THE GEOLOGY OF ADAMS COUNTY

by

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THE GEOLOGY OF ADAMS COUNTY

INTRODUCTION

Location and Area

Adams county is the third county east of Missouri River in the second tier north of the Missouri state line. It lies well up on the eastern slope of the Missouri watershed, its northeast corner not far from the divide, as indicated on figure 1. On account of its position

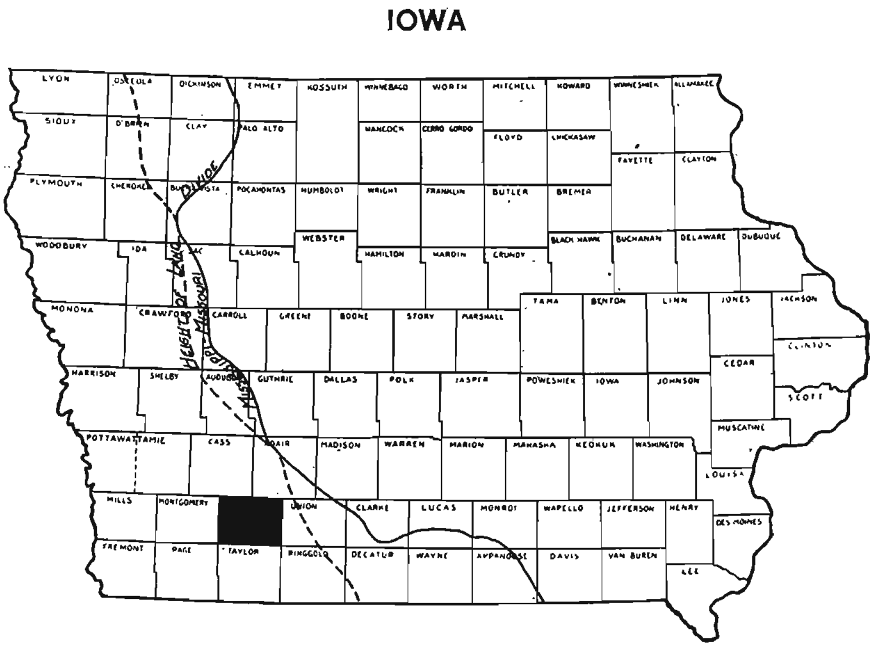

FIG. 1. — Map of Iowa showing location of Adams county with respect to the Mississippi-Missouri divide, and also with respect to the height of land, the probable earlier divide.

thus far from the master stream, its elevation is intermediate to high (1030 to 1330), its topography incompletely dissected, and its soil not so much characteristic of the Missouri slope as intermediate between the Missouri and Mississippi slopes.

The county is divided into 12 civil and congressional townships. The townships are designated by name and by township and range numbers on figure 2, and both townships and sections on Plate I. The county contains 432 sections of land, with a total area reduced by irregularities in survey to about 427 square miles. The 41st parallel of latitude passes within a mile of Corning, and the 95th meridian of longitude is a few miles beyond the west border of the county.

The main line of the Chicago Burlington and Quincy Railroad crosses the county from east to west, and on it are located the towns of Prescott, Corning, Brooks, and Nodaway, the only ones in the county with rail connection. A branch of the Burlington Route cuts about 4 miles across the southeast corner of the county, between Kent, in Union county, and Lenox, in Taylor county. United States Highway 34 crosses the county from east to west, and State Highway 148 from north to south, both passing through Corning. Other state higways within or upon its borders are Nos. 25, 49, 95, 155, and 186. Corning is the county seat and also the largest town. The most important town without rail connection is Carbon. Other named places are Nevinville, Williamson, Carl, Mount Etna, Quincy, West Carbon, Iveyville, Dickieville, and Stringtown, the last two being recent settlements at highway junction points. Former villages of Briscoe, Hayes, Eureka, Hoyt, and Mercer are now abandoned. The 1940 population of the county was 10,230.

Previous Geological Work

In 1868 and again in 1870 White [1] mentioned the topography and other geological features of Adams county, described mining operations in the Nodaway coal at that time, and correctly referred exposures near Corning to the horizon below the Nodaway coal.

In 1894 Keyes [2] discussed the coal of Adams county and mentioned the presence of what is now known to be the Nodaway coal in the northeast part of Montgomery county, adjoining. Lonsdale [3] also described features in the eastern part of Montgomery county and adjoining areas which are of interest in connection with the present report. The clay resources of Adams county were mentioned by Beyer and Williams [4] in 1903 and quarries by the same authors [5] in 1908.

1 White, Chas. A., First and Second Ann. Repts. State Geologist, pp. 66-68, 1868. Also, Report on the Geological Survey of the State of Iowa, pp. 339-344, 1870.
2 Keyes, C. R., Coal Deposits of Iowa: Iowa Geol. Survey, Vol. II, pp. 444-450, 1894.
3 Lonsdale, E. H., Geology of Montgomery County: Iowa Geol. Survey, Vol. IV, pp. 381-451, 1894.
4 Beyer, S. W., and Williams, I. A., The Geology of Clays: Iowa Geol. Survey, Vol. XIV, pp. 415 and 534, 1903.
5 Beyer and Williams, The Geology of Quarry Products: Iowa Geol. Survey, Vol. XVII, p. 484, 1906.

Coal deposits were described by Hinds [6] and tests were quoted and a history of the industry given, by Lees in the same volume.[7] There was also published in the same volume, a report by Smith [8] who discussed the stratigraphy of the Nodaway coal near Carbon. Simpson [9] described the water resources of the county in Volume XXI. Beyer [10] discussed road and concrete materials in 1913. In 1920, Tilton [11] made important contributions to the study of the stratigraphy of this part of the state, though he mentioned Adams county only incidently. The main features of Pleistocene geology in southern Iowa were discussed by Kay and Apfel [12] in 1928; their report does not specifically mention Adams county, but field notes supporting it describe a number of exposures in that area. The Cretaceous formations of western Iowa and adjacent portions of neighboring states were described and interpreted by Tester.[13] Detailed sections in Montgomery and Cass counties not far from Adams county are included. In 1935, Wood [14] gave further details of road and concrete material supply. Adams county was included in the general map of Iowa published in 1937.[15]

The coal industry in Adams county has figured in the reports on mineral production by the Iowa Geological Survey, and the reports of the State Mine Inspectors, since the first inception of these state departments.

Doctor George L. Smith of Shenandoah spent a considerable part of a long life in stratigraphic studies of the Pennsylvanian in Adams and nearby counties of southwestern Iowa. His persistence in the search for truth was never-failing, and it is to his credit that later work has served only to perfect the details of the main outlines that he sketched. His contribution in Volume XIX of the Iowa Geological Survey reports has already been mentioned. Coal deposits near Carbon

6 Hinds, Henry, The Coal Deposits of Iowa: Iowa Geol. Survey, Vol. XIX, pp. 391-396, 1908.

7 Lees, James H., and Hixson, A. W., Analyses of Iowa Coals: Iowa Geol. Survey, Vol. XIX, p. 497, 1908; also, Lees, Jas. H., History of Coal Mining in Iowa: Iowa Geol. Survey, Vol. XIX, pp. 586-588.

8 Smith, Geo. L., The Carboniferous Section of Southwestern Iowa: Iowa Geol. Survey, Vol. XIX, p. 627, 1908.

9 Norton, W. H., and others, Underground Water Resources of Iowa: Underground Waters of Adams County by Howard E. Simpson: Iowa Geol. Survey, Vol. XXI, pp. 1110-1114, 1910-11.

10 Beyer, S. W., and Wright, H. F., The Road and Concrete Materials of Iowa: Iowa Geol. Survey, Vol. XXIV, pp. 58-60, 1913.

11 Tilton, John L., The Missouri Series of the Pennsylvanian System in Southwestern Iowa: Iowa Geol. Survey, Vol. XXIX, pp. 223-313, 1919-20.

12 Kay, George F. and Apfel, Earl T., The Pre-Illinoian Pleistocene Geology of Iowa: Iowa Geol. Survey, Vol. XXXIV, pp. 1-304, 1928.

13 Tester, A. C., The Dakota Stage of the Type Locality: Iowa Geol. Survey, Vol. XXXV, pp. 196-332, 1929.

14 Wood, L. W., The Road and Concrete Materials of Southern Iowa: Iowa Geol. Survey, Vol. XXXVI, pp. 67-70, 1930-33.

15 Tester, A. C., Geologic Map of Iowa: Iowa Geol. Survey, 1937.

were described by him [16] in 1916 and other papers under his name [17, 18] give information on the Pennsylvanian in southwestern Iowa which aids in interpreting structural and stratigraphic details found in Adams county. At the time of his death, he had a large amount of unpublished information on materials penetrated in coal mine shafts in that and adjoining counties.

Soils of Adams county are described by Brown [19] and by Walker and Brown.[20]

The writer's work in southwestern Iowa under the direction of the State Highway Commission has included Adams county at intervals since 1925, and there is a considerable amount of unpublished information on the county in the Highway Commission files. Use has been made of highway profiles prepared by the Commission, and others by the County Engineer, in discussing the topography of the county.

Doctor James H. Lees, formerly Assistant State Geologist, was for many years keenly interested in the geological features of Adams county, and to him was originally assigned the preparation of this report. The present writer remembers many interesting discussions with him on this subject and gratefully acknowledges valuable ideas acquired from them. At the time of his death, he had completed a major part of the field work and was well along in preparation of the manuscript . He was an outstanding physiographer and student of surface formations, and in those parts of the present report, his manuscript and notes are quoted freely. The debt of the present study to his work cannot be overestimated.

Other Acknowledgments

The writer acknowledges valuable information and suggestions from members of the staff of the Iowa Geological Survey, particularly from Doctor A. C. Trowbridge and Doctor H. G. Hershey; Dean George F. Kay and Doctor A. C. Tester of the State University, and Doctor Lewis M. Cline of Iowa State College. Representatives of other state surveys, particularly Frank C. Greene of Missouri and E. C. Reed of Nebraska, have been of assistance on the Pennsylvanian

16 Smith, George L., Contributions to the Geology of Southwestern Iowa: Iowa Academy of Science, Vol. XXIII, p. 77, 1916.
17 Smith, George L., The Paleontology and Stratigraphy of the Upper Carboniferous of Iowa: Iowa Academy of Science, Vol. XXII, p. 273, 1915.
18 Smith, George L., Contributions to the Geology of Southwestern Iowa: Iowa Academy of Science, Vol. XXV, p. 521, 1918.
19 Brown, P. E., Soils of Iowa, Iowa State College, 1936.
20 Walker, R. H. and Brown, P. E., Soil Erosion in Iowa, Iowa State College, 1936.

stratigraphy. The Iowa State Highway Commission, through its Chief Engineer, F. R. White, has kindly given the writer time from his regular duties for preparation of the report, and several of the employees of the Commission have assisted with advice and criticism. Doctor John T. Lonsdale, Head of the Department of Geology at Iowa State College, has contributed suggestions on oil geology, and Doctor Roy W. Simonson of the Department of Agronomy has collaborated in the preparation of the discussion of soils. Mr. Roy Thompson of Carbon, and Mr. David Beasor of Massena, have given information on coal mines and coal prospect holes. The late Robert E. Devereux of Mount Etna has been of great assistance with the local geology.

PHYSIOGRAPHY

Topography

Adams county as a whole may be considered as a partly dissected segment of the great plain which slopes from the Mississippi-Missouri watershed south and west to Missouri River (see figure 1). Upland divides reach about the same elevation in all parts of the county except the southwest, but examination of the soils and their underlying parent materials indicates that the original plain may be preserved in recognizable form only in a few small areas in Grant and northern Mercer townships in the southeast part. Excepting these small areas, and excepting also the alluvial bottomlands along the larger streams, the county is a single topographic unit of slope lying at greater or less distance below the original plain. Figure 2 shows the location and extent of these topographic units, and indicates further a division of the great slope unit into a more gently rolling portion, and a steeper and rougher portion.

Lees' discussion of topography in Adams county includes an excellent general statement of origin quoted here in part as follows:

"The topographic features of Adams county have been shaped chiefly by two factors. The first was the deposition of greater quantities of clay, sand, and similar materials as sheets of glacial drift by the continental glaciers that came from the north during the glacial or Pleistocene period. The second factor, or rather group of factors, is the destructive action on these glacial deposits of rain and running water, of heat and cold, and of chemical forces.

"When the glaciers melted away, they left the load of material that they

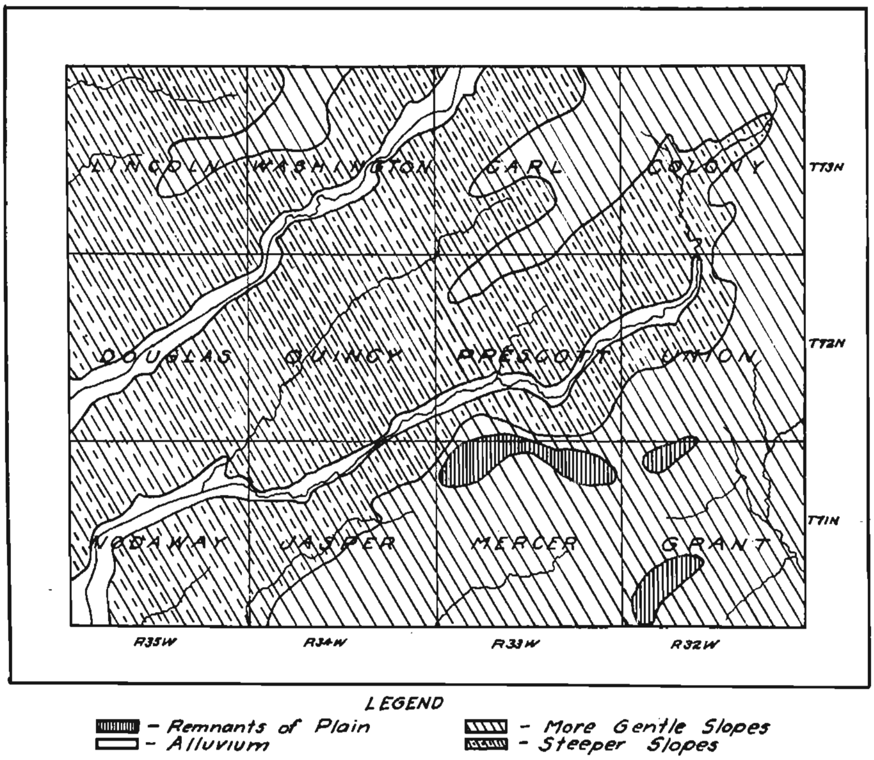

FIG. 2. — Principal topographic units of Adams county.

had brought down spread out as a blanket with a fairly smooth surface and a uniform slope toward the major pre-existing drainage lines. . . .

"Ever since they were uncovered, however, the materials of this . . . drift have been subjected to the action of this other set of agencies — the erosive or down-cutting work of water, the expansive and disruptive effect of freezing and thawing and of sunshine, the disintegration and solution of the materials by percolating water carrying weak acids and other chemicals, and the actual modification and reorganization of the constituents of these materials.

"As a result of these varied activities, the surface . . . has been furrowed with gullies, ravines, and valleys. During the formation of these valleys, immense quantities of material have been cut away and carried down stream. Much other soil and silt have been washed from the hillside into the valleys to form the rich bottomlands. . . .

"In some parts of Iowa, particularly the north-central counties, the time during which these destructive agencies have been at work has been too short for them to have effected great changes. Here in Adams County, however, and in southern Iowa in general, the original surface and the original material left by the glaciers have been immensely modified in the directions indicated in the preceding paragraphs. Hence it is that we find very little level land in the county. With the exception of narrow strips of bottom lands along the Nodaways in the western townships, it is only on a few of the divides between the major streams that there still remains any considerable area that has its original features or anything resembling them."

The Original Plain

Considering first the topographic unit of small areas of original plain in the southeast part of the county, it is to be noted that they are remnants of an old glacial drift plain, covered with a blanket of wind-blown loess. This drift plain is comparable with the flat plains now found in the newer drift areas in such counties as Wright, Hancock, or Webster. During the period following glaciation of Adams county, large areas of this plain escaped erosion long enough to permit chemical weathering of the upper portion of the glacial drift to the material known as gumbotil. By further erosion, however, most of these areas were reduced to gentle slopes lying not far below the original plain, and part or all of the gumbotil was removed. The loess was then deposited on this eroded surface. The areas which escaped erosion both

FIG. 3. Uneroded plain in section 6, Grant township.

before and since loess deposition, are those included in this topographic unit (figure 3). These are the "tabular divides" so well known throughout southern Iowa.

Exact mapping of this unit is the province of the soil survey, a project conducted jointly by the United States Department of Agriculture and Iowa State College, and the areas shown in figure 2 undoubtedly include some of gentle slope. Analysis of about 6 miles of road profile in the area shows 83 per cent of ground slope of steepness less than 2 per cent (2 feet change in elevation for each 100 feet horizontal distance), lying at elevations between 1250 and 1305.

The Slope Unit

The great slope unit of topography is for convenience here divided into two parts, the more gently rolling areas being located in Jasper, Mercer, Grant, Union, Colony, Carl, and small parts of Lincoln, Washington, and Prescott townships, as shown in figure 2. The higher portions of this more gently rolling area are to the eye almost identical with the true tabular divides, but are distinguished by variations in the soil profile. These higher portions now show loess-covered slopes up to about 2 per cent lying at elevations between 1250 and 1310. Such gentle slopes are characteristic of the area between Williamson and Carl, in the north and east parts of Mercer township, and the west part of Grant township.

The gently rolling slope areas merge into steeper slopes leading down to the many tributaries of Nodaway, Hundred and Two, and Platte rivers which drain the east and south parts of the county. Lees' statement in regard to the topography in Colony township is closely applicable and may be quoted as follows:

"Probably the greatest differences in elevation are between the uplands near Nevinville and Williamson in the northern tier of sections, which stand about 1320 feet above sea level, and the valley of the Nodaway in the south part of Colony township, which is 1170 feet above sea level. This relief of 150 feet is accomplished in long gentle slopes and easy grades from upland to lowland. The high steep hills and deep valleys of western Adams county are here conspicuously absent. But even so, the valley of the Nodaway has a wide flat well-defined flood plain in the southern sections of the township. This feature is matched by the fairly level stretches of upland already mentioned, which reach out from the divide.

". . . The features of the topography all bespeak a mature stage of development and a great length of time for their formation."

Of Grant township, Lees says:

"Here as elsewhere — and the condition holds true with almost monotonous uniformity — the land is cut to long gentle slopes, there is very little level land left, the topography is in its maturity. Some of the valleys, while only forty or fifty feet deep, are nearly a mile wide, a fact which shows what a tremendous amount of work has been done by the streams since they began to flow over the newly uncovered glacial plain."

In such areas of intermediate slope in the east and south parts of the county, the surface material is loess, greatly thinned or even entirely removed from the steeper portions by surface wash. Where this is absent, the usual surface material is gumbotil or leached and oxidized till. There are no rock outcrops. Cultivation is largely restricted to the loess areas, the steeper ground being commonly in permanent pasture, or more rarely, in timber.

Areas of moderate slope as previously described merge in the direction of drainage into rougher and more thoroughly dissected regions. This change is gradual, and any such boundary as is drawn on figure 2 is purely arbitrary and greatly generalized. Nevertheless, the central and west parts of the county are notably rougher and steeper; Douglas township has a maximum relief of 265 feet from stream bed to divide as contrasted with the 150 feet mentioned for Colony township. Lees' manuscript may be quoted as follows:

"The southwestern part of the county is controlled by the East and Middle Nodaway rivers, and most of it is strongly rolling. This is true of most of Nodaway and all of Douglas and Quincy townships, as well as most of Prescott. There is very little level land; it is practically all on slopes. In the southwest townships, the uplands rise to about 1280 feet, and the larger streams are flowing two hundred feet lower.

