fish had been buried at the time the silt was forming. Between the point where the scales were found and the railway station, some recent cutting shows beds of stratified sand below the level of the clay. The same yellow silt is found beneath sandy alluvium in the valley of Buchanan creek, east of Braddyville. It is well shown in the bank of the Nishnabotna river west of Essex, where it is overlain by six feet of a fine, loess-like silt and two or three feet of black loam. At the Rankin Brothers' brickyard at Shenandoah, the section of the clay pit shows:

		FEET
3.	Loess-like clay	8
2.	Bluish stratified clay, clearly an aqueous deposit, but flexed more or less as if laid down on an uneven surface	1
1.	Porous, dark, granular clay	7

Numbers 1 and 2 are separated by a ferruginous band which looks as if it had been weathered and oxidized by long exposure to the air. The porosity of No. 1 is due in part to flexuous tubes, one-eighth of an inch in diameter, which pass vertically through it. The tubes are evidently places from which slender plant roots have decayed, for in the upper member, No. 3, there are similar tubes with the rootlets still in place. Some of the tubes in No. 1 are blackened with carbonaceous material due to the decay of the root tissues. No rootlets pass through No. 2. The tubes in the lower member of the section were made by plants which grew upon its surface before the overlying members were laid down. Nos. 1 and 3 resemble loess, but No. 2 records a distinct episode between the more recent and a more ancient period of loess formation during which the valley was temporarily flooded.

The distribution of this deposit is practically universal in all the valleys below a certain level. There has been some valley cutting since it was laid down, but little as compared with what took place beforehand. In the discussion of the topography of Page county there is a somewhat guarded suggestion that the drift upon which the topographic forms are developed by erosion, may be what geologists have been calling the pre-Kansan. Should later study prove this suggestion to be true, the flooded valley deposits would find easy explanation in the hypothesis that the water-shed, as really seems to be the case, coincides with the margin of what has been called Kansan drift. The great thickening of the drift along the water-shed and the marked difference in the character of the till and the maturity of the topography on opposite sides of the divide, certainly favor the probability of such an hypothesis being true. The principal streams of southwestern Iowa have their sources in the water-shed. The melting Kansan ice, under the conditions assumed, would furnish great volumes of turbid water which could find outlet only along the courses of these streams; and large quantities of silt would be distributed along the valleys. Granting this to be the explanation

of the flood-water deposits so conspicuous in this territory, the principal part of valley making, on this assumption, would be referred to the Aftonian interglacial interval. An alternative suggestion may be made to the effect that the flood deposits belong to the age of the Iowan drift. The phenomena around the Iowan margin indicate that during the melting of the ice sheet belonging to this age the land was low, and the waters flowing away from the margin were too sluggish to transport objects larger than grains of rather fine sand. It is possible that the depression of the surface proceeded so far that slack water was backed up into the valleys of Southwestern Iowa, and that the formation discussed was thus deposited. The land was high during the melting of the Kansan ice as indicated by the overwash sheets and valley trains called Buchanan Gravels throughout northeastern Iowa. These point to energetic torrents flowing on relatively steep slopes and capable of carrying very coarse material. The deposits in question, however, are fine silt indicative of slack-water conditions. While the Iowan ice sheet did not come within many miles of Page county, it may have invaded the upper part of the Missouri valley and so have contributed volumes of water loaded with a large amount of fine yellow mud, which, following the Missouri and backing into the tributary valleys, produced the effects observed. On this supposition there would be ample time for the cutting of the valleys to their present depth between the retreat of the ice which distributed the Page county drift and the culmination of the Iowan invasion. Whatever may be the explanation, these valleys have been cut in the drift of the county, and they have been occupied by floods of turbid water since the major part of the valley making was accomplished.

Alluvium.—The broad bottoms of the stream valleys are everywhere covered with a rich alluvial deposit, which has accumulated slowly, partly by wash from the long slopes on either side, and partly by deposition from the very muddy streams when they overflow their flood plains. The streams

of this region during all the medium and high stages of water carry an unusual amount of fine silt in suspension. Some of the alluvium, at least, is younger than the flood deposits described in the preceding section.

Deformations and Unconformities.