"Across Middle Nodaway, the uplands of western Washington and Lincoln townships are not so rough as in those regions nearer the main drainage courses. The valleys are more shallow and open, but still are well along in maturity.

"Some of the most beautiful and peacefully satisfying views one can find among Iowa's prairie scenery may be seen from the upland ridges of Adams County. Thus, on the hilltops of southern Nodaway township the eye ranges across the easy slopes of the shallow tributary drainage lines nearly

Fig. 4. — Topographic view, looking west across East Nodaway valley at Nodaway.

to the deep valley of the East Nodaway and the far hills beyond, in Montgomery and Taylor counties (figure 4). Similar vistas greet one along the high ridge road from Carbon to Corning, where one may look down on either side into the long valleys opening into East or Middle Nodaway. Such scenes embracing mile after mile of crop land and pasture land with their prosperous appearing farmsteads, help one to realize that here, indeed, is the granary of America; here on these wideflung prairies Nature has combined beauty with utility and has done her utmost for man's esthetic and physical well being."

The loess increases slightly in thickness in passing from the east part of the county to the west, so that it is found preserved on steeper slopes than is the case to the east. Erosion here, however, has been more vigorous, and in extensive portions of the area the loess has been completely stripped off, leaving gumbotil or leached till, or even unleached and unoxidized till, at the surface as the parent material for soil formation. Cultivation is confined largely to the loess on the higher slopes, but on those farms where loess is absent, necessarily extends into areas of glacial materials. Some of the steepest slopes are timbered, though much of this natural forest has been cleared off. In Douglas and northern Nodaway townships there are many outcroppings of shale and soft sandstone on bare slopes or in shallow gullies 50 feet or more above the valley bottoms, indicating here a development of topography upon preglacial materials.

It is unfortunate that extensive quantitative measurements of slope are not available for all of Iowa, and especially for a county so nearly all in slope as is Adams. The best approach to such measurements that can be made at this time is a study of ground slopes on roads as determined by engineer's level in the various parts of the county. It is realized that such road slopes in some cases quarter or even run perpendicular to the direction of steepest slope, and therefore do not indicate the full degree of steepness at that point; nevertheless, inspection of the road map of the county (see Plate I) reveals that the roads follow land lines almost entirely, without relation to topography, so that in some cases at least, the slopes shown represent the true maximum.

Some 77 miles of road profile run by the State Highway Commission or the County Engineer have been examined. Sections of road on floodplains have been excluded from this examination. Some 6 miles in the southeast part of the county lies in the flat areas of original plain. Of the remaining 71 miles, about 21 are in the area of more gentle slope and 50 in the area of more rugged slope. The roads in the more gentle slope region show 45 per cent of original ground slope less than 2 per cent, 54 per cent between 2 and 9 per cent, and less than 1 per cent greater than 9 per cent. The roads in the more rugged slope region show 31 per cent of original ground slope less than 2 per cent, 61 per cent between 2 and 9 per cent, 7 per cent between 9 and 15 per cent and 1 per cent greater than 15 per cent. A graphic representation of these road profile differences is given in figure 5, which shows up-

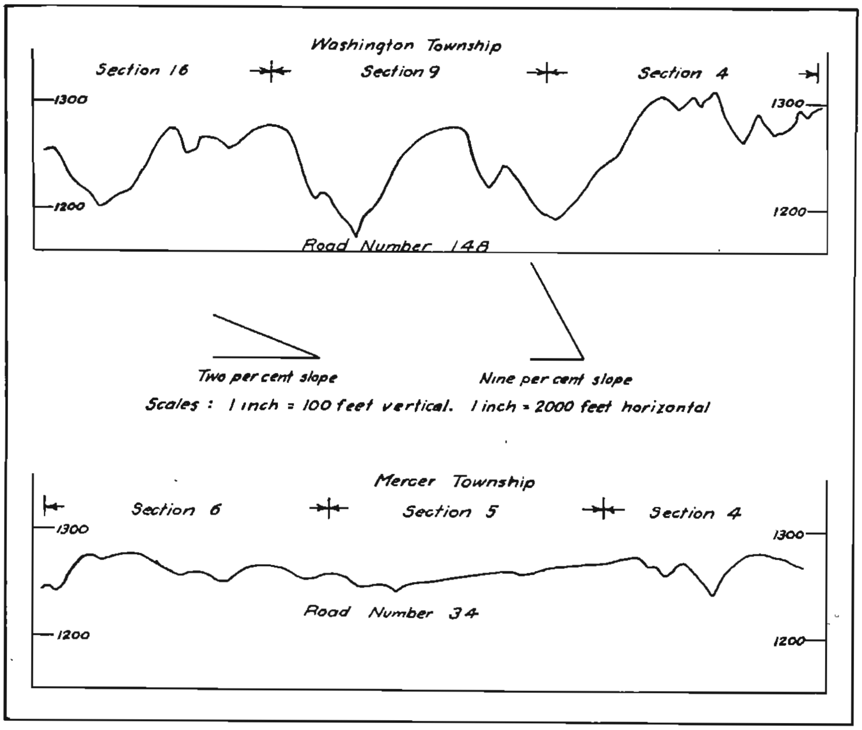

Fig. 5. — Profiles of upland slopes east and north of Corning.

land slopes on sections of Road Number 34 east of Corning and Road Number 148 north of Corning, plotted to the same scale.

A noteworthy feature shown by these road levels is the persistence of high ground and gentle slopes into the most dissected portions of the county. Road K running from Carbon west and north in Douglas and Lincoln townships passes through one of the roughest areas in this region, but yet shows 23 per cent of original ground slope less than 2 per cent. It is not believed that 23 per cent of this part of the county actually has steepest slope of such low order, but visual examination shows that there are notable areas where that condition exists. This persistence of gentle slope in the midst of rough areas testifies to the wide distribution of easily cultivated land in the county.

The Bottom Land

The extent of alluvial deposits in Adams county is difficult of determination. Figure 2 shows those of most importance, but similar materials have been washed down from the upland slopes into the bottom lands of the smaller tributaries reaching back to the higher and flatter areas in every part of the county. Such alluvium is largely reworked loess with minor amounts of glacial materials. It lies nearly level, with gentle colluvial, or talus slopes along the edge of the lowland merging into the lower upland slopes. Large bottomland areas, especially in the west part of the county, must have been originally timbered, but their fertility and ease of cultivation have resulted in their nearly universal clearing. Straightening of the channels of the two major streams of the county has greatly reduced danger of damage from inundation.

Terraces

Features of topography difficult to include either with the upland slope or the alluvial bottom are the terrace areas found along some parts of the valleys of East and Middle Nodaway rivers. They are most extensive in Washington and Jasper townships, and are believed to have been given their form by the presence of resistant layers of

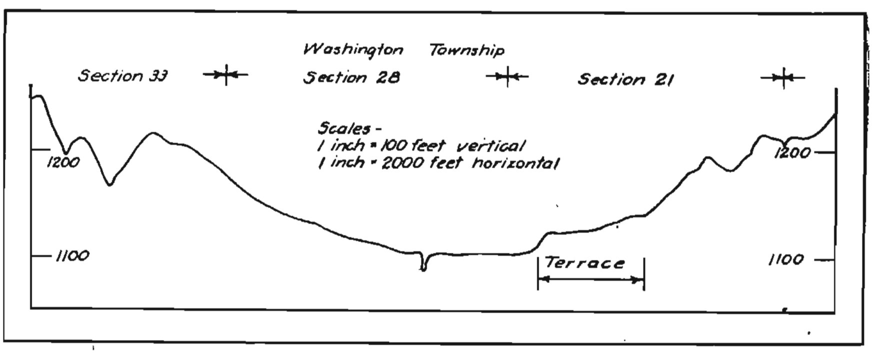

FIG. 6. — Profile across Middle Nodaway River on Road Number 148.

limestone. Where such limestone occurred at or just above the stream level, it resisted lateral cutting by the stream and upheld a portion of the valley somewhat above the surrounding bottom land level. Surface slope is now commonly less than 2 per cent. Figure 6 shows a profile of a typical terrace where crossed by Road Number 148 between sections 21 and 22, Washington township, and figure 7 is a photo-

FIG. 7.— View of terrace in section 22, Washington township.

graphic view of the same terrace about 1/2 mile farther east. The significance of this feature of topography will be discussed further in connection with the history of the East and Middle Nodaway valleys.

Altitudes

Profiles run many years ago by engineer's level along the Chicago Burlington and Quincy Railway and quoted by Lees[21] gave the following elevations in feet above sea level at stations in or near Adams county:

Cromwell (Union county)	1253
Prescott	1153
Corning	1117
Brooks	1095
Nodaway	1084

21 Lees, James H., Altitudes in Iowa: Iowa Geol. Survey, Vol. XXXII, 1925-26.

Villisca (Montgomery county)	1050
Kent (Union county)	1191
Lenox (Taylor county)	1295
Spaulding (Union county)	1350
Orient (Adair county)	1346

During the years from 1925 to the present, a network of some 80 miles of highway levels has been run into all parts of the county, reaching every township except Union and Colony. More recently, second order levels by the United States Coast and Geodetic Survey along the main line of the Burlington Route give the following sea level elevations for two permanent bench marks established in Corning:

Bench Mark Z108, 8 feet west of curb and 12 feet north of sidewalk in southeast corner of city park south of courthouse in Corning, elevation 1169.118.[22]

Bench Mark Y108, north corner of central base of railroad water storage tank south of depot at Corning, elevation 1120.834.[22]

The network of highway profiles has been connected with these bench marks by means of street grade levels in Corning, thus transferring sea level elevations to nearly all parts of the road system, with a probable error of less than 1 foot. Plans for these highways are on file at the County Court House, the following tabulation indicating necessary corrections for elevations shown, to tie to the Coast and Geodetic Survey bench marks:

United States Road No. 34, Corning west 10.129 miles, Project F. A. 26, add 3 feet.

United States Road No. 34, Corning east 14.179 miles, Project F. A. 152, add 3 feet.

State Road No. 148, Corning south 6.162 miles, Project F. A. 227, add 3 feet.

State Road No. 148, Corning north 12.540 miles, Project P. 708, add 3 feet.

State Road No. 186, Prescott south 3.199 miles, Project F. A. 349, add 3 feet.

County Road C, Prescott north 3.265 miles, Project W. P. S. O. 658, add 3 feet.

County Road C, north from above 2.26 miles, County Project, add 3 feet.

State Road No. 49, Lenox north 6.681 miles, Project F. A. 558, add 3 feet.

22 These figures are subject to final adjustment, which may result in changes of a few tenths of a foot.

State Road No. 25, south from Road No. 34, 5.547 miles, Project N. R. S. 451, subtract 4 feet.
State Road No. 95, Carbon east 3.709 miles, Project N. R. S. 424, add 3 feet.
County Road K, Carbon west and north 6.117 miles, County Project, add 943 feet.
County Road K, north from above 1.93 miles, County Project, add 1049 feet.
State Road No. 155, Nodaway north 4.472 miles, Project N. R. S. 520, add 3 feet.

More approximate elevations of many other places have been obtained by hand leveling from the foregoing, or by barometric altimeter with corrections at known points. The following table of maximum and minimum elevations by townships serves to indicate the general range, but should not be depended upon for more accurate values:

	Highest Point		Lowest Point	
Township	In Section	Elevation	In Section	Elevation
Colony	2	1325 (Approx.)	33	1160
Carl	11	1310	7	1115
Washington	4	1330 (Approx.)	31	1075
Lincoln	13	1320	6	1145
Douglas	4	1300 (Approx.)	30	1035
Quincy	22	1305	31	1085
Prescott	5	1305 (Approx.)	30	1105
Union	12	1290 (Approx.)	18	1140
Grant	31	1305	25	1150
Mercer	2	1300	31	1175 (Approx.)
Jasper	25	1300	7	1065
Nodaway	4	1260	31	1030

It is of interest to note in the foregoing table that the high divides have the greatest elevation in the four northern townships. There seems to be little slope to the west, except that the high point in Nodaway township is notably lower than any of the others, this being the result of more complete dissection of that part of the county. Low places are of course in the channels of the larger streams. The greatest relief indicated is 265 feet in Douglas township, and the least is 125 feet, in Mercer township. The highest place in the county is probably in the north part of section 4, Washington township, elevation about 1330 (1334 found on Road Number 148, 700 feet north of the county line), and the lowest place is the bottom of East Nodaway River in the south part of section 31, Nodaway township, elevation 1030.

Drainage

Figure 8 indicates the location of the principal streams of Adams county, and the boundaries of the basins drained by each. It shows the Platte, Hundred and Two, East Nodaway, and Middle Nodaway rivers, while West Nodaway lies scarecely a quarter-mile beyond the northwest corner of the county. These are all tributaries of the Missouri, joining that stream in northwest Missouri, many miles beyond the area under discussion.

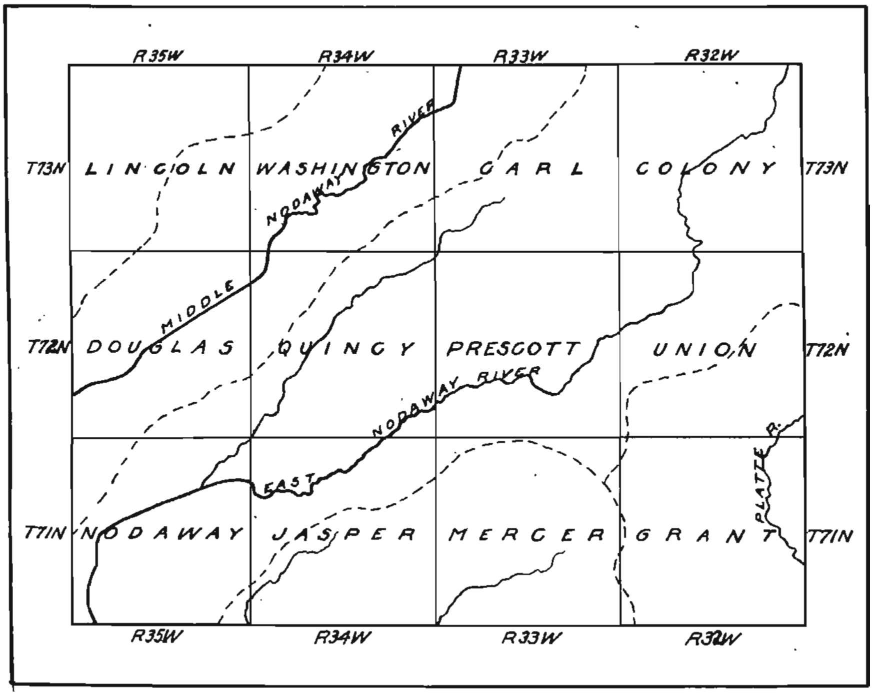

FIG. 8. — Principal streams and drainage basins of Adams county.

Lees' general statement on the drainage of Adams county reads in part as follows:

"The direction and character of the sub-basins of the county are determined almost entirely by the high ridge extending from Creston beyond Audubon, and forming the crest of the Mississippi-Missouri divide in southwestern Iowa. . . . Its height at Creston is 1314 feet, at Greenfield 1370 feet, and at Adair probably 1430 feet or more, as the station is 1404 feet above sea. From its one-time smooth but now more rolling slopes flow the creeks which unite to form the major streams of our region."

The Orient-Spaulding upland previously mentioned is a part of this ridge, and its location and direction are indicated as "Height of Land" in figure 1.

West Nodaway River

This stream does not quite reach Adams county, but one of its major tributaries is a small creek known locally as Slate's Branch, which drains the north part of Lincoln township and the northwest part of Washington township. Smaller creeks in the southwest part of Lincoln and the northwest part of Douglas township also feed it. Slate's Branch near the site of old Briscoe (NW 1/4 section 3, Lincoln township) has, in the words of Lees:

"made for itself a valley of no mean proportions. In the vicinity of Briscoe, for instance, the slopes extend back nearly a mile from the stream and rise from an elevation of about 1150 feet to heights of about 1300 feet on the higher ridges."

Other tributaries of the West Nodaway are shorter and have narrower valleys, which nevertheless cut deeply below the upland and give Lincoln township some of the most rugged topography in the county. Outcroppings of Pennsylvanian and Cretaceous beds appear at a few small scattered localities.

Middle Nodaway River

Lees' manuscript on this stream reads, in part, as follows:

"The Middle Nodaway has a wide mature valley all along its course across Adams county. The stream rises in northwestern Adair county and has developed a flat-floored valley and a wide flood plain . . . . The characteristics of a well developed mature valley are especially well shown along the county road southwest of Carbon, where the floor is nearly a mile wide and the walls are gently sloping, cultivated to their summits and productive of rich harvests. The one drawback in the picture, of course, is the fact that the level bottom lands are subject to occasional overflows, such as occurred, for instance, in the summer of 1928, when the river rose several feet above its banks. Even though the slopes are so gentle they rise, nevertheless, 200 feet or so to the divides, and some of the minor tributaries have cut rather steep-sided ravines and valleys into the uplands near their heads. There is thus an intermediate belt of fairly strongly rolling topography between the gently rolling uplands and the gently sloping lowlands."

Figure 2 shows the extent of bottomland along the Middle Nodaway, and figure 9 gives a profile of elevation of its bed across the

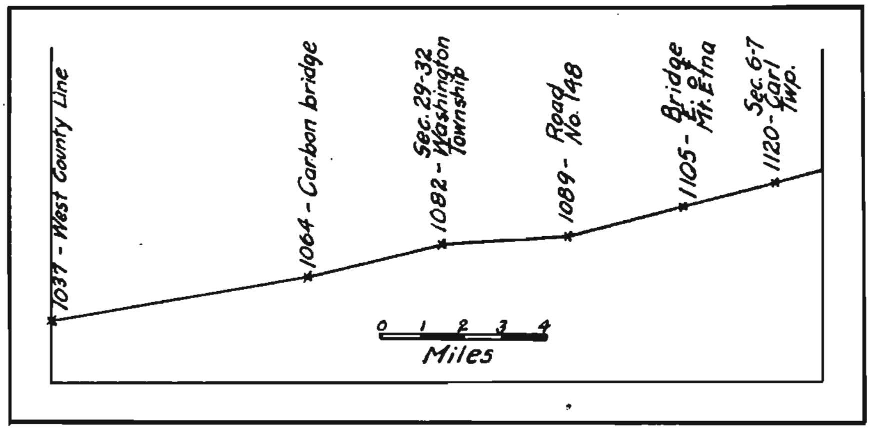

FIG. 9. — Profile of elevation of bed of Middle Nodaway River.

county. Figures 6 and 7 illustrate the character of the rock terraces; these are frequent and conspicuous from Carbon to Mount Etna. Outcroppings of Pennsylvanian shales and limestones appear in the lower banks of the river in this part of its course, and the presence of these more resistant materials seems to have been an important factor in determining the position of the terraces. No rock outcrops above Mount Etna are known, either in this, or in Adair county.

The character of the stream below Carbon is somewhat different; the channel has been straightened and former meanders against the valley wall largely filled with slope wash, so that no rock outcrops appear along the stream itself. On the other hand, the lower valley slopes for a height of 50 feet or more above bottomland are composed of Pennsylvanian and Cretaceous shales and soft sandstones, thinly and incompletely covered with glacial materials. The older beds are but little more resistant to erosion than is the glacial drift at other points, and consequently, the topography is not as a rule noticeably more rugged. There is an exception in the west-central part of Douglas township, where the persistence of a Cretaceous sandstone at the top of the preglacial section has resisted headward extension of the small tributary streams, and thus resulted in the preservation of steep timberclad hills 200 feet or more in height.

East Nodaway River

The following is taken from Lees' description of the valley of this stream:

"East Nodaway River drains and controls the largest of the drainage basins into which Adams county is divided. It stretches entirely across the county from the northeast portion to the southwest corner. Even at that its tributary area is only 6 to 8 miles wide and is in this respect quite typical of the long narrow parallel valleys that together make up the Missouri slope of southwestern Iowa. . . .

"The river itself has the characteristics common to the streams of this region. It has cut a winding channel through an alluvial plain that is nearly a mile wide in Nodaway township but somewhat narrower above the mouth of Kemp Creek. This plain begins, we may say, in southern Colony township and is a very well-defined feature across Union township. Its general slope is indicated clearly by the altitudes of the railway stations that are located in it as follows: Prescott, 1153 feet above sea level; Corning, 1117 feet; Brooks, 1095 feet; Nodaway, 1084 feet. Above this flood plain the upland rises to elevations of 1260 and 1280 feet and in Colony township to 1300 feet or possibly more. In other words, the river, insignificant as it appears today, has eroded a passageway for its waters that is nearly 200 feet deep near Nodaway, 140 feet near Prescott, and is more and more shallow as one approaches the gathering grounds in Colony township and southern Adair county."

Figure 2 shows the extent of bottomland along the East Nodaway, and figure 10 gives a profile of elevation of its bed below Prescott.

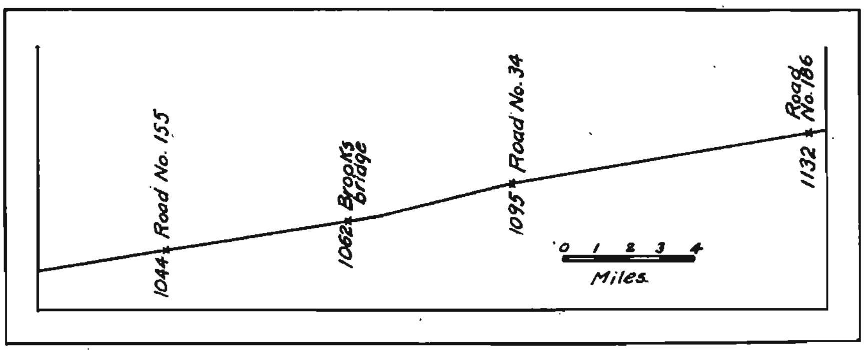

FIG. 10. — Profile of elevation of bed of East Nodaway River.

The steeper grade between Corning and Brooks shown in figure 10 is the result of the presence of resistant layers of Pennsylvanian limestone in its bed. Outer rock outcrops along its valley are infrequent, and none above Corning is known.

Terraces such as those found along Middle Nodaway River are less frequent and extensive on the East Nodaway. There are a few, however, between Corning and Brooks, of origin similar to those on the Middle Nodaway. The layers of Pennsylvanian limestone commonly crop out where the present channel cuts against the bases of such terraces. Of related origin is the narrow inner gorge of the river at Corning, shown in profile contrasting with the wider flood plain at Prescott in figure 11, and in photographic view in figure 12. At this

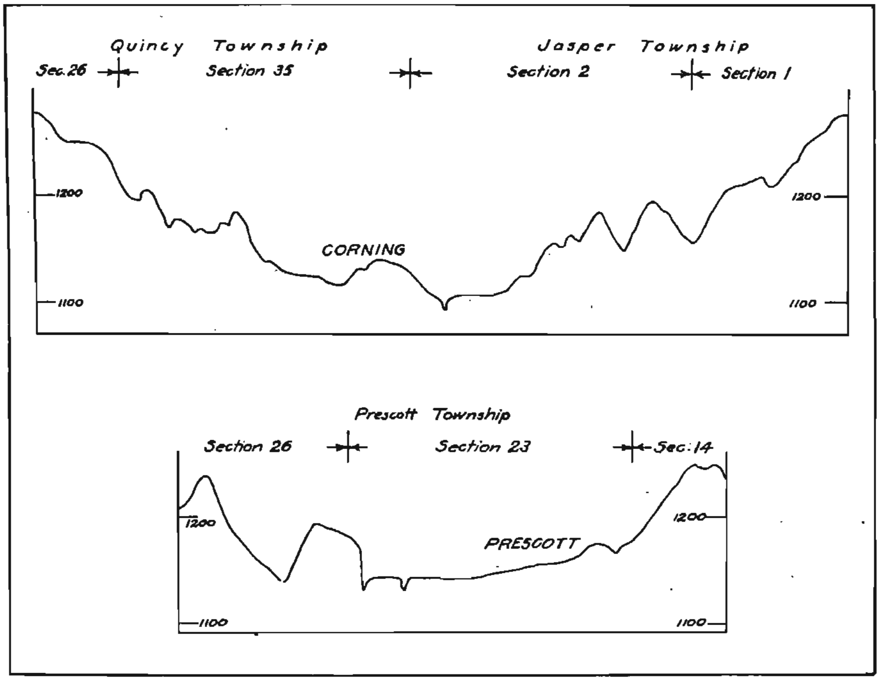

FIG. 11. — Highway profiles across East Nodaway River at Corning and Prescott, showing contrasting widths of flood plain.

place, the Deer Creek, one of the thicker limestones of the Pennsylvanian in this region, comes up to river level, and by its superior resistance to erosion prevents lateral extension of the valley floor through the meandering of the stream. Even so, the valley from rim to rim has its normal width of more than 2 miles.

An important tributary of East Nodaway River is Kemp Creek, as designated by Lees, or known more popularly to present residents

FIG. 12. — View of East Nodaway Valley at Corning, showing narrow inner gorge.

as Walter's or Lockwood's Branch. Lees' manuscript on this stream reads as follows:

"While it is not a large stream — it is not over 20 miles long — it has cut out for itself a deep wide valley, whose slopes are still rather strongly rolling and which is incised into the earth 100 feet in southwestern Carl township, in whose eastern parts the stream has its sources."

Where United States Highway Number 34 crosses its valley, its bed is at elevation 1095, nearly 200 feet below the high ridge between it and Corning. The valley shows no rock outcrops and its topography is apparently unaffected by the presence of rock.

Hundred and Two River

Of this stream, Lees' manuscript reads in part as follows:

"Most of Mercer township and the southeast half of Jasper are tributary to West One Hundred and Two River, whose upper branches rise on the high divides and prairies of these two townships. Since these branches are near their sources, they have not yet cut very deep valleys nor formed very steep slopes. So while the hills rise to 1270 or 1280 feet above sea level the streams are flowing a mile or so away, at the foot of gentle, cultivated slopes that descend — in the southernmost sections of the county —

to levels of 1180 and 1190 feet. Flood plains are developed very slightly or not at all in these townships."

Platte River

Lees' manuscript adequately describes this stream as follows:

"The drainage of nearly all of Grant and the southeast half of Union townships is controlled by Platte River. This stream rises in northwestern Union county on the high ridge on which are located Creston and Greenfield, with other smaller towns. It extends across the eastern sections of Grant township and then winds back into Union county; thence across Ringgold county and into Missouri. It has several small branches that reach back into the prairies for a few miles, but all of the country drained by them is still gently rolling, and their upper valleys are wide open swales.

"Just west of the county line, in the southeast quarter of section 24, Grant township, where the Creston to Bedford branch of the Chicago, Burlington and Quincy Railroad crosses Platte River to extend up a small tributary toward Lenox, the grade is 1169 feet above sea level. At the road crossing a mile farther west, the elevation is 1176 feet; at the crossing near the southeast corner of section 27, Grant township, about 1 1/2 miles to the southwest, it is 1191; and at the county line, perhaps 1 1/4 miles farther southwest, it is 1202. Beyond here for 2 miles to Lenox, the rise is quite steep as the town is 1295 feet above sea, or practically at the upland level. These figures give a very fair idea of the gradients of these tributary valleys in the Kansan drift region."

Age of the Drainage

The minor streams of the county, and even those as large as the Platte and Hundred and Two rivers have not cut their valleys deeply enough to have left any record older than that of the time since the last ice sheet retreated from the county. It seems evident that the development of such valleys was well along before the time of deposition of the loess, as that material blankets uplands and slopes as well, except where stripped off by recent erosion. The fact that loess is thickest on the upland flats and is absent on so many of the lower and steeper slopes is evidence that valley development and deepening has continued during and since loess deposition. The importance of the erosion problem to the agriculturist is evidence of further continuance at the present time.

For the two major streams, the East Nodaway and Middle Nodaway, and also for the West Nodaway just beyond the borders of the county, the record may be longer. These streams certainly antedate loess deposition. It appears, however, that they are younger than the glacial drift, except at the extreme west edge of the county, where they may be much older. For further discussion of this point, the reader is referred to a later section of this report, on post-Cretaceous preglacial history.

STRATIGRAPHY

It might seem that a logical discussion of the formations underlying Adams county should begin at the surface, and consider successively lower deposits down to the limit of present knowledge. An understanding of stratigraphy, however, is inseparable from a knowledge of the geologic history of the area, and since any historical discussion must be in chronological order, that order will be preserved in the treatment of the various formations in the county.

Geologic time is too long to be measured in terms of years, except so approximately as to be almost meaningless. It is customary therefore to divide it into eras, periods, epochs, etc., this division being made on the basis of significant changes in the character of the life present on the earth, major interruptions of deposition in the continental areas, or important disturbances of the earth's crust by mountain building. Rocks laid down or formed during the various time intervals are correspondingly divided into sequences and systems, which may be subdivided into series, groups, formations, and members. The following tabulation indicates in chronological order from bottom to top the main divisions of geologic time and rocks:

Era (Sequence)	Period (System)
Cenozoic	Quarternary (Pleistocene) Tertiary
Mesozoic	Upper Cretaceous Lower Cretaceous Jurassic Triassic
Paleozoic	Permian Pennsylvanian Mississippian Devonian Silurian Ordovician Cambrian
Proterozoic Archeozoic	Incompletely differentiated

Iowa strata are classified as follows:

Sequence	System	Series or Other Division
Cenozoic	Pleistocene	Eldoran Centralian Ottumwan Grandian
Mesozoic	Upper Cretaceous	Colorado Dakota
Paleozoic	Permian(?)	Fort Dodge
	Pennsylvanian	Virgil Missouri Des Moines
	Mississippian	Meramec Osage Kinderhook
	Devonian	Upper Devonian
	Silurian	Cayugan? Niagaran Alexandrian
	Ordovician	Maquoketa Galena-Platteville St. Peter Prairie du Chien
	Cambrian	St. Croixan
Proterozoic Archeozoic	Algonkian Not exposed	Sioux

Of the above, there is evidence in Adams county of the Cambrian, Ordovician, Silurian, Devonian, Mississippian, Pennsylvanian, Cretaceous, and Pleistocene systems. The older formations do not appear at the surface, and are known only from well records. Pennsylvanian and later beds crop out, and are understood in much more detail.

Pre-Pennsylvanian

Available knowledge of the pre-Pennsylvanian in this county is extremely limited, and only the most general statement can be made. There are no deep wells in the county which reach through the Pennsylvanian, but consideration of deep drillings at Clarinda [23] and Bedford [24] to the south, Greenfield [25] to the north and an oil prospect (Phillips Petroleum Company's Creston No. 1) to the east [26] affords some idea of what may be found here.

Cambrian

A deep well at Clarinda penetrated 666 feet of sandstone with some

23 Complete log in Iowa Geological Survey, Vol. XXXVI, pp. 398-419, 1930-33.
24 Complete log in Iowa Geological Survey, Vol. XXI, pp. 1182-1186, 1910-11.
25 Complete log in Iowa Geological Survey, Vol. XXXIII, pp. 211-215, 1927.
26 McHugh, W. E., Log of Wildcat Well, Union County, Iowa: Bull. Am. Assoc. Petroleum Geologists, Vol. XXIV, No. 8, pp. 1495-1497, August, 1940.

dolomite and shale, referred to upper Cambrian, and 1275 feet of red sandstone and shale, referred to middle Cambrian, but now known to be older. The top of the Cambrian there is at 2357 feet below sea level. These deposits are in the deep central portion of an extensive geosyncline now commonly known as the Forest City Basin. The major axis of this basin trends north and south, and it is probable that similar deposits extend into Adams county. The top of the Cambrian here is probably between 2100 and 2200 feet below sea level.

Ordovician

The Prairie du Chien, St. Peter, Galena-Platteville, and Maquoketa divisions of the Ordovician are recognized in the Clarinda and Phillips wells. The Prairie du Chien and Galena-Platteville are largely dolomite, the St. Peter a dolomitic or shaly sandstone, and the Maquoketa shale and cherty dolomite. The same formations are recognized in other wells to the north and east, and are probably continuous beneath Adams county. The St. Peter is only some 40 feet thick and is probably not the important water-bearing bed that it is in central and eastern Iowa. Approximate elevations of the top of the Ordovician are from 1250 feet below sea level in the north part of the county to 1400 feet in the south part.

Devonian-Silurian

Beds of this age are identified in deep wells as a distinct limestone and dolomite terrane bounded by the Maquoketa formation below and the Sheffield-Maple Mill shale succession of uppermost Devonian and lowermost Mississippian age above. The top of this terrane in the Clarinda well is 1028 feet below sea level, and at Greenfield is 410 feet below sea level. Elevations ranging from about minus 500 at the north to minus 850 at the south are thus indicated for Adams county.

Mississippian

In addition to the drillings at Clarinda, Bedford, and Greenfield, an attempted water well at Lenox, about a mile from the south county line also penetrated about 300 feet of beds referable to the Mississippian system. The lowermost Mississippian is the Maple Mill shale formation of the Kinderhook, possibly including some shale which should be assigned to uppermost Devonian. The thickness of the Maple Mill varies rather widely from an average of about 50 feet. Above this is a succession of chert-bearing dolomites and limestones from 250 to 300 feet thick representing the Hampton and Gilmore City formations of the Kinderhook series and the Burlington and Keokuk-Warsaw formations of the Osage series. The St. Louis limestone with some shale and sandstone below, and at Lenox a Ste. Genevieve sandstone and shaly limestone above, represent the Meramec series. Thickness of the Meramec may be expected to vary from zero up to about 100 feet.

Pre-Pennsylvanian History

The historic record of the older Paleozoic rocks is almost entirely obscured by reason of their deep burial under the younger beds. It is known from examination of the exposures farther east, and can be inferred from study of well records in southwestern Iowa, that breaks in the cycle of deposition occurred at the close of the Ordovician and Silurian periods. Such breaks indicate an interruption of sedimentation, with elevation above sea level and consequent subaerial erosion before submergence again took place and deposition was resumed. Erosion of the sediments may have resulted in a great irregularity of surface, and this irregular surface would then have become the floor to receive new deposits when sedimentation was resumed, and would profoundly affect the character of the later system, especially in its earlier stages.

An important and long-continued break occurred at the close of the Mississippian. At that time the beds were elevated and deeply eroded before Pennsylvanian deposition began. Deep wells in southwestern Iowa are too far apart to give much indication of the relief of the pre-Pennsylvanian surface, but Lugn [27] has found in Lucas county, not far to the east, a relief on the top of the Mississippian of as much as 200 feet within a few miles. The elevation of that surface is not known at any place in Adams county, but at Lenox it is about 100 feet below sea level, or about 1400 feet below the ground surface. Examination of deep well logs at greater distance indicates that it may range from near sea level in the northeast to as much as 400 feet below sea level in the southwest part of the county. There is no reason to doubt that changes of as much as 200 feet may take place within a few miles distance.

[27] Lugn, A. L., Geology of Lucas County: Iowa Geol. Survey, Vol. XXXII, p. 137, 1925-26.

Pennsylvanian

The lowermost Pennsylvanian beds were laid down on the irregular Mississippian surface; they include much of clastic or mechanical sediments and lie in more or less discontinuous basins, making them exceedingly difficult to trace over any distance by intermittent exposures or well records. These beds have therefore had little or no subdivision. Younger deposits are much more persistent and uniform in character, so that subdivisions, some of very small size, can be

DIVISIONS OF THE PENNSYLVANIAN

Series	Group	Formation
Virgil	Wabaunsee	Wakarusa limestone
		Soldier Creek shale
		Burlingame limestone
		Silver Lake shale
		Rulo limestone?
		Cedar Vale shale (Includes Elmo coal)
		Happy Hollow limestone?
		White Cloud shale
		Howard limestone
		Severy shale (Includes Nodaway coal)
		Topeka limestone
		Calhoun shale
		Deer Creek limestone
Lower limit of Adams county exposure		
	Shawnee	Tecumseh shale
		Lecompton limestone
		Kanwaka shale
		Oread limestone
	Douglas	Lawrence shale
		Stranger shale
Missouri	Lansing	Iatan limestone
		Weston shale
		Stanton limestone
		Vilas shale
		Plattsburg limestone
	Kansas City	Bonner Springs shale
		Wyandotte limestone
		Chanute shale
		Westerville limestone
		Cherryvale shale
		Winterset limestone
		Galesburg shale
		Bethany Falls limestone
		Ladore shale
		Hertha limestone
	Pleasanton shale and sandstone	
Des Moines	Henrietta — incompletely differentiated	
	Cherokee — undifferentiated	

traced throughout the whole area of the Forest City basin. The accompanying synoptical table indicates the more important divisions of the Pennsylvanian of Adams county, in columnar order with the youngest at the top.

The divisions given in this table are in use by the Kansas, Nebraska, and Iowa State Geological Surveys, with some exceptions.

Previous classifications have included the Oread with the Douglas group rather than with the Shawnee, and the Missouri Survey still prefers to include it in the Douglas. It is believed that the persistent character and thickness of the Oread, and the predominance of limestone in it, relate it more closely to the overlying persistent limestones and shales than to the irregular channel-filling shales and sandstones below.

The Haskell limestone is dropped from the list of formations in the Douglas group for the reason that it is too thin to have been recognized in any of the well sections in or near Adams county.

No reason is known for setting off the Iatan and Weston formations in a group separate from the underlying Stanton, and they are therefore included in the Lansing group, and the term Pedee of the Kansas and Missouri Surveys dropped altogether. It may be that later work in this area will allow more precise differentiation of the beds between the Stanton and the Oread and warrant reestablishment of the Pedee as an independent group.

The Frisbie-Argentine-Farley series of limestones with intervening shales has been included by the Kansas Survey in the Wyandotte limestone. The present state of information from well logs in or near Adams county does not warrant an attempt to subdivide the Wyandotte.

"Chanute shale" as used here follows the practice of the Missouri Survey in including all beds between the Wyandotte and the Westerville. It includes the Raytown and Cement City limestones, which may be present in the Adams county section but are difficult to recognize in well logs.

Galesburg and Ladore shale members include here the thin Canville and Middle Creek limestones with overlying shales of the Kansas Survey, these thin members being not recognized in well sections now available.

Recent work by L. M. Cline of the Iowa Geological Survey shows that a series of sandstones and shales of widely varying thickness lying next below the Hertha limestone are occupying deep channels eroded in an underlying series of shales and thin limestones. The unconformity thus indicated is important enough to be used to mark the base of the Missouri series. Older reports included these channel sandstones and shales, together with some of the older beds, in the Pleasanton group of the Des Moines series, but the more recent work shows their closer relationship to the Missouri. The term Pleasanton is therefore moved up into the Missouri series, to include beds which extend downward from the Hertha limestone to the erosion unconformity.

The series of shales and thin limestones below the Pleasanton is now being studied by the Iowa Survey and will undoubtedly be subdivided into several formations. Names for these formations are not yet finally determined, and since they are only questionably recognizable in well sections near Adams county, no such subdivision will be attempted in this report. The term Henrietta of the Missouri Survey is retained to include the beds at the top of the Des Moines series down to the lower Fort Scott limestone or its equivalent in southwestern Iowa.

Beds below the Henrietta are largely divided by the high points of the underlying Mississippian limestone into more or less separate basins, so that correlations over large areas are most difficult. No attempt at any division is made in this report, and all beds from the lower Fort Scott limestone down to the top of the Mississippian are referred to the Cherokee group.