The rocks of Page county show a number of small folds and eccentricities of dip, but none are of very great amplitude. The most important is the Braddyville anticline. The rocks exposed in the sections of Braddyville and Hawleyville seem to constitute the crest of a fold, the axis of which trends north-northeast and south-southwest. The axis passes east of the old Shambaugh mill and all the coal mines in that vicinity, and in its northward extension it passes east of Henshaw in Taylor county. West of the axis the coal dips strongly toward the west. Between the Shambaugh mill and the Ingraham coal mine there is a dip of sixty-five feet in about two miles, while at Henshaw there is a dip of thirty-five feet in a quarter of a mile. East of the Burnside shaft at Henshaw the Braddyville limestones rise to the surface in the wash of a small creek, and at a level not very much below the mouth of the pit. The strong inclination noted in the localities mentioned is not continued as far west as the limestone quarries on the Tarkio, for there the beds assume a more nearly level position. The limestone exposed in section 36 of Pierce township, near Essex, dips rapidly westward, and indicates another fold which is probably parallel to the Braddyville anticline.

The principal unconformities to be noted are, *first*, that between the Carboniferous and the Cretaceous strata, and, *second*, the unconformity between the Pleistocene deposits and the underlying indurated rocks.

Soils.

There is little to be said concerning the soils of Page county. There is practically but one class, and that is the best. The surface is almost everywhere covered with loess.

The depth of the loess is not great, except in a few localities, but whether deep or not it is loose, easily cultivated, and so porous as to give the freest access to air and moisture. Even the underlying till, which was at first tough and intractable, has been thoroughly subdued and pulverized at the surface by long exposure to weather and the modifying effects of organic agencies. The annual growth and decay of the rank prairie vegetation for many centuries, the burrowing of animals that live beneath the surface, the influence of frost and rains, together with the chemically active constituents of the atmosphere, have all contributed to the making of a mellow soil, rich in all plant foods, and thoroughly permeable to great depths, to gases and moisture. The soils are not only deep and mellow and exceptionally fertile, but they are free, as a rule, from the bowlders which, in many parts of the United States, encumber the surface of the drift. There are here ideal conditions for succesful, scientific agriculture. Black, sandy alluvial loams have been developed in the broad valleys and other lowlands, and cover a large proportionate area of the surface. In the high quality and uniform excellence of her soils, Page county is not excelled by any similar area in Iowa, and Iowa furnishes a standard which is surpassed in very few instances the world over. Immense crops, especially of corn, annually bear testimony to the wealth-producing power of the soils; and this wealth expresses itself again everywhere in homes of comfort, culture and intelligence; in active, busy, growing towns, and in all the other external signs of thrift and prosperity.

ECONOMIC PRODUCTS.

Coal.

Next to the soils, which enormously outrank all the other geological formations of the county in economic value, may be reckoned the coal. The most important seam is that known as the Nodaway coal. It is this that is mined at Hen-

shaw and New Market in Taylor county. The seam underlies Page county to an extent not fully determined. It crops out in the river bank at the old Shambaugh mill, and it is worked by shafts at the Ingraham and other mines near Clarinda, and at all the mines in the neighborhood of Shambaugh. At a distance greater than three or four miles west of the Nodaway river, it in general lies too deep to be worked with profit. The vein is very persistent. It is known in Adams, Montgomery, Taylor and Page counties in Iowa, and it is quite extensively worked at a great many points down the Nodaway valley in Missouri. The thickness of the vein is unusually constant, the range being from fourteen to eighteen inches; and the quality varies but little over large areas. The coal is usually worked by the "long-wall method." The Ingraham mine in the Ne. ¼ of section 11, Tp. 68 N., R. XXXVII W., is one of the new mines of the county, and one of the most important. The coal is found at a depth of about 100 feet from the surface. The shaft passed through the following succession of strata:

		FEET.
7.	Soil and drift; drift very much weathered near the top, and along joints to a greater depth	22
6.	Yellow shale	20
5.	Blue laminated shale	50
4.	Non-laminated shale	3
3.	Cap-rock	1½
2.	Shale	2
1.	Coal	1½

Quite a number of mines have been opened and worked at various times near Shambaugh. Lately most of the mining in this region has been done by J. W. Turner, Henry Fulk and G. W. Howard. Somewhat recently a shaft, more than 100 feet in depth, was made on the Maley farm, and good coal was found; but at the time the mine was visited very little had been taken out.

That the Nodaway coal was laid down on an extensive area of sea bottom is shown by the large territory over which it is

distributed, the practically unvarying thickness and other characteristics of the seam, and the manner in which the coal is interstratified with marine sediments. There is no soil bed below the coal, and it is overlain, without transitional deposits, by shales rich in marine fossils. It bears a constant relation to a bed of limestone of nearly uniform thickness, the cap-rock, which likewise carries a number of typical marine species. That the coal was made of terrestrial plants is also clear; for an examination of the coal itself shows recognizable impressions of fern fronds, together with the stems of other pteridophytes. The microscopic structure is in accord with the evidence derived from more casual examination; the characteristic vascular tissues of ferns and their Carboniferous allies are readily detected.

Not much is known of the Linquist coal. It has not been prospected except at the one locality where an attempt was made to mine it with rather unsatisfactory results. The Linquist mine, as already noted, is located in the Nw. ¼ of section 24, Fremont township. Only a few thousand bushels altogether have as yet been taken out. The relations of this coal to the other members of the general Missourian section have already been discussed. The coal is doubtless present under quite a large area in the county. Since it lies near the surface it can be mined inexpensively; and when found under better roof, it will prove an important addition to the geological resources of the region.

The amount of coal mined in Page county varies from year to year. The output for any given year will not be recorded here; the reader being referred to the annual report of the Survey on Mineral Statistics. The limited thickness of the Nodaway coal precludes the possibility of working it on an extensive shipping or commercial scale. It, however, satisfactorily supplies local needs, and is an important factor in the development of the country. Its persistence or continuity over a large area makes prospecting a simple and easy matter, and wherever it occurs within 150 feet of the surface

there is no doubt of the possibility of working it at a profit. It should be found within working distance of the surface on the East Tarkio, and it will yet be worked in many neighborhoods where it is not yet prospected.

Building Stone.

The stone quarries of Page county are of local importance. Some building stone is taken from the limestones of the Hawleyville and Braddyville horizon, but the greater part of the quarrying is done in the valley of the Tarkio. Local quarries are here quite numerous, and the more important of these have been already noted. The "blue ledge" of the Tarkio limestone is the most serviceable and the one most generally sought for. The stone has excellent lasting qualities, and is suitable for quite a variety of purposes. In meeting local needs this stone has a value difficult to estimate.

Brick and Tile.

The clay industries of the county are capable of much greater development than they have yet attained. The Carboniferous shales afford raw material for the manufacture of a large variety of clay products, from pottery to sewer tile and paving brick, but so far, in this county, no attempt has been made to utilize this inexhaustible source of supply. Just north of the county line, at Villisca, the McNaughton brickyard, well equipped and operated on a large scale, makes use of Carboniferous shales; but even here only a few of the possibilities of the material are realized. In Page county there are a number of brickyards, but all use Pleistocene clay.

One of the largest brick making plants in this county is operated by Mr. J. M. Crabill, on the east side of the river at Clarinda. River silt, or alluvium, is used. The plant is equipped with steam power, a Monarch machine made at Burlington, Ohio, large drying sheds, and all other necessary tools and machinery. The capacity of the machine is about 40,000 brick daily. The brick are dried on pallets, and are

burned in large clamp kilns. There are three kilns, each with a capacity of 500,000. The annual output ranges from 2,000,000 to 2,500,000. The local market is supplied and shipments are made abroad within a radius of 100 miles.

There are brickyards at Essex and Coin, which also use alluvial clays. At both places the brick are moulded by hand, dried on the yard, and burned in small clamp kilns. The yard near Essex is located west of the Nishnabotna river, in a locality where the yellow, flood-water deposits described in a foregoing section of this report, occur in great abundance. These deposits might be used in tile making, and there are other purposes to which they are adapted.

The Rankin Brothers operate a large brick and tile plant at Shenandoah. The clay used is a loess-like silt divided by a band of blue clay of undoubted aqueous origion. Steam power is used. There is a stiff-mud, auger, end-cut machine of the latest pattern; and there are well constructed drying sheds and all the other equipments for the manufacture of brick and tile. Six clamp kilns are used. The output of brick will average about 2,000,000 annually.