Unexposed Pennsylvanian

It is impossible to give detailed descriptions of beds known in or near Adams county only from a few well sections. Brief mention of their thickness and character is worthwhile as an aid to their identification in future deep drillings.

The Cherokee at Lenox is predominantly sandstone, with some shale, and one thin limestone in the upper portion. The Henrietta is nearly all shale, with several thin limestones, some sandy beds in the lower part, and one horizon of a few feet of red shale. The Pleasanton includes gray and red shales and one thin limestone. The combined thickness of Cherokee, Henrietta, and Pleasanton groups is about 700 feet in the Lenox well. A prospect core drilling at New Market for the New Market Coal Company (see Appendix A) indicates 100 feet or more of similar beds referred to the Pleasanton and upper Henrietta stages.

A conspicuous horizon in drillings of the Pennsylvanian is that of the two thick limestones, Bethany Falls and Winterset, with a rather thin shale between. Correlation of well records usually begins with a determination of that horizon. These two limestones are commonly found in thickness of 20 or 25 feet each, and that thickness may be expected in Adams county. The thinner Hertha below is persistent, as are also the Westerville and Wyandotte limestone above. A sequence of strong limestone beds alternating with shales is expected in Adams county to extend from the base of the Bethany Falls to the top of the Wyandotte, a distance judged from comparison with corresponding intervals at Lenox and New Market to the south and Madison county to the north, to be somewhere around 140 to 150 feet.

This terrane of strong limestones is terminated at the top by the Bonner Springs formation, which, with its conspicuous red shale, is commonly easy to recognize in well cuttings. The red shale is found in the drillings at Lenox and at New Market, and in the outcrops in eastern Adair and western Madison counties, and it is expected to be persistent throughout Adams county. Thickness of the Bonner Springs in Adams county will probably be 35 or 40 feet.

The series of limestones and shales included in the Lansing group are recognized in the Lenox and New Market drillings and may be expected in Adams county except insofar as the upper members are missing as a result of pre-Virgil erosion. From comparison with the Lenox and New Market wells, it is judged that the interval from the top of the Bonner Springs to the base of the Virgil series in Adams county will be found to be about 65 feet, or in places perhaps considerably less.

Beds at the base of the Douglas group of the Virgil series are commonly sandy or silty and may be set off from the underlying Lansing group by that characteristic. These coarser sediments are succeeded above by shales which reach to the base of the next thick limestone, the Oread. This sand-silt-shale sequence includes the Stranger and Lawrence formations. It appears to be about 100 feet thick at Lenox and at New Market, and may be about the same in Adams county, or where filling a pre-Virgil channel, perhaps more. A thick red shale in the upper part of the Lawrence is recognized in wells at Bedford, Lenox, and New Market, and may persist through Adams county, though not conspicuous in the exposures on Middle River in Adair county.

The Oread formation consists of a series of coarse-grained limestones separated by shale beds, with a full thickness in Adams county expected to be from 50 to 75 feet.

Beds above the Oread are differentiated in well sections only with difficulty until the Deer Creek is reached. The upper member (Ervine Creek) of this formation is a limestone thicker than any other for some distance above or below, and is usually recognizable by that characteristic, as well as by its uniform distance about 50 feet below the Nodaway coal. The interval from the top of the Oread to the top of the Deer Creek appears to be 102 feet at New Market, and about 80 feet in the Greenfield well, so that some intermediate figure may be expected in Adams county.

Deer Creek Limestone

Of this formation, only the uppermost member, equivalent to the Ervine Creek along Missouri River south of Plattsmouth, is exposed. The following section at the Adams County Limestone Company quarry on East Nodaway River in SE 1/4 SW 1/4 section 3, Jasper township, is typical of this member, and beds immediately above and below:

		Feet
8.	Limestone, gray, rather fine-grained, hard, durable, one ledge	$\frac{1}{2}$–$\frac{3}{4}$
7.	Shale, calcareous, the top 2 feet yellow, the remainder drab, all soft	7
6.	Limestone, the quarry ledge. The top 2 feet or 3 feet is one strong ledge of light gray fine-grained dense and durable stone. The next 2 feet is dark-colored and somewhat shaly. The next 3 feet is harder, but includes a few thin shaly seams. The lower 4 feet is dark-colored, more fossiliferous, and includes about 25 per cent of shaly unsound stone in irregular veins and pockets	11–12
5.	Shale, black in the middle, gray above and below	2$\frac{1}{4}$
4.	Limestone	1$\frac{1}{4}$
3.	Shale, black	3
2.	Limestone	1
1.	Shale and bluish-gray clay	12

Nos. 1 to 5, inclusive, are not exposed but were found by core drilling by the Highway Commission in the quarry here. No. 1 evidently represents the Tecumseh, Nos. 2 to 6, inclusive, the Deer Creek, No. 7 is the Calhoun, and No. 8 the lowermost member of the Topeka. The top of the Ervine Creek member (No. 6) is at elevation 1089, about 3 feet above river level. Doctor Lees' manuscript lists several brachiopods and one crinoid from No. 7.

The upper part of the Ervine Creek member lies at river level from here upstream to the east part of Corning (north quarter-section corner section 2, Jasper township) and has been quarried at several places. The nature of the structure known along Middle Nodaway River farther north indicates that from Corning east it may have lain nearly level, but examination of the bedrock surface suggests that it has been cut away by preglacial erosion. It is not present at Lenox and possibly not at Bedford, but is recognizable at and northeast of Greenfield; its eastern boundary is therefore drawn tentatively and approximately from north to south near the center of the county.

The Deer Creek does not appear along Middle Nodaway River, but is known from core drilling by the State Highway Commission in NW 1/4 SW 1/4 section 28, Washington township. Following is the description by the Iowa Geological Survey of that part of the core referred to this formation:

"Limestone, in part light to very light gray, very fine textured, moderately fossiliferous, in part medium to dark gray clean finely crystalline limestone to limestone containing numerous interlaminated shale partings, highly fossiliferous (crinoid stems very abundant) grading in at least one place to a thin layer of black shale, 13.7 feet.

"Shale, black to dark gray, black portions showing excellent flat fracture parallel to bedding, black shale slightly pyritic, gray shale partings show highly fossiliferous surface, 2.3 feet.

"Limestone, medium gray, very shaly, medium hard, very irregular fracture, non-fossiliferous, 0.8 feet.

"Shale, medium gray to black, two bands of highly fossiliferous black shale, trace of pyrite, 2.3 feet."

The uppermost limestone represents the Ervine Creek, its top being at elevation 1059.

Extension of the Deer Creek northeast from the foregoing location is difficult to estimate. It is apparently present in the Greenfield well at elevation 1102. Beds found in core drilling in SE 1/4 NE 1/4 section 14, Washington township, are similar to a part of the Topeka, thus placing the Ervine Creek below elevation 1085 at that point. This or slightly higher level to the northeast toward Greenfield is well below drainage, indicating a good possibility that the Deer Creek has escaped preglacial erosion along Middle Nodaway River all the way to its source.

From the points previously mentioned, the Deer Creek extends west, without interruption as far as known, to and beyond the borders of Adams county.

The section at the old Fox quarry 1/4 mile north of the southwest corner of section 31, Edna township, Cass county, is well known and has been described by several geologists. Recent quarry workings there expose the following succession of beds:

	Feet
9. Limestone, brown, soft, deeply weathered and partially displaced masses	2
8. Shale, drab, upper portion fossiliferous and very calcareous, perhaps in part a shaly limestone	10
7. Limestone, yellowish-gray, one strong ledge	¾
6. Shale, drab, clayey	8
5. Limestone, light gray, hard, durable, one bed when unweathered, rather fine-grained, sparingly fossiliferous	4
4. Limestone, yellowish-gray, fairly hard, in irregular lumps imbedded in yellow calcareous shale. About two-thirds of this member is shale or soft shaly stone	2
3. Limestone, as above, but with shale or soft stone totaling only about one-fourth	1½
2. Limestone, gray, in several beds separated by shale partings which constitute about six per cent of the member. Some of the shale partings are horizontal and persistent, and others are irregular	5½
1. Shale, drab, poorly exposed	4

Nos. 2 to 5, inclusive, comprise the quarry ledge, and higher members were uncovered in the stripping operation. The top of No. 5 is at elevation 1151 (barometric) and a strong southward dip has been observed in working the quarry. Fossils found in this section have been listed by Tilton.[28]

Correlation of the isolated series of outcrops along West Nodaway River from Grant upstream as far as the Fox quarry has been a puzzling problem to geologists for many years. Tilton[29] referred the Fox quarry to the Oread, while Smith[30] believed it to represent the Forbes (now better known as Deer Creek). Lee's visited it in 1933 and gave in his notes the opinion that it was higher in the section than the beds at Corning (Deer Creek) and perhaps higher than the Nodaway coal. The present study shows that a coal, which from its character and associations must be the Nodaway, occurs in N 1/2 SE 1/4 section 1, Douglas township, Montgomery county, hardly a

28 Tilton, John L., Geology of Cass County: Iowa Geol. Survey, Vol. XXVII, pp. 194-195, 1916.
29 *Ibid.*, pp. 198-203.
30 Smith, Geo. L., Carboniferous Section of Southwestern Iowa: Iowa Geol. Survey, Vol. XIX, pp. 627-628, 1908.

mile south of the Fox quarry, and just west of the Adams-Montgomery county line. It seems most reasonable to assume that the limestone of the Fox quarry is stratigraphically not far from the Nodaway coal, and since no important limestones are known for 200 feet above, it must lie below, and thus represent the Deer Creek, the Lecompton, or the Oread. The Lecompton is not known to include any limestone as thick as the Fox quarry ledge. If it is the Oread, there should be some sign of the Lecompton or Deer Creek in the thoroughly eroded country between it and the coal exposure; moreover the lithology of the quarry ledge and beds above suggests the Deer Creek more than the Oread. It thus appears that the preponderance of evidence favors reference of the Fox quarry ledge to the Deer Creek formation. It is of interest to note that more recent quarrying in NW 1/4 SE 1/4 section 3, Douglas township, Montgomery county, some 2 1/2 miles west-southwest of the Fox quarry, has exposed a ledge with abundant large fusilinids of a species different from those in the Fox quarry and similar to those characteristic of the Oread of Adair county and along Missouri River near Plattsmouth. This ledge may represent the Oread in this locality.

Calhoun and Topeka Formations

Natural exposures of beds referable to the Calhoun or Topeka in Adams county are confined to the lower banks of Middle Nodaway River in Washington township, and of East Nodaway River in sections 8, 9, and 10, of Jasper township, and even these are so fragmentary and obscure as to preclude positive correlation. The Calhoun is recognized only in the foregoing section of the Adams County Limestone Company near Corning, the Fox quarry section, and in core drilling in NW 1/4 SW 1/4 section 28, Washington township. A composite of that drill hole with another in SE 1/4 SW 1/4 section 29, Washington township, about 3/4 mile west, is the best known continuous section from the Deer Creek to the Nodaway coal. It is illustrated in graphic form in figure 13, and described in more detail below:

	Feet
22. Coal, the Nodaway seam	1.5
21. Underclay, gray, soft	2.0
20. Limestone, gray, with irregular shale laminations, many crinoid joints	1.5
19. Limestone or dolomite, gray, silty, finely crystalline, few fossils	2.5
18. Shale, gray, soft	0.5
17. Shale, black, soft	0.6

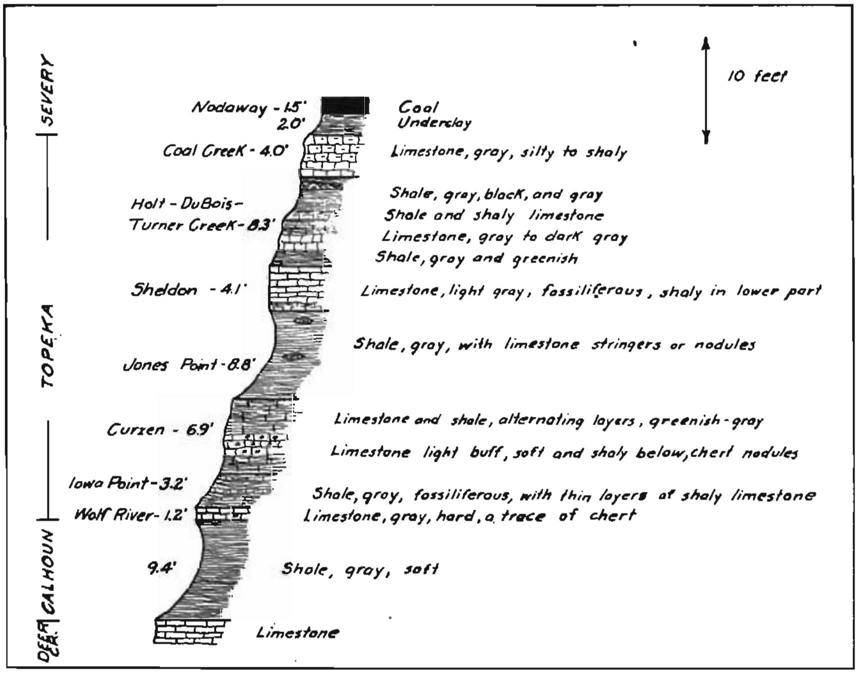

FIG. 13. — Graphic section of Deer Creek-Nodaway interval, from core drillings in sections 28 and 29, Washington township.

16.	Limestone, gray, shaly, fossiliferous	1.2
15.	Shale, black to gray, hard, grading down to	1.7
14.	Limestone, gray, very soft, shaly, fossiliferous	1.4
13.	Limestone, gray to dark gray, fossiliferous grading down to	0.7
12.	Shale, gray, hard, fine-grained	0.9
11.	Shale, light greenish-gray, calcareous	1.3
10.	Limestone, light gray, hard, fine-grained, some questionable oolites, very fossiliferous, with crinoid stems, shell fragments, and Osagia, with thin partings of green shale except in lower part which shows some calcite-filled cavities	3.0
9.	Limestone, as above, but shaly and grading down to	1.1
8.	Shale, medium gray above, dark gray below, rather soft, with a few limestone stringers or nodules	8.2
7.	Limestone and shale, greenish-gray, alternating layers	3.4
6.	Limestone, very light buff, hard, with green shale veinlets, a few calcite masses, and chert nodules, non-fossiliferous, chalky texture	2.0
5.	Limestone, as above but softer and more fossiliferous, grading down to	1.5
4.	Shale, gray, calcareous, fossiliferous, with thin layers of gray soft shaly limestone. Shell fragments and joints of crinoid stems are most common	3.2
3.	Limestone, gray, hard, slightly fossiliferous, with a trace of chert	1.2
2.	Shale, medium to dark gray, rather soft, sparsely fossiliferous	9.4
1.	Top of Deer Creek limestone	

Examination of the foregoing section shows several points of similarity to the excellent exposures of the same horizon along the Missouri River valley south of Council Bluffs. This similarity is believed to be enough to warrant extending the subdivisions and nomenclature of the Nebraska Survey on Missouri River [31] to the Adams county section, as follows:

Coal Creek limestone,	Nos. 19 and 20,	4.0′
Holt-DuBois-Turner Creek members,	Nos. 11 to 18,	8.3′
Sheldon limestone,	Nos. 9 and 10,	4.1′
Jones Point shale,	No. 8,	8.2′
Curzen limestone,	Nos. 5, 6 and 7	6.9′
Iowa Point shale,	No. 4,	3.2′
Wolf River limestone,	No. 3,	1.2′
Calhoun shale formation,	No. 2,	9.4′

The Holt member includes a black shale, the only noteworthy one between the Nodaway and the Deer Creek. Osagia and questionable oolites are characteristic of the Sheldon, limestone stringers or nodules of the Jones Point, and chert of the Curzen. Altogether it seems that here is a very satisfactory correlation with the beds to the west.

Core drilling by the Highway Commission at an abandoned quarry site in SE 1/4 NE 1/4 section 14, Washington township, shows a weathered limestone and underlying shale similar to the Sheldon and Jones Point members. The hole was not carried to the Deer Creek and this correlation cannot be considered positive. The Sheldon appears at river level at the site of the core drilling in section 28, and is reported to have been quarried there many years ago. Former exposures reported to have been near center section 22 and in NE 1/4 NW 1/4 section 23, Washington township, are now concealed, but from the nature of rock once quarried there, they are believed to represent the Sheldon. The Nodaway coal is near or just below river level from the southeast corner of section 29, Washington township, to the town of Carbon, and a small doming of the strata brings the Coal Creek to view at the old Eureka bridge site in SE 1/4 NE 1/4 section 31, Washington township. The exposure here shows a ledge of dark-colored hard limestone 2 or 3 feet thick, partly fossiliferous, hard below but more shaly above. Broken fragments of black fissile shale nearby may have come from the underlying Holt shale, or from beds adjacent to the coal which was at one time mined in the bench east of the river. Old quarrying nearby may have been in the Coal Creek or in the Nodaway caprock, but there is now no trace of the old openings.

31 Condra, G. E., and Reed, E. C., Correlation of the Members of the Shawnee Group in Southeastern Nebraska and Adjacent Areas of Iowa, Missouri and Kansas: Nebraska Geol. Survey, Bulletin 11, Second Series, pp. 18-25, 1937.

The series of exposures along East Nodaway River between Corning and Brooks has been examined by many geologists, including Smith [32] and Lees. Lees was of the opinion that they represented beds below the Deer Creek. More recent information on coal prospecting near Brooks shows that the Nodaway coal is near or just below river level there. The limestone at Corning must be Deer Creek as there is none of equal importance above the coal; it therefore follows that the fragmentary exposures between Corning and Brooks represent beds between the Deer Creek and the coal. Correlations of the following sections are based upon this reasoning and upon their similarity to parts of the Topeka formation as known on Middle Nodaway River.

The south or east bank of the river north of the south quarter-section corner of section 8, Jasper township, exposes the following section:

	Feet
4. Slope, glacial till with pebbles and boulders, with signs of 1 foot or more of soft weathered yellow shale at the bottom	15
3. Limestone, dark brownish-gray, weathers yellowish-brown, two or three thin beds separated by fossiliferous shaly partings, with *Myalina, Leda, Astartella,* and many broken fragments of shells of *Myalina* and other clams	3/4
2. Shale, calcareous, weathered yellow, soft above, harder below	2
1. Unexposed to water, but probably chiefly shale. Near the middle is indication of a 4-inch bed of very dark gray hard limestone filled with unaltered shells of *Derbya* or *Marginifera*	6

Generic identifications of the fossils in this section were made in the field by L. M. Cline of the Iowa Geological Survey. No. 3 may represent the lower part of the Sheldon and lower members the Jones Point. The thin limestone of No. 1 is about 1 foot above water in the south river bank about 1/4 mile farther upstream, and there can be seen above it signs of 3 or 4 feet of gray and yellow weathered shale. The section is again repeated in SW 1/4 NW 1/4 section 9, Jasper township, the *Marginifera* limestone being there about 6 feet above water in the south river bank.

The following section is poorly exposed in the south river bank in NE 1/4 NE 1/4 section 9, Jasper township:

	Feet
7. Gravel, variable but persistent	3±
6. Shale, greenish-gray, with fenestelloid and rhomboporoid bryozoans and crinoid stems, a 4-inch layer of nodular shaly limestone in the upper portion	2
5. Limestone, yellowish, nodular, argillaceous, upper part mixed with shale	2 1/4
4. Limestone, one bed when unweathered, light gray, weathers yellowish,	

[32] Smith, George L., Carboniferous Section of Southwestern Iowa: Iowa Geol. Survey, Vol. XIX, p. 624, 1908.

	fine-grained, hard, with a large *Chonetes* abundant, also *Marginifera*, small clams, and worm tubes	1
3.	Shale, yellow to drab, calcareous, partly a shaly limestone	2
2.	Limestone, dark gray, weathers greenish, hard, durable, sparingly fossiliferous, to water level	½
1.	Shale, gray, hard, calcareous, grading up to the above	½

It is probable that this whole section may be referred to the Curzen, though the lack of chert is an argument against such a correlation. The beds dip westward 1 foot in each 100 feet.

The east bank of the river south of the northwest corner of section 10, Jasper township, shows an obscure exposure of 1 foot or more of hard gray limestone just above water. It is probable that this is the upper part of the Ervine Creek member which has been described at the Adams County Limestone Company quarry 1/2 mile east.

Nodaway Coal and Associated Beds

In sharp contrast with the scattered and obscure exposures of lower beds is the wealth of information on the Nodaway coal and associated strata from the mines of western Adams county. There is little variation in character, but rather, a remarkable degree of uniformity throughout the area. It is thus unnecessary to give details of more than a very few sections.

A typical section in the northwest part of the county is that in the Hendrickson mine in SE 1/4 NE 1/4 section 4, Douglas township, elevation 1200:

		Feet
8.	Clay, glacial till, grading at the bottom to soft weathered shale	45
7.	Shale, gray, soft, with occasional hard layers less than an inch thick	22
6.	Shale, as above, but thinner-bedded and harder	70
5.	Limestone caprock, soft above, harder below, dark gray, shaly, fossiliferous, thinly laminated at bottom	1½
4.	Shale, dark gray, hard, with black streaks	1±
3.	Coal	1¼-1½
2.	Underclay, gray, soft	2
1.	Limestone, bottom rock, gray, partly shaly, bottom of shaft	

The Linker and Landrus mine in NE 1/4 NE 1/4 section 32, Douglas township, elevation 1173, shows a similar section, as follows:

		Feet
7.	Clay, glacial till above, some red clay (Cretaceous?) below	90
6.	Shale, gray to dark gray, medium hard, a few thin stony layers	90
5.	Limestone caprock, variable in hardness, seamy and slabby	2
4.	Shale, dark gray to black, slaty, with thick lenses of stony calcareous material, irregular in stratification and hardness	0-2
3.	Coal	1-2
2.	Underclay, gray, soft	5½
1.	Limestone, bottom rock, penetrated in sump	1+

A shale below the Nodaway coal seam in the exposures along Missouri River is not recognized here unless a part of the recorded underclay (No. 2 of both sections) is equivalent to it. The interval between the coal and the bottom rock (Coal Creek limestone) thickens from 2 feet at the Hendrickson mine to 5 1/2 feet at the Linker and Landrus mine. The general section for northwestern Missouri shows a still greater interval, evidently including a shale below the underclay. The dark shale and irregular limestone above the coal, but separate from the caprock, are known locally as "slate" and "bastard" respectively, and are highly variable in thickness from zero to a maximum of 4 feet for the "bastard" phase. Silicified fragments of various Pennsylvanian woods, some a foot or more in length, are found in this bed, or at its contact with the underlying coal. Both Nebraska and Missouri State Surveys include all beds between the bottom rock and the caprock in the Severy formation, and since that interval shows the same general sequence here, the term is adopted for the Adams county section.

The caprock above the coal, though thin, is very persistent and constitutes one of the main factors which permit extensive development of a seam as thin as the Nodaway. Natural exposures of the caprock are limited to the Middle Nodaway River between Carbon and Road No. 148. It forms rapids in the river bed for several hundred feet near the center of section 12, Douglas township. It appears at intervals thence upstream as far as a point north of the southeast corner of section 29, Washington township, where it and the coal can be seen dipping rather sharply westward below water level in the south river bank. It is not known to outcrop on East Nodaway River, but piers for the river bridge on Road No. 155 north of Nodaway are set upon it. The bottom part is commonly more shaly, grading down to the underlying dark shale. The caprock is similar to the Howard limestone which occupies the same position above the coal in the Missouri and Nebraska sections, and that term may be applied to it here.

Both coal mine sections previously given show a thickness of nearly 100 feet of gray to dark gray shale above the caprock. This shale is found in nearly all of the mine shafts, in various thicknesses up to 106 feet maximum at two points south of center section 9, Douglas township. The report of 138 feet thickness in a mine between Nodaway and Villisca is not verified. Natural exposures are rather frequent in

Douglas township, the best known being in SE 1/4 SW 1/4 section 9, as follows:

	Feet
7. Clay, red and light gray, with thin ferruginous plates or veins (Cretaceous)	4
6. Shale, greenish, soft and much weathered	10
5. Shale, weathered buff, hard, calcareous, perhaps an earthy limestone	1
4. Shale, gray to drab, weathers buff, with thin hard calcareous stony layers	18
3. Shale, gray to drab	4
2. Clay, bluish-gray, not stratified, the bottom marked by a thin stony layer	4
1. Shale, light bluish-gray, soft, stratified	4

The upper part of this section is very near a new mine shaft which penetrates the same beds, and goes on down to coal about 65 feet below the bottom of the section. A characteristic noted in this shaft and reported from others in the county, though not seen in the natural exposure, is the presence of septarian concretions in the upper beds, most of them from a few inches to a foot in diameter. These are reported to be found usually at or near the top of the shale and at different distances above the coal in the different mines, thus indicating that they may be a product of secondary infiltration arrested at the shale surface, rather than a primary layer at a definite stratigraphic horizon. It is possible that they occurred originally in the upper members of the shale and during erosion and weathering in preglacial times became concentrated on its surface, just as gravel and pebbles wash out of glacial till at present and are left as a lag concentrate on the surface by currents of water too weak to carry them away. This latter explanation is more nearly in agreement with their occurrence at certain definite stratigraphic levels in the Missouri and Nebraska sections of this formation.

A thick bed of shale with septarian concretions is well known at this horizon in the parts of Missouri and Nebraska nearest to southwestern Iowa. It has been called the White Cloud in recent reports by the geological surveys of those states. Overlying it is a thin shaly fossiliferous limestone known as the Happy Hollow and above that another shale known as the Cedar Vale. The White Cloud-Happy Hollow-Cedar Vale horizon is equivalent to the Scranton of earlier reports by the Iowa Survey. No Happy Hollow limestone has been recognized in the Adams county section, though it may be present. The thick shale in the mine shafts here is therefore given the name White Cloud, with the recognized possibility that it may be White Cloud-Cedar Vale. Whatever terms are used, the fact remains that there is above the Nodaway caprock a bed of not less than 105 feet of shale without any limestones of importance or any other key beds by which it can be readily subdivided.

The geological map of the county (Plate I) shows the eastern margin of the Nodaway coal, a rather sinuous line approximating the east edge of range 35. Since the underclay of the coal marks the base of the Severy formation and of the Wabaunsee group here, the same line indicates the eastern margin of the Wabaunsee. So far as is now known, the coal occupies all of that part of the county lying west of this line. The lower portion of the White Cloud shale probably extends nearly as far east as the coal, perhaps within an average distance of a mile. Greater thicknesses of the White Cloud, up to 100 feet or more, seem to be present over all the area farther west. Natural exposures of it are confined almost entirely to Douglas township and the northwest quarter of Nodaway township. In these areas the presence of a capping of the Cretaceous sands and clays seems to have protected the Pennsylvanian beds from the severe preglacial erosion which they suffered farther east, and they appear therefore well up in the present drainage, frequently under a rather thin covering of glacial drift and loess. Sections with vertical range up to 50 feet are known.

Higher Pennsylvanian Beds

The following section (see also figure 14) is a composite of exposures in gullies in SE 1/4 section 31, Douglas township, and N 1/2 section 36 and S 1/2 section 25, Washington township, Montgomery county:

	Feet
12. Limestone, shaly, or calcareous shale, drab to dark gray, rather thinly bedded, with abundant segments of crinoid stems, spines of *Archeocidaris* and productids, fenestellid and rhomboporoid bryozoa, a few fusilinids, and one layer with many large specimens of *Dictyoclostus americanus*	5
11. Shale, siltstone, and sandstone, drab to dark gray. The lower 15 feet is darker colored and argillaceous, and locally includes small carbonized and pyritized wood fragments. Upper beds are silty to sandy, and include some lenses of drab fine-grained micaceous sandstone, usually poorly cemented. The whole member tends to be massive when unweathered. Full thickness is unexposed at any one point, but by hand leveling is determined to be approximately	30
10. Limestone, dark gray, full of broken fossil fragments among which a few Pennsylvanian brachiopods can be recognized	½
9. Shale, very dark gray, soft, clayey	1½
8. Shale, gray, laminated, calcareous, some layers almost a shaly limestone. This bed locally includes sandy lenses	6½
7. Limestone, gray, weathers brown, dense, fine-grained and evenly bedded below, concretionary and very sandy above, one strong ledge	1½

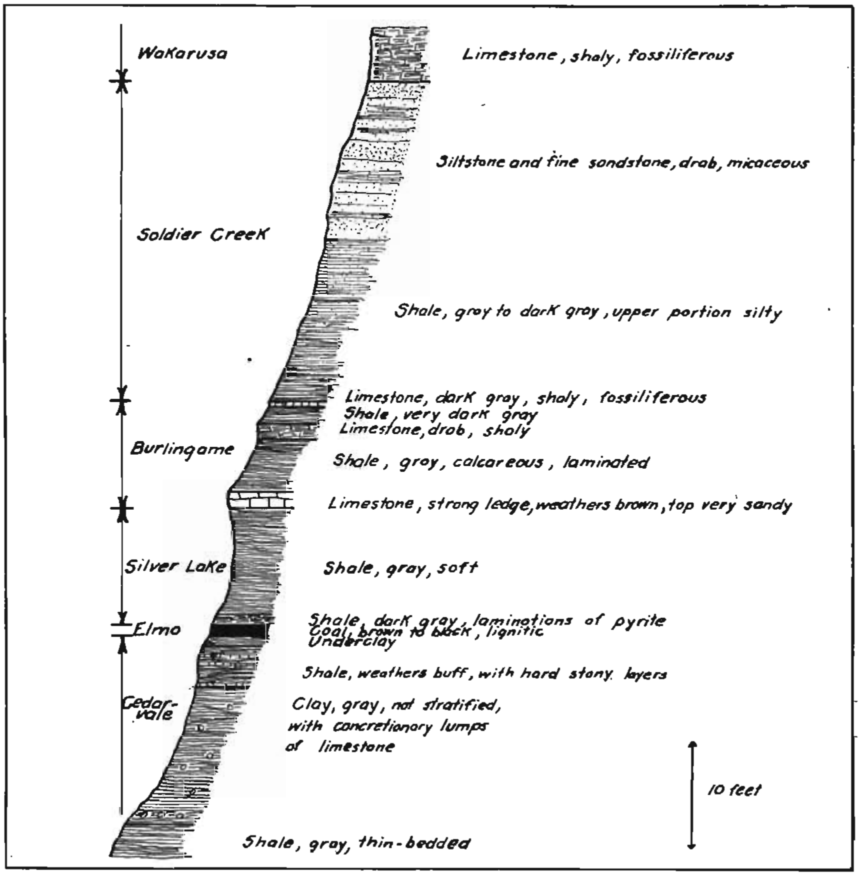

FIG. 14. — Graphic section of the Pennsylvanian in western Adams county.

6.	Shale, gray, argillaceous, weathers out to a bright gray clay	10
5.	Shale, dark gray, with laminations of pyritic material	1
4.	Coal, impure, dark brown to black, soft	1
3.	Shale, weathers yellow to buff, with thin hard stony layers	5
2.	Clay, bright gray when unweathered, not stratified, includes concretionary lumps of fine-grained fresh-water limestone up to 6 inches in diameter, scattered throughout the bed and forming a persistent layer near the bottom	13
1.	Shale, bluish-gray, rather thinly bedded	3

Fossil identifications in No. 12 are by the Nebraska Geological Survey.[33]

This section evidently lies entirely above the White Cloud shale, unless No. 1 may be considered a part of it. The presence of Pennsylvanian fossils in the uppermost bed proves that it is all Pennsyl-

[33] Nebraska Geological Survey, Private correspondence, E. C. Reed, 1938.

vanian. Comparison with Nebraska and Missouri sections indicates that the coal is probably the Elmo, the limestones above (Nos. 7 to 10, inclusive) are the Burlingame, and the uppermost limestone the Wakarusa. The shale below the Elmo is known in those states as the Cedar Vale, the shale above the Elmo as the Silver Lake, and the shale above the Burlingame as the Soldier Creek. A limestone just above the Elmo coal, in the position of the Rulo of the Nebraska and Missouri sections, is not recognized. Since the lithology and fossil content of this section agrees with that observed in Nebraska and Missouri, their terms may properly be applied to this area.

It is not known whether or not there is an unexposed gap between the base of the foregoing section and the top of the White Cloud shale as found in the coal mine shafts. The shaft of the New Market Coal Company at Clarinda is reported to have penetrated a low-grade coal 140 feet above the Nodaway seam. There is information that a prospect shaft in SW 1/4 NW 1/4 section 3, Jackson township, Montgomery county, about 3 miles from the Adams county line, found a coal seam at 80 feet depth and that another seam was formerly exposed in a nearby gully about 20 feet above the top of the shaft. This information seems contradictory to the exposures of more than 100 feet of White Cloud shale in mine shafts, with no sign of the Elmo or underlying beds at the top; on the other hand, a local dip may make the true interval in section 3, Jackson township, greater than the 100 feet apparent. A very limited and obscure outcrop of a yellowish-gray limestone about a foot thick 1500 feet north of center section 19, Lincoln township (Adams county) appears to represent something above the White Cloud and yet is not like anything in the Elmo-Wakarusa section; this might be the equivalent of the Happy Hollow limestone of the Nebraska and Missouri sections. Considering all these lines of evidence, it appears probable that there is an unexposed interval between the lowest Cedar Vale of the foregoing section and the highest White Cloud exposed in mine shafts, and that the interval is something in the order of magnitude of 25 feet. This figure places the Elmo seam about 150 feet above the Nodaway.

Outcrops known to represent the horizon of the Elmo and beds above are confined in Adams county to sections 19, 30, and 31, of Douglas township. Other exposures in the west part of Douglas and Nodaway townships may represent this horizon in part, but present information favors their reference to the Cretaceous. It is almost certain that the

Elmo nowhere extends more than a mile or so into the western edge of the county. Some of the best outcrops are in the eastern part of Washington and Jackson townships of Montgomery county.

Pennsylvanian History

Evidence from beyond Adams county shows that the three series into which the Pennsylvanian is divided are set apart by stratigraphic breaks which indicate interruptions of sedimentation and elevation and erosion before the later beds were laid down. These breaks are of importance in the interpretation of well logs in this county which may in the future penetrate the beds involved. The exposed Pennsylvanian of the area is all included in the Virgil series, and the beds succeed each other conformably, with no evidence of any important break in deposition. Such fossils as have been identified indicate the persistence of marine conditions throughout Virgil time.

Evidence of cyclic or repetitive sedimentation in the Pennsylvanian beds is very meager. The best developed cyclothems observed elsewhere in the Pennsylvanian seem to be associated with the thicker limestones, and since only one such is exposed in Adams county, and it only meagerly, nothing can be said of the possibility of correlating a sequence of associated beds with other sequences at higher or lower level.

Coal seams are essential units in many Pennsylvanian cyclothems, and since two coals are known to be exposed in Adams county, it might be profitable to make a careful search for evidence of repetitive characteristics in the associated beds. Such a search has not been made, and information at hand does not indicate much repetition of important features.

Following the deposition of the Pennsylvanian beds, Adams county, as a part of a much larger area, was elevated above sea level and maturely eroded before the invasion of the Cretaceous sea.

Pennsylvanian Structure

The large number of Pennsylvanian exposures in the west part of the county, both natural, and in mine or prospect shafts, permits a better knowledge of its structural features than elsewhere. In this area, the Nodaway coal is a key bed whose position is known at a great many places, and is shown on the accompanying structural map (figure 15). Elevations of points on this map were determined by hand level

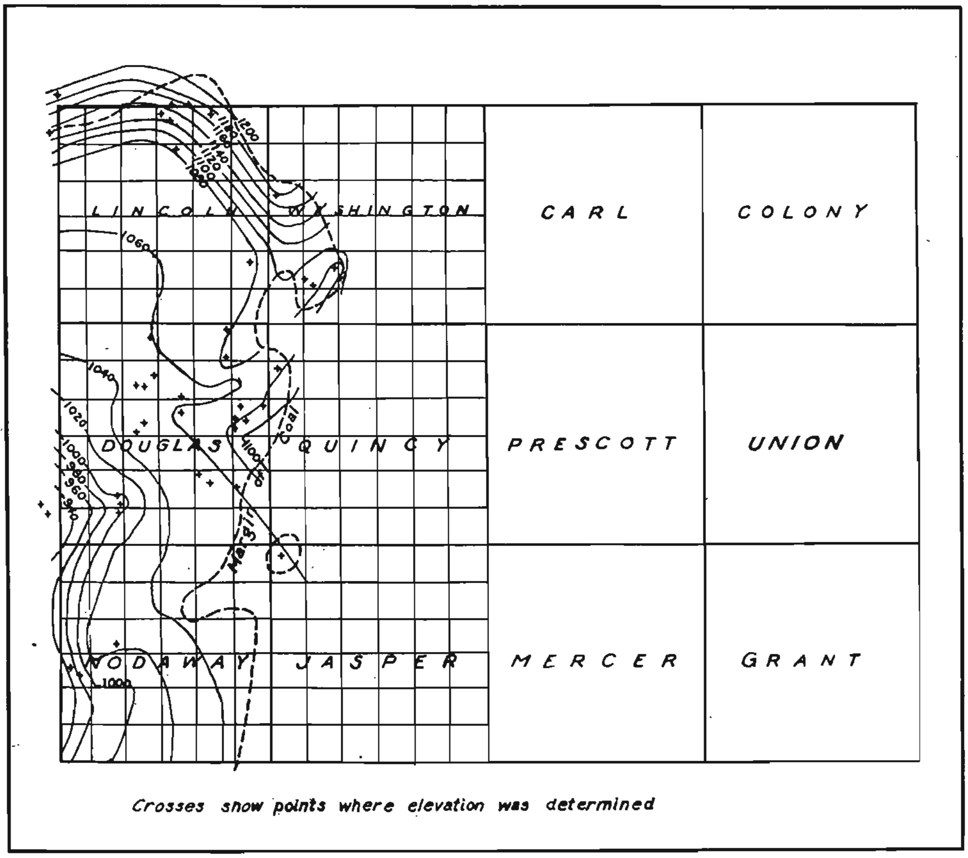

FIG. 15. — Sketch map of Adams county showing elevation of base of Nodaway coal above sea level. Contour interval 20 feet.

or barometric altimeter, and may be in error by a few feet or up to as much as 10 feet; they serve, however, to show the main structural features.

One feature shown prominently is the belt of steep westward dip along the west edge of Douglas and Nodaway townships. Exposures in the west part of the adjoining township in the northwest corner of Taylor county show that the belt continues that far. Smith [34] noted the same westward dip at Clarinda and referred to it as the west limb of the "Hawleyville anticline." It thus appears that a belt of steep westward dip is continuous from Clarinda north to the west part of Adams county. The present study indicates no reversal of dip to the

34 Smith, Geo. L., Carboniferous Section of Southwestern Iowa: Iowa Geol. Survey, Vol. XIX, p. 626, 1908.

east of this belt, either in Adams or in Taylor county, so that it is believed that the term "monocline," indicating dip in only one direction, is preferable to Smith's term "anticline." In recognition of Smith's discovery of this structure at Clarinda many years ago, the term Clarinda monocline is proposed. Its extreme northward extension in Adams county is indefinite, on account of lack of information in northwestern Douglas and southwestern Lincoln townships, but it evidently does not reach beyond the middle of Lincoln township.