South of the state line at Blanchard there is a brick yard using a heavy bed of clay which is well stratified throughout a thickness of fifteen to eighteen feet, and capped by three or four feet of loess. The main body of this clay belongs to the age of flooded river valleys.

Water Supplies.

The streams of the county afford a large proportion of the people permanent supplies of water suitable for certain purposes. Wells, however, in some form or other, are the principal source from which water for domestic uses is obtained; and wells, after all, constitute the main reliance for all purposes for which water is needed, throughout the greater part of the county. Water is found in sand and gravel beds at various depths in the drift. Owing to the great depth of the Pleistocene deposits, it is seldom necessary to bore into the indurated

rocks, water in abundance usually appearing before they are reached. In the neighborhood of Shenandoah, in sections 16 and 17 of Grant township, the drift is thinner than usual, ranging from fifty or sixty down to twenty feet, and a few wells are known to have entered the Cretaceous sandstone. Water seems to be abundant in this formation. In only one case was the entire thickness penetrated. Dr. Smith reports a case which illustrates in a typical way the water-bearing quality of the Cretaceous formation. Mr. A. Culp, who owns the Se. ¼ of section 16, Morton township, had a well dug on his place. At seventy-six feet he found sandstone and went into it five feet when water forced him to cease.

A well is reported to have reached "slate" at a depth of twenty-eight feet, in section 25, Nodaway township; another in section 24 of same township reached the shale at a depth of 108 feet; and in section 28 of Harlan township wells, it is said, reach rock at seventy-five or 100 feet. Along the ridges on both sides of the East Tarkio valley the limestone is encountered at depths ranging up to sixty or seventy-five feet. In general, however, water is obtained in beds of sand or gravel in the drift, before the underlying rocks are reached, and some of these drift-wells are fully 200 feet in depth. Beginning on the highlands of the divides, they descend below the level of the water in the adjacent streams.

Clarinda is supplied from a number of drive wells located in the lower part of the city, in the Nodaway valley. The wells end in gravel or coarse sand, at depths ranging from forty-five to fifty-nine feet. The supply is not all that those most interested desire. The amount pumped reaches about 70,000 gallons a day. At the hospital, near Clarinda, one five-inch and two six-inch Cook wells were used in 1899. The depth is seventy-one feet, and water is found in a bed of coarse gravel, eight feet in thickness, overlying blue shale. The amount pumped reaches about 110,000 gallons daily. The beds down to the shale beneath the water-bearing gravel

are river deposits, which record a certain amount of aggradation or filling of the valley since erosion reached its maximum depth.

The town of Shenandoah draws its water supply from a number of drive wells supplied with Cook points, located in the river valley northwest of the main part of the city. The conditions here are quite similar to those at Clarinda. The wells stop in sand and gravel, at a depth of about forty-five feet from the surface. The volume pumped exceeds 80,000 gallons a day. The Nishnabotna valley has been aggraded in the same manner as that of the Nodaway.

A number of small springs are found along the small creek west and southwest of the town of College Springs. On land belonging to Mr. J. Dunbar, in the Nw. ¼ of the Nw. ¼, of section 5, Amity township, there is a mineral spring which has attained some reputation for its medicinal properties. Formerly patients resorted to this spring in considerable numbers to drink the water, and use it in the form of baths. The results were usually highly beneficial. More recently, for lack of time and capital to provide and maintain the requisite accommodations, no effort has been made to attract patients. The water, according to the report of Mr. Juan H. Wright, Analytical Chemist, Saint Louis, Missouri, contains per gallon :

Carbonate lime	8.415 grains
Carbonate magnesia	3.813 grains
Carbonate iron	3.566 grains
Sulphate iron	1.141 grains
Sulphate magnesia	3.761 grains
Chloride sodium	2.840 grains
Silica	.576 grains
Organic matter	1.265 grains
Carbonic acid	42.300 cu. in.
Bromide magnesium	trace
Phosphoric acid	trace

Water Power.—Owing to the fact that the streams of Page county have been working at their valleys long enough to cut

their channels to grade, there are no water falls to furnish natural water power. Power has been obtained artificially at a few points on the Nodaway and East Nodaway, by putting in dams. There is a well equipped mill using 80 horse power, at Braddyville; a new mill has recently been erected at Shambaugh; and there is a mill with nine foot head of water, doing an excellent business at Hawleyville. Formerly there was a good water power at the site of the old Shambaugh mill near Clarinda; but the mill burned and the property has been allowed to fall into decay. There is also a small mill on the Tarkio river near Coin.