A reproduction of the Clarinda monocline on smaller scale is a similar structure parallel to and about 5 miles east of it. This does not appear on the contour map, but is indicated by the two east-west structural profiles, figures 16 and 17. It is of less importance than the

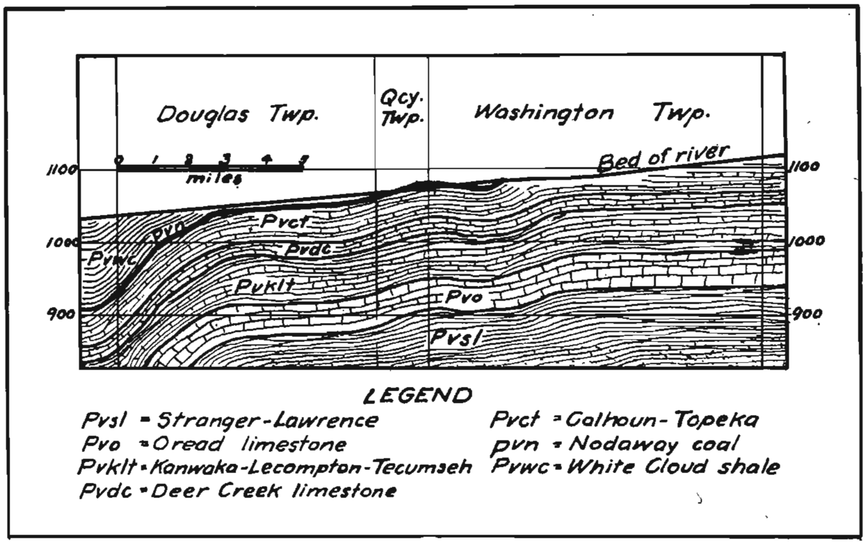

FIG. 16. — Structural profile along Middle Nodaway River across Adams county.

Clarinda monocline but serves to indicate that the prevailing structure in this area is of the "terrace and monocline" type.

Another feature of importance is the strong southward dip in the northwest corner of the county. This is deducted partly from coal mine and well records, and partly from the position of the Deer Creek limestone as previously described in the Fox quarry just north of the county corner. Reports from coal operators in the north part of Lincoln township indicate a southward dip unbroken by faults and persistent at the rate of about 100 feet per mile. When the Fox quarry

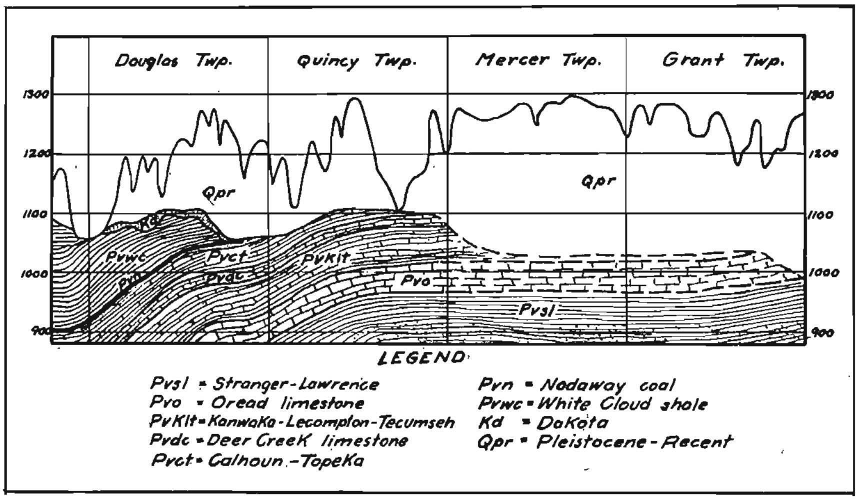

FIG. 17. — Structural profile on road No. 34 across Adams county.

was being worked a few years ago, an even steeper southward dip was noted.

Recent studies by Condra and Reed [35] show that the well-known Thurman-Wilson deformation which crosses Missouri River near Thurman is an asymmetrical anticline whose south flank is much the steeper. Their studies also show that dips on the south flank are very steep near the axis and more gentle farther away. The presence of this structure to the northeast from Thurman seems to be well established, its axis passing about 2 miles north of Red Oak. The northeasterly trend of that axis beyond Red Oak carries it near the northwest corner of Adams county, and the persistent southward dip in the north part of Lincoln township, becoming steeper in the Fox quarry, strongly suggests that the latter point is on the south limb and very close to the top of the same anticline. The change in dip to the southwest in northeastern Lincoln township may indicate a change in direction of trend of the structure, or perhaps a zone of elevation crossing it from northwest to southeast. Relation of the structure in the northwest part of Adams county to the Thurman-Wilson deformation does much to support the view of the anticlinal nature of the latter as contrasted with the earlier conception of it as a fault. The present study has not been extended far enough into Cass county to determine

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35 Condra, G. E., and Reed, E. C., The Redfield Anticline of Nebraska and Iowa: Nebraska Geol. Survey, Paper No. 12, 1938.

whether or not a syncline parallels this anticline on the north, and it is doubtful if that determination can be made without subsurface explorations.

Condra and Reed have given the term Redfield to the anticline crossing Missouri River near Thurman, for the reason that they consider it to be continuous with an anticlinal structure of similar trend near Redfield in the central part of Iowa. It is believed that the present state of structural knowledge in southwestern Iowa does not justify such a long-range correlation. There is good evidence of important change or possibly interruption in the anticline between Redfield and the Fox quarry, and it is not even proven positively that it is the same structure at the Fox quarry and at Red Oak as it is near Thurman. Cline [36] is of the opinion that the condition from Thurman to Redfield is one of more or less interrupted anticlines or domes of various amplitudes following a general trend between those places. This view seems to be the most reasonable to explain the facts as now known. Such being the case, no name is given to the structure in the northwest part of Adams county; it may be and probably is a part of the general trend of highs which runs from Missouri River near Thurman northeastward perhaps as far as central Iowa. If any name is applicable at present, it should be some such local term as Grant, for the nearby town in northeastern Montgomery county. It is hoped that future work will afford more details of this structure and show its relation to, or its independence from others of southwestern Iowa.

The age of the structure now visible in the Pennsylvanian beds cannot be determined accurately. The beds affected could not have been formed on slopes as steep as some where they are now found, so that the latest folding must be post-Wabaunsee. There is no evidence that the Cretaceous beds are affected, although details of Cretaceous stratigraphy are very difficult to determine, and it may be that fuller knowledge of those beds would show some evidence of their having been folded. It is therefore concluded that the folding now observed in the Pennsylvanian took place either at the time of original elevation above the sea, or at some later period before the Cretaceous.

36 Cline, L. M., Oral communication, 1939-40.

Cretaceous

Description of Formations

Beds of this age in Adams county consist almost entirely of clays and soft sandstones, evidently representing the Dakota stage. They appear at the surface chiefly in Douglas township and in a few localities in Lincoln and Nodaway townships. Their occurrence is irregular, and many exposures cannot be positively referred to them on account of their similarity to some of the uppermost Pennsylvanian beds with which they are in contact.

The only known Cretaceous in Lincoln township is in the north part. Gray to red and lavender clays appear in the slopes in a few places in NE 1/4 SE 1/4 section 6. Good springs issue from a bed of fine-grained soft massive sandstone about 10 feet thick in NW 1/4 SE 1/4 section 5. Small springs at other points in the slopes nearby may indicate the presence of the Cretaceous, but nothing is exposed. The Septer farm well in SW 1/4 NW 1/4 section 10 reports a thick bed of sand, which may be Dakota, above Pennsylvanian shale. Exposures in the deep valleys in section 19 give no evidence either for or against the presence of the Cretaceous there.

A number of excellent exposures in the central and west parts of Douglas township, extending into the eastern part of Washington township, Montgomery county, afford good opportunity for study of the Dakota. Two terranes are recognized, a lower one consisting almost entirely of fine-grained sandstone, and an upper one of coarser sandstone and bright-colored clay. There is ample evidence of unconformity between the two. A most interesting section is the following, south of the west quarter-section corner of section 19, Douglas township:

	Feet
4. Till, dark gray, unoxidized, unleached, with scattered lime concretions, and a definite layer of concretionary lime marking contact with the bed below	5
3. Sandstone, brown, coarse-grained, some lenses conglomeratic, grains of quartz, iron oxide, and reddish-brown oxidized shale. The upper surface of this member is strongly eroded and thickness is variable down to zero, allowing the till in places to rest directly on the light-colored beds below	8 (max)
2. Shale, silty, and siltstone, light gray to drab, massive, with brown ferruginous concretions and thin layers, and a few thin lenses of sandstone. Much of the ferruginous concretionary material is derived from or surrounds plant fragments. The upper surface of this member shows strong erosion and its contact with the overlying sandstone is sharp	33 (max)
1. Sandstone, buff, medium-grained, a strong massive ledge	5

There can be no question of the unconformity between Nos. 2 and 3; the eroded surface and development of secondary material indicate weathering of the lower bed, and a part of the upper is a typical basal conglomerate. The first conclusion might be that No. 3 is Cretaceous, and Nos. 1 and 2 Pennsylvanian. Several difficulties arise from this interpretation: in the first place, no sandy interval of this thickness is in the known Pennsylvanian section here, and where sands identifiable as being of that age are found, they do not commonly include the ferruginous concretions and layers; furthermore, light colored sandy shales with ferruginous concretions are known at one or more places farther east (notably 1/4 mile north of center section 15, Douglas township) at levels from 35 to 75 feet above the Nodaway coal, there replacing the non-sandy White Cloud shale; and lastly, exposures about 1/2 mile west of the section given show a bed of lithology apparently identical with No. 2, underlain by a few feet of brown, coarse-grained sandstone varying to conglomerate, which can hardly be referred to any Pennsylvanian known in this area. There is a possibility that the light-colored sands and silts represent some late Pennsylvanian or perhaps Permian deposition unconformable upon the Wabaunsee stage. They include, however, so much material typical of the Dakota at other places in southwestern Iowa as to favor their reference to the Cretaceous.

A small creek running south through W 1/2 SW 1/4 section 19, Douglas township, shows along its lower course frequent exposures of light gray to drab sandy and silty beds with ferruginous concretions and thin layers, in various thicknesses up to 10 feet, overlain by deep brownish-orange clays exposed in a few feet to 15 feet thickness. The contact between the two is sharp and irregular, having the appearance of an eroded surface, marked at one point by a very thin layer of ferruginous sandstone. At another point are small lenses of material composed of 1/8 inch to 1/16 inch grains of ferruginous shale similar to the bed below and marking its contact with the brownish-orange clay above. The surface of the light gray sand and silt shows slopes in general parallel to the present surface slope, indicating here a resurrection of an older erosion slope.

The slopes in NW 1/4 NW 1/4 section 30, Douglas township, show light gray siltstones and fine sandstones, overlain at one point by a few feet of deep brownish-orange sandy clay, the contact between the two being sharp and irregular, indicating an erosion unconformity.

The general slope on the top surface of the light gray siltstone is to the south, paralleling the present surface slope, as if a valley in the same location as that of Middle Nodaway River were developed in the lower beds before the brownish-orange clay was laid down. This same slope to the present valley shows patches of undisturbed glacial till at levels below the higher exposures of older beds to the north, indicating strongly that the Middle Nodaway valley may here be very old.

These bright colored clays and coarse brown sands appear at many places in Douglas township, always at the top of the preglacial section. They are lithologically similar to the clays and sands in the adjoining counties of Cass and Montgomery, which have for many years been known as Dakota. The lighter-colored sandy and silty beds below are more like the Dakota near Sioux City as described by Tester.[37] These two formations are exposed in unconformable contact in Adams county, and the older seems to be definitely post-Pennsylvanian, while the younger, from its absence of grains of foreign material in the sandy beds, is preglacial. It is concluded that both formations represent unconformable portions of the Dakota, with the alternate possibilities that the younger is post-Dakota (perhaps Tertiary), or that the older is pre-Cretaceous. The present study is not sufficiently extensive or detailed to permit a more definite conclusion.

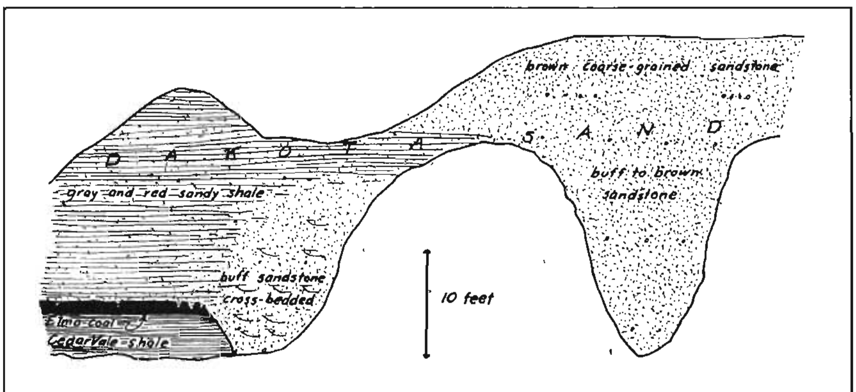

FIG. 18. — Sketch showing Cretaceous sandstones and sandy shales in contact with the Elmo and Cedar Vale formations of the Pennsylvanian north of the southeast corner of section 32, Douglas township.

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37 Tester, Allen C., The Dakota Stage of the Type Locality: Iowa Geol. Survey, Vol. XXXV, pp. 235 to 254, 1929.

The best exposures of Dakota beds between Middle and East Nodaway rivers are those in contact with the Elmo coal north of the southwest corner of section 32, Douglas township (see figure 18). Lying directly on the coal is about 20 feet of gray and red shale and sandy shale, grading, where the coal is cut out, to a massive soft, buff, cross-bedded sandstone. The upper part of the sandy shale can be traced along the slopes for some distance to the southeast, where it is capped by a few feet of deep brown, coarse-grained, poorly cemented, ferruginous sandstone. The upper brown sandstone can be traced still farther east to a gully where 30 feet of it is exposed and its lower part is water-bearing and feeds a small spring.

Springs issuing from sand beneath glacial till at several points in the south part of Douglas township indicate that the Dakota may be present in some of the hill slopes where it does not now appear. A few gullies in the northwest part of Nodaway township expose light gray clays and siltstones with ferruginous concretions and thin layers, evidently equivalent to the lower part of the Dakota. The sands there are micaceous, and it is possible that they are referable, at least in part, to the upper Pennsylvanian.

There is no evidence of the presence of the Cretaceous in Adams county south of East Nodaway River, or in the adjoining northwest part of Taylor county.

Pennsylvanian-Cretaceous Relationships

The extent of pre-Cretaceous erosion on the Pennsylvanian surface is difficult to estimate accurately, as exposures of the pre-Cretaceous surface are few. The best now known is north of the southwest corner of section 32, Douglas township, as previously described, and illustrated in figure 18. Another pre-Cretaceous surface, in E 1/2 SW 1/4 NW 1/4 section 9, Douglas township, is included in the following section:

	Feet
3. Shale, soft, sandy, bright red and light gray, with lenses of incoherent white and yellow sand	5
2. Sandstone, brown, ferruginous, variable in induration, coarse-grained, lower part varying locally to conglomerate	4-5
1. Shale, drab, clayey, the upper portion showing evidence of weathering, with veins or stringers of iron oxide possibly from infiltration along joints or cracks from the bed above. The upper surface is irregular and oxidized, marking the effect of erosion. Several springs issue at or just above this surface	2-6

No. 1 is evidently a part of the White Cloud shale, and beds above are Cretaceous. Figure 19 is a photographic view of this exposure.

FIG. 19. — View of Cretaceous sandstone overlying Pennsylvanian shale in section 9, Douglas township.

Better evidence of the degree of erosion on the Pennsylvanian before the transgression of the Cretaceous seas may be seen in the overlap of Cretaceous upon Pennsylvanian beds of different age. For example, the section just described shows Cretaceous beds in contact with the White Cloud, while the one sketched in figure 18 shows them in contact with the Elmo. Mine and prospect shaft records indicate Cretaceous in contact with all horizons of the White Cloud from top to bottom, or even with the underlying "slate" and coal (NE 1/4 NW 1/4 section 35, Douglas township). Contacts with beds above the Elmo are less certain on account of the sandy character of the beds of both systems, but appear to be present in section 25, Washington township, Montgomery county, within a mile of the Adams county line.

The present Pennsylvanian surface has a known relief of 100 feet or more, but some of this has undoubtedly been developed since the Cretaceous beds were laid down. Pre-Cretaceous relief on the Pennsylvanian surface is more difficult to estimate; however, the base of beds of that age lies as high as elevation 1150 in S 1/2 section 16 and as low as elevation 1060 in SW 1/4 section 19, both of Douglas township.

Cretaceous History

Cretaceous sediments of Adams county have not been studied in enough detail to permit final conclusions as to the environment under which they were laid down. It is known, however, from Cretaceous studies at other points in western Iowa that at least a part of the Dakota was laid down under near-shore marine conditions, with stream gravels and sands in some local areas. From the character of the sediments in Adams county, it appears probable that the lower formation of fine-grained sandstone was deposited in a shallow sea not far from a land which supported an abundant vegetation. At some later time the area was elevated above sea level and received the continental stream deposits of clay and coarse sand of the upper formation.

Post-Cretaceous Preglacial History

Deposition of the Dakota beds was followed by another long period of erosion whose effects are illustrated on a small scale in the previously described section south of the west quarter-section corner of section 19, Douglas township (p. 316). It is probable that a large part of the Cretaceous was swept away, and that further cutting in the Pennsylvanian shales took place. A rolling erosional topography was developed, perhaps originally on a scale comparable to that of the present topography. As time went on, however, the hills were gradually reduced to more or less gentle slope, with a relief of possibly 100 feet. It was upon this thoroughly dissected and worn down surface that the first glacier moved and laid down its load of detritus.

The long cycle of erosion following Dakota deposition entirely removed deposits of that age from many large and small areas where they had been originally laid down. The fact should be kept in mind in studying the geological map, Plate I. Cretaceous areas shown on that map are approximate and within them are undoubtedly many patches from which beds of that age are entirely missing.

Natural exposures and mine shafts and water wells afford a fairly good idea of the position and attitude of the bedrock surface in the west half of the county. Whether that surface remained undisturbed through the Pleistocene period or whether erosion at some time during the Pleistocene cut through early glacial deposits and further reduced the bedrock cannot be certainly said. It may be true, since preglacial post-Dakota time was so long in comparison with the Pleistocene period, that most of the energy of later erosion was spent on the accumulation of earlier glacial materials, with penetration of older beds only locally. The present bedrock surface is therefore considered to be a fair representation of the preglacial surface, at least in its broader features.

There is almost no knowledge of the position and attitude of the bedrock surface in the east half of the county, but the information available indicates that an elevation of about 1000 in section 17, Union township, may be typical of most of that area.

Figure 20 shows by means of 25-foot contours the general features

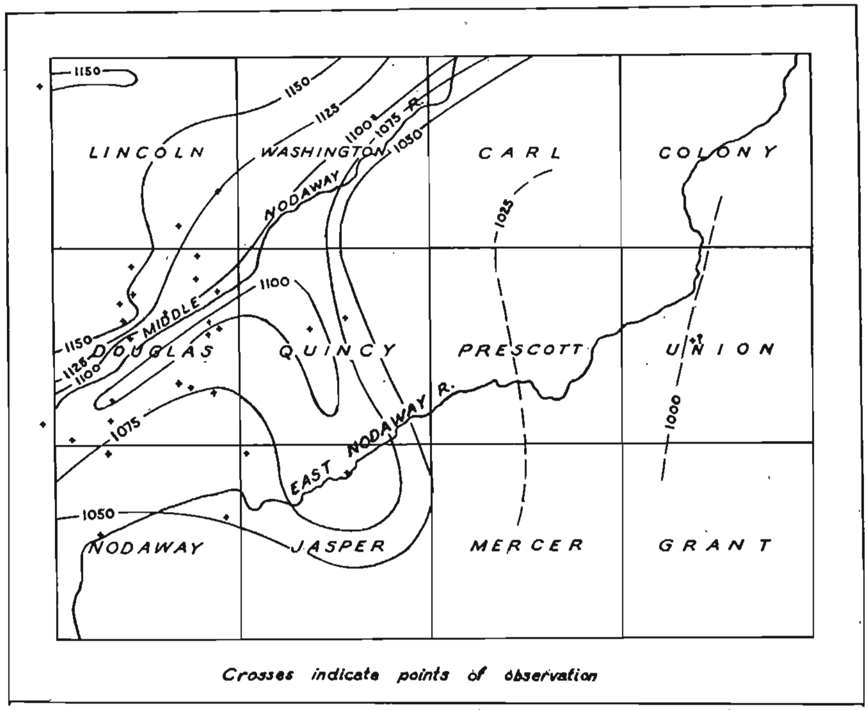

FIG. 20. — Generalized contours at 25-foot intervals on the bedrock surface.

of the present bedrock surface. In sketching these contours some records of doubtful authenticity were not used. Other elevations which plainly mark the result of recent and localized erosion are also omitted, so that the map can be considered only to show the more prominent features.

The most important feature of the bedrock surface is its general slope to the southeast. An eastward slope of about 50 feet in a mile or so along a line trending north from Corning may be related to the monoclinal structure on the Pennsylvanian, but this relation is not positive. Reasons for this general southeasterly slope are not clear; it is certainly true that in counties to the west that slope is generally to the south or even southwest. The east part of the county may mark some broad preglacial valley with gently sloping sides. More likely, the area was in preglacial time tributary to streams running southeasterly, as does now the Grand River farther east. Rapid development of the Missouri river valley above Kansas City later resulted in the capture of the drainage of the area and diversion of it to the present streams.

Consideration of the post-Cretaceous preglacial surface affords some basis for conclusions as to the age of the East Nodaway and Middle Nodaway river valleys in Adams county and the West Nodaway River valley near the northwest county corner. As mentioned in an earlier section of this report, these rivers may have had a longer history than that of the smaller streams of the county. The following facts may be significant.

A strong line of evidence against the assumption of preglacial age of these major valleys is their general trend in the county independent of or even opposed to the general slope of the preglacial surface. This slope trends to the southeast, and in the central part of the county nearly east. The East and Middle Nodaways flow generally southwest and the latter in the central part of the county runs more nearly west. It is difficult to understand how any major line of drainage could have developed at that time at such an angle to the general slope.

The bedrock surface through Douglas township lies generally from 20 to 100 feet higher than the bed of Middle Nodaway River. The slope of that surface to the present valley is largely mantled with loess, but glacial till and gravel are exposed on it at a few places, notably in sections 16, 19, and 30, on the north slope, and less clearly in section 31 on the south slope. These patches of till indicate survival of this portion of the valley through at least one glacial stage. No till has been found on the slopes to the present valley in the east part of the township, near Carbon, but it is admitted that it may be present.

The bedrock surface in Washington township on the Middle Nodaway, or in Nodaway and Jasper townships on the East Nodaway, is not so well known, and where determined, shows very little slope to the present major streams.

Glacial till occurs beneath loess on the terraces along East and Middle Nodaway Rivers, a circumstance suggesting partial filling of an older valley with till. Many of the terraces are so modified by recent erosion as to make it impossible to determine whether or not their topography was constructional in origin. The thickness of till on them is notably less than that of either till on the upland. In none of them is more than one till now exposed, and in most cases, the till present cannot be identified as to age.

Cretaceous exposures in W 1/2 SW 1/4 section 19, Douglas township, show an upper and lower phase of the Dakota in unconformable contact, the surface of the lower having a general slope paralleling the present slope. This is believed to be a local and perhaps accidental resurrection of the older drainage system, rather than a valley continuously surviving since Dakota time. The upper phase of the Dakota is found along the road 1/4 mile south of center section 16, Douglas township overlapping nearly 40 feet of Pennsylvanian shale. The shale surface here slopes to Middle Nodaway River, parallel to the present surface, and it appears that here also a post-Pennsylvanian valley has been resurrected, if not continuously surviving.

A curious circumstance which may be significant is the abrupt change in direction of all three Nodaway rivers from a southwesterly course to a southerly course at points near the west line of Adams county. These points lie on or near the axis of the Clarinda monocline. The river courses thence downstream are closely parallel to the trend of that structure (see figure 21) and may have been inherited from older valleys whose locations were determined by it.

It will thus be seen that evidence of long history for the three Nodaway rivers in the near Adams county is fragmentary and indefinite. A reasonable conclusion seems to be that they are post-glacial except at the extreme west edge of the county where they may be much older. The long narrow ridge between the East Nodaway and the West Nodaway along the eastern edge of Page county is evidently older, as glacial materials appear in the lower slopes along both sides, while a well record (see Appendix A) shows a Pennsylvanian backbone rising 50 feet or more above the river bed on either side.

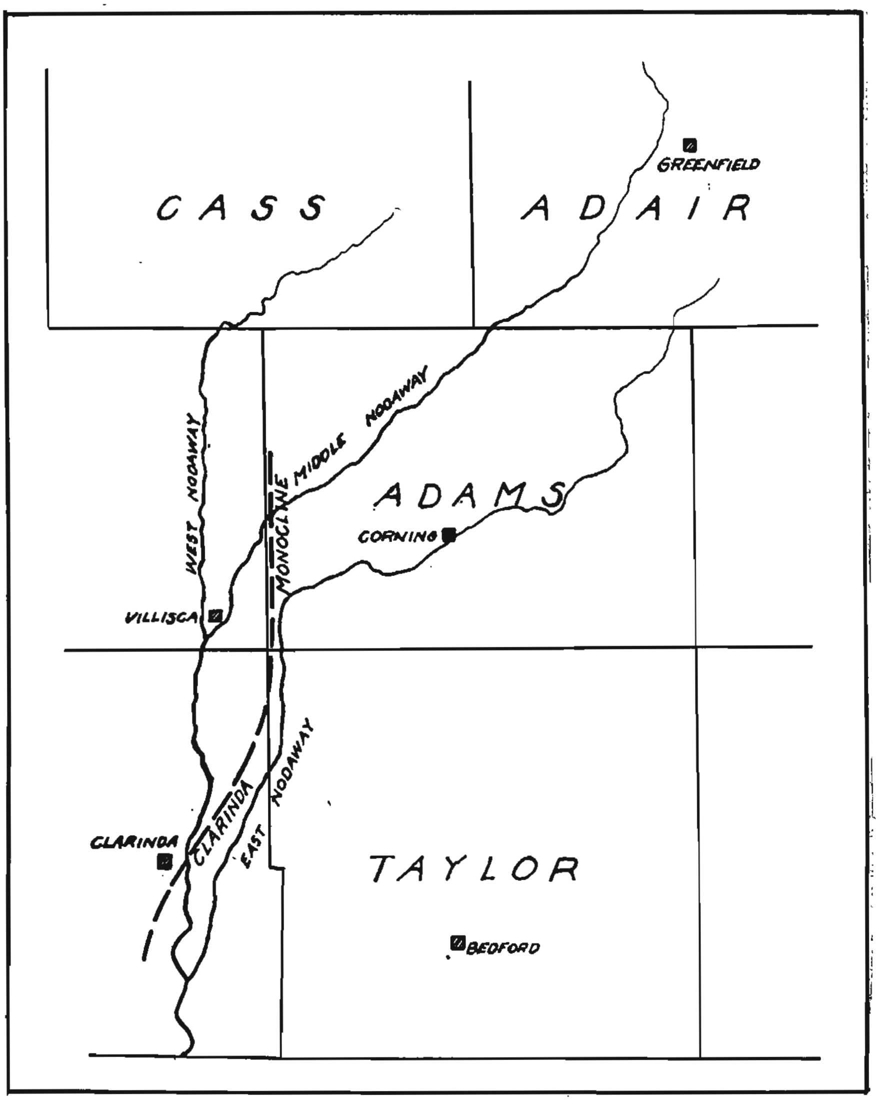

Fig. 21. — Map of Adams and parts of adjoining counties, showing parallelism between axis of Clarinda monocline and courses of Nodaway rivers.

Pleistocene

Following is the classification of the Pleistocene of Iowa now adopted by the Iowa Geological Survey:

PLEISTOCENE SYSTEM

Series	Stages	Substages
	Recent-soil formation, erosion, deposition of alluvium	
Eldoran	Wisconsin	Mankato Peorian Iowan
Centralian	Sangamon Illinoian	
Ottumwan	Yarmouth Kansan	
Grandian	Aftonian Nebraskan	

Lees' manuscript includes the following general statement of Pleistocene history:

"Millions of years went by (after Cretaceous time)[38] during which the mild, uniform climates of Mesozoic time were gradually replaced by cooler climates. At times these climates were so cold (and wet)[38] that ice fields formed in the northern regions and also in the far south. These ice fields, in the form of continental glaciers, traveled hundreds of miles from their sources and covered parts or all of the northern United States. The glaciers carried with them great loads of clay, sand and boulders, which they had picked up along the way. These materials were left behind when the glaciers melted away upon the return of a warmer climate. They formed what we know today as the glacial drift sheets. Some of the materials remain practically in the condition in which the glaciers left them; others have been modified by chemical processes or mechanical agencies until they are far different from the materials that the glaciers laid down.

"This was the Pleistocene or glacial period, popularly called the Great Ice Age, and the beds of material formed during this time are the rocks of the Pleistocene system. . . ."

Nebraskan

The Nebraskan till is composed of a heterogeneous mixture of rock fragments and ground-up rock obtained by the glacier from any materials present at or near the surface over which it passed. The rock fragments are thoroughly planed and worn down and in large measure reduced to sand sizes, though boulders up to several feet in diameter are not unknown. Particles of sand or larger size commonly con-

38 Parenthetical material added by the present writer.

stitute from 10 to 50 per cent of the whole. The remainder is in silt and clay sizes, well characterized by the common term "rock flour". Since the Nebraskan ice originated from the Keewatin center of glaciation near Hudson Bay, Canada, it moved over a great diversity of materials, and a corresponding diversity is found in the recognizable rock fragments included in the till of that age. Common types in Adams county are quartz, quartzite, granite, and various dark-colored igneous rocks, with smaller amounts of limestone, chert, jasper, and many others. The till is compact in texture and very hard when dry. It shrinks with loss of moisture and exposed surfaces show the small shrinkage cracks which give rise to the starchlike texture noted by so many observers. Its compactness makes it rather impervious to the entrance or passage of water.

The original till was probably gray in color, and in the lower portions dark gray to almost black. Oxidation of iron compounds has changed the upper portion to a yellow or brown color. Leaching has removed most of the carbonates (chiefly calcium carbonate) from the upper 15 feet and redeposited them as concretions in the material below.

Further weathering of the till on undissected plains under conditions of restricted surface drainage has resulted in hydrolysis and solution of most or all of the larger particles, and reduction of the iron compounds, so that there develops an extremely fine-grained plastic clay of gray color, with shrinkage characteristics and starchlike texture more pronounced than in the till. This clay is known as gumbotil. It has been shown by Kay[39] to mark the position of the original ground moraine plain left by the Nebraskan ice.

Erosion of till on slopes leaves in many cases a concentrate of pebbles on the surface, left behind by currents of water too weak to carry them away with the finer particles.

The thickness of Nebraskan till and allied materials is variable from zero in the west part of the county to 100 feet or more in the east part, as will be explained more fully later.

Exposures of till and gumbotil which can be definitely referred to the Nebraskan are confined to the central and western portions of the county, where stream erosion has removed the younger materials. The majority known are in Prescott, Quincy, and Douglas townships, none

[39] Kay, George F., and Apfel, Earl T., The Pre-Illinoian Pleistocene Geology of Iowa: Iowa Geol. Survey, Vol. XXXIV, p. 207, 1928.

has been found in Colony, Union, Grant, or Mercer townships, and only one from the extreme west edge of Carl township.

Lees describes the following section:

"On the east-west road in the west part of section 18, Carl Township:

	Feet
Till, Kansan, yellow, pebbly, unleached below	15
Gumbotil, Nebraskan, gray, many concretions, a little lime in gumbotil	7
Till, Nebraskan, unleached, yellow, with concretions	

The elevation of the gumbotil is 1150 feet."

This section is now obscured by vegetation and overwash. The presence of lime in the gumbotil is explained as a secondary development from carbonates leached down from the overlying younger materials.

A similar succession is described by Lees in northern Douglas township, as follows:

"On the east-west road near the southwest corner of section 3, is an exposure that shows the normal succession of unleached yellow Kansan till overlying gray Nebraskan gumbotil with many lime concretions, about 3 feet thick; under the gumbotil is unleached Nebraskan till, yellow, pebbly. The elevation is 1145 feet. Around the corner of the road, between sections 3 and 4, another exposure shows the same succession and also a pebble band showing above the Kansan till. Above this is 6 feet of gray, leached loess. The elevation is about 1150 feet."

The same succession is now visible in the east road cut in NW 1/4 SW 1/4 section 13, Douglas township, top elevation about 1175:

	Feet
4. Loess, light buff, top few feet dark brown	12
3. Till, deep brown, pebbly, a ferretto (thoroughly oxidized) zone	2–3
2. Gumbotil, gray, a few sand grains, and with calcareous concretions	4
1. Till, yellow, pebbly, unleached, oxidized, calcareous concretions most abundant in upper portion	12

In spite of the sand grains present in No. 2, it is believed to represent the Nebraskan gumbotil, here also with concretionary material of secondary origin leached down from the overlying younger till and loess. No. 3 is a weathered remnant of Kansan till.

Grading of Road No. 34 from Corning west involved several deep cuts, which exposed good sections of loess or loess and till, and in a few cases, loess and two tills. These exposures are now obscured by slumping and vegetation, but when fresher, they were examined by Doctor George F. Kay, then State Geologist. The following description of one of the more significant exposures, near the middle of the line between sections 28 and 33, Douglas township, is taken from his unpublished notes.

	Feet
4. Loess	5
3. Till, Kansan, oxidized and unleached, many concretions	2
2. Gumbotil, Nebraskan, drab, concretions in base	5½
1. Till, Nebraskan, oxidized and leached, but with concretions of secondary calcium carbonate, exposed	3

Kay gives the barometric elevation at the top of No. 2 as 1180, but comparison with levels of the road profile here indicates that 1190 is more nearly correct.

Kay's field notes refer also to an exposure of Nebraskan gumbotil overlain by Kansan drift along what is now Road No. 95 in SW 1/4 section 7, Quincy township. He gives the base of the gumbotil an elevation of 1150, and describes it as being "drab colored, 11 feet thick, filled with concretions. Just above is unleached oxidized Kansan drift with concretions, fully 25 feet thick. The drift below the gumbotil is like the Kansan in every respect, and appears to be about 50 feet thick."

The following road cut section is now visible west of the east quarter-section corner of section 25, Quincy township:

	Feet
5. Loam and dark-colored loess	2
4. Till, brown, ferretto zone, with pebble concentration at surface	1
3. Till, yellow, pebbly, oxidized, all but lower few feet leached	10
2. Till, gray, to dark iron-gray below, unoxidized, unleached	10
1. Till, yellowish, oxidized, unleached, set off sharply from the overlying dark gray till	2

The oxidation of No. 1, sharply set off from overlying unoxidized till might be interpreted as evidence that the lower till is Nebraskan, with leached material eroded away before deposition by the Kansan ice. This interpretation, however, is open to some question, as oxidation alone does not necessarily prove a time interval as long as the Aftonian. It may be that No. 1 is early Kansan, exposed and oxidized during a temporary retreat of the ice and then buried under the deposits resulting from a readvance.

Lees' manuscript gives the following in regard to Nebraskan exposures in Prescott township:

"A good section of Nebraskan gumbotil is shown at the railroad cut one mile west of Prescott at mile post 408 . . . as follows:

	Feet
Soil	2
Loess, gray and buff	4
Loess, brownish	1
Clay, brown, hard, starchy structure, sandy, in places much so; probably Nebraskan gumbotil	2
Clay, progressively more sandy below, some pebbles, an indication of joint structure	6
Clay, still more sandy and finer; all clay leached	5

"The first cut one mile west of Prescott evidently shows loess over Nebraskan gumbotil, about 12 feet of gumbotil being exposed above the tracks. It does not show a typical starchy fracture in most places, but near the base of the cut where the clay is damp, it looks typically gray, sticky, finely granular. This cut and the next one west are through ridges sloping to the river valley, and evidently Kansan till was eroded before loess was deposited. Hence the Nebraskan gumbotil is blocky and hard in most places."

In Adams as in other counties of Iowa are a few exposures of very dark gray or almost black till resting upon the preglacial surface. This very dark gray till is commonly assumed to be Nebraskan, although there is a possibility that it is Kansan, occupying valleys eroded through the earlier drift to the bedrock. A typical exposure is in the quarry of the Adams County Limestone Company in SE 1/4 SW 1/4 section 3, Jasper township. Pennsylvanian beds appearing here are described in an earlier part of this report. Above the Pennsylvanian is the following section:

	Feet
4. Silt, drab, clayey, grading up to a brown loess	10 (approx.)
3. Sand, medium to fine, clean; leached	10 (max.)
2. Gravel, coarse, oxidized and leached	1
1. Till, black, unleached, soft and weathered on the surface, with pebbles and small boulders, and a ferruginous concretionary layer at the top	0 to 3

The till is referred to the Nebraskan. In part of the exposure, it has been eroded, allowing the gravel to rest directly upon an oxidized surface of Pennsylvanian shale. This fact, together with the development of concretionary materials at the top of the till can be considered as evidence of unconformity, in which case the gravel is Aftonian or younger; on the other hand, the concretionary layer may be more recent, resulting from the arrest of downward moving waters at a surface of impervious material, in which case the till and gravel are almost contemporaneous. The silt above may be related to loess, perhaps a reworked loess deposited by water in its present position in

East Nodaway valley. The elevation of the top of the till here is 1100, about 40 feet lower than nearby exposures of Nebraskan gumbotil.

Nebraskan till and associated materials have been observed at many other places in the county, but the foregoing sections serve to bring out its most important characteristics. Where seen separately, the Nebraskan and Kansan tills are indistinguishable by eye, and some exposures now referred to the former may represent the latter occupying a valley eroded in Aftonian time. Only where two tills can be shown to be separated by some recognizable mark of interglacial time is there positive assurance of the presence of the Nebraskan.

Aftonian

After the melting of the Nebraskan ice, the drift plain left by it remained for some time essentially unattacked by the agents of erosion. The upper layers of till were thoroughly weathered and leached, and rock fragments broken down, resulting in the formation of gumbotil. In time, either with or without the aid of uplift, drainage courses began to establish themselves, and their tributaries extended farther and farther until much of the area was subjected to their influence. Thus, when the Kansan glacier moved in from the north, it found here a region of slopes and of well-developed valleys, alternating with flat and poorly drained expanses; a region topographically in late youth. Both gumbotil formation and erosion are slow processes, and the great amount of work accomplished in those directions is eloquent testimony of the great length of Aftonian time.

Exposures of Nebraskan gumbotil have been previously described and little more needs to be said of its nature (see also Appendix B). It is stated by Kay and Apfel[40] to have been formed in Iowa to an average thickness of 9 feet, and several exposures in Adams county show thickness approximating that figure. The elevation of the Nebraskan plain on which gumbotil is now found has been determined at fifteen places in the county. Most of these lie within 20 feet of elevation 1150, with an area in southern Douglas township rising nearly to 1200 feet. These places are fairly well distributed throughout all parts of the county except the east and south, and show no general slope in any direction. This general flatness of the Nebraskan plain may be contrasted with the southeast slope of the preglacial surface

40 Kay and Apfel, *op. cit.*, p. 205.

and the southwest slope of the later Kansan plain; it evidently indicates a time in the development of Missouri River drainage when Adams county lay on the divide between tributaries flowing southeast and those flowing southwest, or in other words, on the "height of land". The total upland thickness of Nebraskan till and gumbotil must have been very small in Douglas, Lincoln, and Washington townships, increasing to 100 feet or more in Prescott township, and perhaps still more farther east. Where the drift filled preglacial valleys its thickness was correspondingly greater.