Summary.

Page is preeminently an agricultural county, and the cultivation of her splendid soils must always remain the principal industry of her people. The topography is of the mature erosional type. The surface is rolling, presenting on all the high lands a succession of swells and sweeping convex curves, with surfaces insuring perfect drainage, but not so steep as to cause serious wash or waste of the soil, or to interfere with easy cultivation. The stream valleys are old, wide, and deep. Practically all the topographic features have been developed in the deep mantle of drift which overspreads the surface. This dift is very old as compared with the glacial deposits covering northeastern and north-central Iowa.

With the exception of a few small and undefined patches of Cretaceous sandstone, the rocks beneath the drift belong to the Carboniferous system and to the Upper Coal Measures, or Missourian stage. These strata consist of limestones and shales, the shales predominating as to thickness, but the limestones appearing in the greater number of natural exposures owing to their greater powers of resistance. The shales and limestones found in Page county occupy a position from 500 to 600 feet above the Bethany or Winterset limestones that lie at the base of the Upper Coal Measures. There are two limestone horizons in the county, one represented by the

exposures at Hawleyville and Braddyville, and the other by the ledges outcropping in the valley of the East Tarkio. These limestones are separated by more than 100 feet of shale. Near the top of the lower limestone there is an important coal seam, the Nodaway coal, which has been mined quite extensively along the valley of the Nodaway and its branches in Iowa and Missouri. The coal is from fourteen to eighteen inches in thickness, and has the great advantage of maintaining uniform characteristics as to thickness and quality over large areas; and over a large portion of the region in which it is known, it lies near enough the surface to make mining comparatively inexpensive. The persistence of this seam insures an aggregate volume of coal within a given territory quite equal to that occurring in other localities where coal mining is carried on on a more extensive scale. The Nodaway coal in Page county is capable of much greater development than it has yet attained. Some of the new mines, the Ingraham mine near Clarinda for example, show some of the possibilities in this direction. The Linquist coal, which lies near the top of the Missourian section in this county, has not yet been prospected enough to enable any to forecast its possibilities.

The building stone industry is not likely to attain much greater prominence than it has already. The ledges quarried in the Geers and Erickson quarries will always be of great local importance. The quality of the stone as material for bridge peers and heavy foundations, especially in the case of the "blue ledge," is all that could be desired. The fact, however, that in general there is but a single ledge available will prevent the installation at any point of labor-saving appliances, and hence the work of quarrying will remain comparatively expensive.

The clays of Page county are inexhaustible as to quantity and excellent as to quality. Shales similar to those above the Nodaway coal are manufactured on a large scale into

IOWA GEOLOGICAL SURVEY

GEOLOGICAL MAP OF PAGE COUNTY, IOWA.

BY

SAMUEL CALVIN

1901.

Scale 1/125000

1 ½ 0 1 2 3 4 5 Miles.

1 ½ 0 1 2 3 4 5 Kilometers

LEGEND

GEOLOGICAL FORMATIONS

CRETACEOUS (NISHNABOTNA)

MISSOURIAN

INDUSTRIES

QUARRIES

BRICK YARDS

COAL MINES

DRAWN BY F. C. TATE

IOWA LITHO. CO.

paving and structural brick, at Nebraska City, and they are used extensively in brick making at Villisca. At present only Pleistocene clays are worked at the various brick and tile plants in this county. The Pleistocene deposits include (1) glacial clays or drift, (2) yellow, silt-like clays, which were laid down in flooded valleys, (3) loess, which seems to present an older and a later phase separated one from the other by aqueous or eolian deposits of a different type, and (4) alluvial sands and silts of recent origin, found in the valleys, especially upon the flood plains of streams, overlying all deposits which are referable to the coming and going of the great ice sheets of the glacial period.

The question of rock oil and natural gas is one of universal and ever present interest. The strata underlying Page county are probably as rich as the average rocks anywhere in bituminous material from which oil or gas might be derived by natural distillation. There are some anticlinal folds, as the Braddyville anticline, which might afford conditions for the accumulation of these products; and if boring is to be successful, it must be done along or near the crests of these folds. The prospect hole near Clarinda, to which reference was made in the early part of this report, could scarcely have been more favorably located, and yet this boring was carried down 1002 feet without finding either gas or oil. No assurance can be given that these products occur in commercial quantities beneath the surface of this region, but if either is found, it will be at a depth greater than 1000 feet. It must be remembered however, that the folds here are small, and small folds could not affect the strata to any considerable distance from the surface. The test hole referred to has explored the rocks away beyond the depth at which the small superficial folds could possibly produce any effect.

Apart from the natural resources, which a study of the Geology of Page county reveals, the phenomena of the region are of the highest scientific interest. In these counties of

southwestern Iowa there is material which, when properly collated and interpreted, will aid in the solution of some of the intricate problems of geological history, and many of these problems will have very direct economic bearings.

NOTE ON THE CORRELATION OF THE CLARINDA WELL SECTION WITH THE SCHEMATIC SECTION OF THE CARBONIFEROUS.

BY CHARLES R. KEYES.

The Clarinda well section, as given by Professor Calvin on page 419 is of special interest at this time for the reason that it furnishes very important exact data regarding the formations represented in the southwestern part of Iowa. These formations are nowhere very well exposed at the surface, partly on account of the peculiarities of the surface relief, and partly because the stratified rocks are covered by unusual thicknesses of glacial deposits. The general section of the Coal Measures has been accurately determined farther to the south, and along the Missouri river and many of its tributaries in Missouri and Kansas, because of the many fine outcroppings. In the tracing of the boundaries of the several terranes from Missouri into Iowa certain unlooked features in the stratigraphy and the geological structure are met with that are not forced upon the attention of the observer when approach is made wholly from the Iowa side.

In consequence, several modifications of interpretation are suggested in the consideration of the general correlation of the beds passed through in sinking the Clarinda well. The changes in themselves are of small import and do not materially affect the conclusions reached by Professor Calvin. However, as tending towards accurate results which must be obtained with reference to the region still farther north, the proposed modifications in the correlation of the beds of the Clarinda well are thought to be worthy of note.

The parallelism of the formations and beds of the two sections are best shown in tabular form:

TERRANES OF THE MISSOURIAN SERIES.	Thickness in Feet.	
	General Section.	Clarinda Well.
11. Cottonwood limestone	10	
10. Atchison shales	500	
9. Forbes limestones	30	
8. Platte shales	150	100 5 20
7. Plat smouth limestones	30	20
6. Lawrence shales	300	105
5. Stanton limestones	35	20
4. Parkville shales	100	
3. Iola limestones	50	180
2. Thayer shales	75	
1. Bethany limestones	100	20

The most noteworthy feature brought out is the fact of the absence of the Iola limestones. This terrane thins out and disappears before reaching the southern limits of Iowa. The Thayer and Parkville shales are thus brought together in Iowa, giving to the shale formation immediately overlying the Bethany terrane, an unusual thickness.

In the Platte shales is a limestone five feet in thickness. Thin bands of limestone occur in all the shale formations and the presence of one of them in the Platte is not anomalous. Instead of being regarded as representing one of the great limestones it is best considered as an unimportant layer that is liable to be found at almost any horizon in the shales. By ignoring the presence of this thin limestone in the upper part of the Clarinda well, the more normal thickness of the Platte shales is displayed.

This readjustment gives for the thickness of all the beds passed through in the well the values that should be expected from a consideration of the work done in Missouri.

The Clarinda well was manifestly begun at a horizon a few feet beneath the top of the Platte shales. The Forbes for-

mation, which is represented in the region by the limestones exposed at Hawleyville and Braddyville, were of course not encountered. The Nodaway coal, which is an easily recognizable horizon throughout a large area in southwestern Iowa, should be expected to be found about 100 feet above the top of the well section.