Kansan

The general description of till and associated materials previously given in the discussion of the Nebraskan applies also to the Kansan. A possible difference may arise from the fact that the Kansan ice overrode a surface largely covered by weathered till and gumbotil, and its drift may therefore be expected to include more of the clay materials and less of the bedrock fragments. There are a few instances where recognizable masses of the older drift can be seen incorporated in the younger.

The thickness of Kansan till and allied materials is variable from almost nothing in Douglas township to 100 or 150 feet in the east and northeast parts of the county, as will be explained more fully later.

The best exposures of Kansan till and gumbotil are in the east and south parts of Adams county, where post-Kansan erosion has not swept so much of them away. A large number have been laid bare by road grading operations, but only a few show features of enough significance or interest to warrant detailed description in this report. Some have been mentioned in the previous discussion of the Nebraskan.

Lees' manuscript gives the following section along the road between the west part of sections 4 and 9, Colony township:

	Feet
4. Loess, gray, may be in part gumbotil, with concretions	
3. Gumbotil, Kansan, gray, sticky, starchy, grading down abruptly with fingerlike extensions into the member below	6
2. Till, Kansan, yellow, pebbly, leached in one place, some lime concretions in the base of the gumbotil	6
1. Till, Kansan, unleached, with large lime concretions	2

"The base of the gumbotil is at 1265."

Lees also observed a good exposure at the railroad cut at the county line in section 12, Union township, as follows:

		Feet
3.	Loess, gray and buff above, gray and brown below	10
2.	Gumbotil, Kansan, brown and gray, joint structure very well developed, very few siliceous sand grains, leached, grading down into the member below	6
1.	Till, Kansan, yellow and gray, numerous small siliceous pebbles	6

"Near its west end this same cut on the north side shows a similar succession except that the loess is five feet thick, and below the leached till is exposed 8 feet of unleached till. This lower till is abundantly calcareous and contains numerous concretions, some as large as one's fist. It also contains many pebbles, some of them limestone. The south face shows a similar succession, but the unleached zone is lighter yellow on the surface than the leached zone."

The top of the gumbotil is here at about elevation 1280.

A cut 1/4 mile east of SW corner section 20, Union township, shows about 10 feet of loess and 5 feet of gumbotil, underlain by a few feet of yellow oxidized till. This is at elevation 1250 or perhaps higher, and is evidently Kansan.

Recent grading operations on County Road C from Prescott north have exposed several excellent sections of Kansan and younger materials. Mention of two will suffice to show the characteristics of these formations in this part of the county. A cut in SW 1/4 NW 1/4 section 25, Carl township, shows in descending order the following: loess, dark-colored, 5 feet; gumbotil, gray, very sticky, without pebbles, 6 feet, top at elevation 1260. The cut 1/4 mile south of the NE corner section 35, Carl township, shows in descending order the following: loam, 2 feet; till, oxidized and leached, 5 feet; till, oxidized and unleached, with many lime concretions, 6 feet. The top elevation here is 1250, evidently a short distance below the gumbotil plain.

An exposure in a road cut east of the south quarter-section corner of section 16, Prescott township, shows 6 feet of leached and thoroughly oxidized till, underlain by 6 feet of yellow unleached till with calcareous concretions. Strong erosion at the west end of the cut brings unleached till within a foot or so of the present surface. A cut at lower level just west shows a mass of gray gumbotil 20 feet long and 5 feet thick, with till above and beside it, and a small pocket of coarse gravel adjacent. This is evidently Nebraskan gravel and gumbotil, ploughed up and incorporated in the Kansan while frozen, indicating that this horizon may be very near the base of the Kansan. The elevation is probably between 1150 and 1175.

A road cut exposure east of the south quarter-section corner of section 18, Prescott township, gives a rather complete section, as follows:

	FEET
4. Loess, upper portion dark brown grading to black at top, remainder drab to light buff, all leached	14
3. Till, buff to brown, a ferretto zone, with a concentration of pebbles and cobbles, leached	2
2. Till, buff, oxidized, top 3 feet leached, lower 5 feet unleached and with a few calcareous concretions	8
1. Till, yellow to gray, unoxidized and unleached	8

The till is at such elevation as to be evidently referable to the Kansan. Erosion at the east end of the cut brings unoxidized and unleached till within a foot or two of the present surface.

The Kansan gumbotil in Mercer township is shown in the following road cut section north of SW corner section 22:

	FEET
3. Loess, tan, darker colored at top, leached	8
2. Gumbotil, gray, starch-like fracture, few pebbles, leached	11
1. Till, mottled yellow and gray, leached, more pebbles than the above	3

"Gumbotil elevation here is about 1265."

Grading operations on Road No. 148 north from Corning have laid bare several good sections of Pleistocene materials. Most of these show a sequence normal for the area, but one, near the west quarter-section corner of section 10, Washington township, is more difficult to interpret.

	FEET
5. Loess, brown, grading at top to dark brown loam	4
4. Loess, mottled gray and buff, weathers to tan	5
3. Till, brown, leached, well oxidized, gravelly	3
2. Gumbotil, gray, leached, pebbles infrequent, a few secondary lime concretions in basal portion, thickness variable on account of erosion before deposition of the overlying till	7 to 10
1. Till, buff, unleached, limestone pebbles and concretions, and igneous pebbles	10

No. 2 can be recognized as a gumbotil, and the eposure is extensive enough to preclude the possibility of its being a ploughed-up and displaced mass. It is at the proper elevation to be the Kansan gumbotil, and about 115 feet higher than exposures of Nebraskan gumbotil reported by Lees at some 4 miles distance. Correlation with the Kansan seems thus to be more reasonable, even though this may imply the existence of a post-Kansan till at this point.

Lees' notes mention a road cut in SE 1/4 SW 1/4 section 30, Quincy township, which shows 10 feet of loess, 3 feet of leached Kansan till, 6 feet of unleached Kansan till, and 5 feet of gumbotil with concretions. This cut is now obscured by vegetation and slumping. The top of the gumbotil is at elevation 1180.

Recent road grading west of the north quarter-section corner of section 29, Jasper township, exposes the following: Loess, light buff, leached, grading at top to dark brown loam, 10 feet; gumbotil, gray, waxy, a few pebbles chiefly siliceous, leached, 4 feet.

Kansan till is well exposed by recent road grading south of NW corner section 22, Lincoln township, as follows: loess, brown, leached, 2 to 4 feet; till, gray to brown, partially leached at top, including masses of oxidized sandy and silty material possibly ploughed up from the Cretaceous surface, 15 feet. The top of the till is at elevation 1270, and no gumbotil is seen.

The Nebraskan is high in the Dickieville locality in southwestern Douglas and northwestern Nodaway townships, and the Kansan correspondingly thin and locally missing. Kansan exposures are not frequent, and those seen are commonly difficult of correlation. The following, in SW 1/4 NE 1/4 section 5, Nodaway township, shows what is believed to be the Kansan till.

	Feet
5. Black loam, grading down to brown loess, leached	3
4. Loess, mottled brown and gray, weathers to tan, leached	10
3. Till, chocolate brown, pebbly, oxidized, leached	3
2. Till, or gumbotil, less pebbly than the above, iron gray, leached	8
1. Till, pale yellow to gray, unleached	3

Road levels show the top of No. 2 to be at elevation 1238. This is rather high for Nebraskan gumbotil in comparison with nearby exposures of that horizon. No. 1 is largely unoxidized, and it seems probable that the whole till section should be referred to the Kansan.

Gumbotil appears in the following succession in the road cut in SE 1/4 SE 1/4 section 32, Douglas township, about 1/2 mile from the preceding section, as follows:

	Feet
3. Loess, brown above, light buff below, thin ferruginous layer 10 feet down, mottled with ferruginous spots below	16
2. Gumbotil, iron-gray, a few quartz pebbles, leached	5
1. Till, unleached, partly oxidized, with lime concretions	3

The top of the gumbotil is at 1230, and this probably represents Kansan gumbotil.

Another interesting section is in and below the deep road cut about 1/4 mile east of SW corner section 19, Nodaway township, as follows:

		Feet
3.	Loess, light buff, leached, darker colored at top by organic material	12
2.	Till, yellowish-gray, pebbly, top 2 feet oxidized and darker colored, top 3 or 4 feet leached, remainder partially leached. At one point is a sharply defined mass of sticky gray gumbotil 15 feet long and 3 feet thick, underlain by about half a foot accumulation of pebbles and cobbles, evidently ploughed up from below and incorporated while frozen	24
1.	Clay, gray, sticky, without pebbles, thoroughly weathered, exposed in a small gully leading north from the east end of the cut, contact with No. 2 not visible	10

The top of No. 1 is at elevation 1115. This bed seems to be a thoroughly weathered Pennsylvanian shale, but is much higher than any other exposed Pennsylvanian nearby, though little higher than an unverified report of shale in a mine shaft about 1/2 mile north. The elevation is about 165 feet above the Nodaway coal, in the horizon of the Burlingame or lower Soldier Creek formations. It may be that the clay is a ploughed-up mass of Pennsylvanian shale incorporated in the till at a level above its natural position. The included mass in No. 2 seems to be gumbotil, so that No. 2 is necessarily Kansan, indicating that the Nebraskan is here missing. It is to be remembered that both Nebraskan and Kansan tills were originally thin in this part of the county, so that it is easy to understand the absence of either from any particular section.

Glacial Sand and Gravel

Before proceeding to the discussion of post-Kansan history, it may be well to mention the glacial sands and gravels found in Adams county. Some are below the level of the Nebraskan gumbotil plain, a circumstance pointing to Nebraskan age. Others, above the Nebraskan gumbotil plain, can be referred to the Kansan. In most cases, determination of their age must await more careful observations of their elevation and condition of leaching. Since known occurrences in Adams county are rare and economically unimportant, such observations have not been made. It is known, however, that glacial sands and gravels in other counties of southwestern Iowa are chiefly Nebraskan rather than Kansan, and those in this county are probably as old.

Prospecting by the State Highway Commission in Adams county has revealed a few sand and gravel pockets, none of important size. The largest now known are near the center of the NW 1/4 of section 26, and near the center of the SW 1/4 of section 31, both of Washington township. Pits have been worked at both of these places, but available material is now largely exhausted. Other known locations,

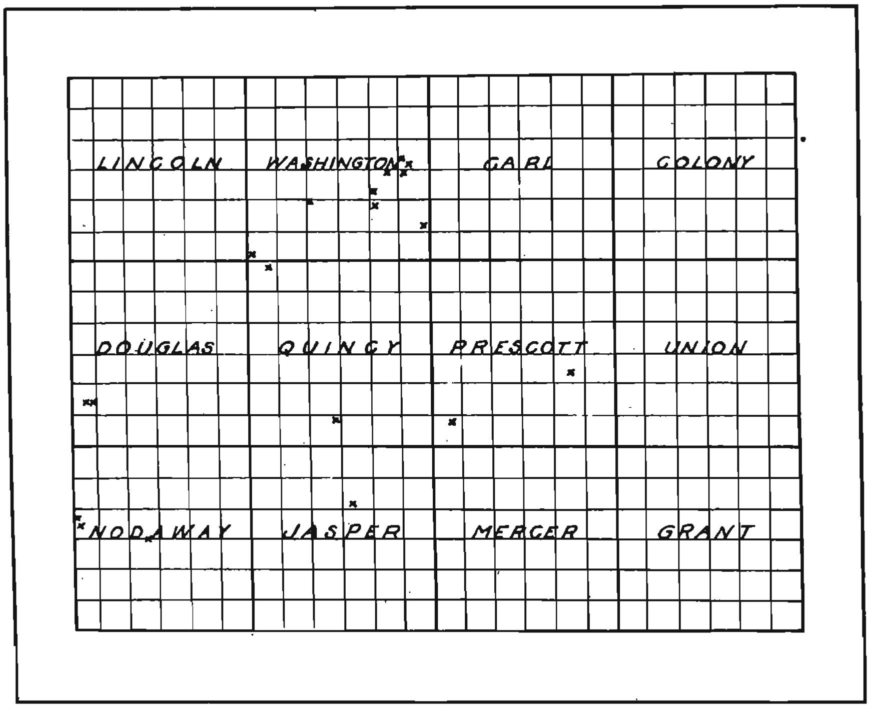

FIG. 22. — Sketch map of Adams county, showing known locations of glacial sands and gravels.

of apparently smaller deposits, are shown on the sketch map, figure 22. The grouping of these in the central and west parts of the county reflects the relative abundance of till exposures in those areas.

Sand commonly predominates over gravel in these deposits, although the lower few feet is coarse and in places bouldery. Thorough oxidation is usual, and much of the material is stained yellow or brown by finely divided iron oxide derived from the weathering of included iron-bearing pebbles or granules. The rocks and minerals represented are much the same as those in other gravels of southwestern Iowa, with quartz, quartzite, and chert conspicuous, but many others present. Quartz predominates in the sand sizes. The more sandy deposits commonly show rather complete stratification, but coarser phases seem to have been laid down in more turbulent waters, and are imperfectly bedded. Mapping of the occurence of these materials is not complete enough to permit any estimate of the location or direction of the ancient streams which laid them down.

An interesting exposure just beyond the limits of Adams county is seen in a deep gully north of the south quarter-section corner of section 25, Washington township, Montgomery county, as follows:

		Feet
14.	Glacial till, leached, oxidized, bottom elevation 1135	2–8
13.	Sand, brown, clayey, leached, the top marked by a thin concretionary layer of iron oxide, thickness variable up to	23
12.	Boulders and coarse gravel, leached and oxidized, granite and other igneous and metamorphic rocks, bedded with brown ferruginous clay	1–3
11-6.	Pennsylvanian shales, sandstones, and limestones, as described under these numbers in a Pennsylvanian section for this locality given earlier in this report	48

The diversity of rocks and minerals present in the boulder bed proves that it, and therefore the overlying sand, are glacial outwash. Evidence of erosion unconformity between the sand and the overlying till indicates that the latter may be Kansan, even though below the level of the nearby Nebraskan gumbotil plain. The sand and boulders may thus be either Nebraskan or Aftonian; in either case, Nebraskan till is presumed to be missing, a fact not unexpected in an area where it does not seem to have had any great original thickness. The presence of Kansan till below the level of the Nebraskan gumbotil plain is evidence of the existence of an Aftonian valley here, perhaps in or near the present course of Middle Nodaway River.

Yarmouth

The interglacial stage following the retreat of the Kansan ice is commonly known as the Yarmouth, from exposures near the town of that name in southeastern Iowa. Kay and Apfel [41] have pointed out that gumbotil was formed on the Kansan plain during this interval to a thickness of 11 feet, indicating a lapse of time even longer than that of the Aftonian. With the gradual development of a drainage system, aided perhaps by general uplift of the area, erosion became more widespread, and the topography gradually assumed a form much the same as at present.

In Adams county, the Kansan gumbotil has been observed at many places, chiefly in the eastern half. The foregoing sections indicate that it reaches a maximum thickness comparable with that in other parts of southern Iowa. From the gumbotil exposures it is possible to reconstruct the main features of the original Kansan plain, and this is shown by generalized contours on the sketch map, figure 23. The main feature shown here is the general southwesterly slope, paralleling the

41 Kay and Apfel, *op. cit.*, p. 257 *et seq.*

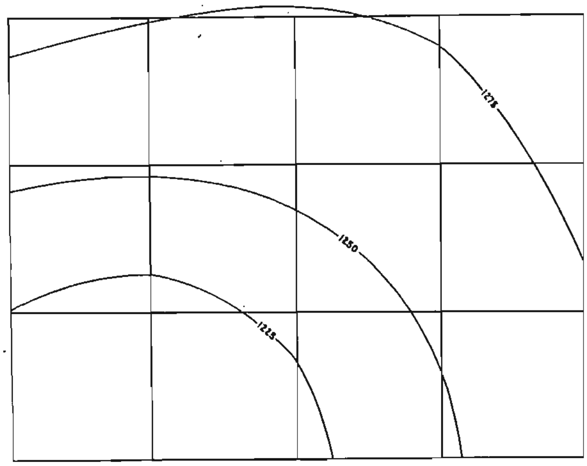

FIG. 23. — Sketch map showing approximate elevation of Kansan gumbotil plain by 25-foot contours.

present upland surface, and reflecting the present control of the area by the Missouri river above Kansas City, as contrasted with its earlier dependence on southeasterly drainage.

Comparison of the attitude of Nebraskan and Kansan gumbotil plains gives a very fair idea of the original upland thickness of Kansan drift. This is seen to range from almost nothing in Douglas township to 100 feet or more in the east part of the county, and possibly almost 150 feet in the extreme northeast corner. Where the Kansan filled an Aftonian valley these figures are of course greatly increased. Post-Kansan erosion has greatly reduced the original thickness, and in some areas in the southwest part of the county it is now entirely missing.

Loveland Formation

The existence in western Iowa of a compact loess-like clay with interbedded sands and silts and traces of volcanic ash, younger than the Kansan and older than the main body of loess, has been known to geologists for many years. Shimek [42] described materials of this kind in Harrison county giving them the name of Loveland, from the town of that name near Missouri Valley. More recently, Kay and Apfel [43] have published further details of the Loveland formation, and described its occurence in widely separated areas of the state.

[42] Shimek, B., Geology of Harrison and Monona Counties: Iowa Geol. Survey, Vol. XX, pp. 371-375, 1909.

[43] Kay, George F. and Apfel, Earl T., Tbe Pre-Illinoian Pleistocene Geology of Iowa: Iowa Geol. Survey, Vol. XXXIV, pp. 277-281, 1928.

The Loveland is recognized in Adams county as a silty clay, commonly mottled light buff and brown, locally with as much as 20 per cent of fine sand. It is commonly well set off from the Peorian loess above by its difference in color or texture, or by an oxidized zone or even a soil horizon at its top. It is distinct from the Kansan till or gumbotil in its smaller content of very fine colloidal particles and consequently lower degree of plasticity, and lighter texture. An exception to the latter statement must be made in the case of the very flat areas where restricted surface drainage and consequently greater percolation has resulted in a thorough weathering of the material by hydrolysis and solution, with accompanying increase in colloidal content and development of a clayey texture almost indistinguishable from gumbotil. The Loveland is known in the county in thickness up to 6 feet, but in some loess sections it is either missing or unrecognizable. As it has not been found except where overlain by the Peorian loess, details of its occurrence will be given with the loess sections. It is of little or no economic importance so far as is now known.

Peorian Loess

During and after the time of Iowan glaciation farther north and east, Adams county lay uncovered, its surface subject to further weathering, erosion, and deposition. Great quantities of dust were blown up by the prevailing winds from the west where the cold climate had so stunted vegetation as to expose the surface to their sweep. This dust settled on Adams as well as other counties of western Iowa, and formed the material known as loess.

The Adams county loess shows the typical characteristics of an aeolian deposit. Its source was evidently to the west, and at some distance, for its thickness and its fineness show no significant change from the west edge of the county to the east. Mechanical analysis of loess from the ridge between East and Middle Nodaway Rivers shows it to have the same fineness there as in other parts of the county, thus indicating that those valleys contributed little to its formation. On the other hand, there is a distinct coarsening of loess near the Missouri river (see Appendix B) and a corresponding increase in its thickness in that area, so that it appears that the valley of that stream furnished most of the loess material.

An interesting section of loess and underlying materials is in a road cut north of the west quarter-section corner of section 25, Grant township, as follows:

		Feet
3.	Peorian loess, light buff, leached, top few feet darker colored by organic material	7
2.	Loveland silt, sandy, evidently an aqueous deposit, mottled tan and brown by uneven distribution of iron compounds, top few inches distinctly darker colored and showing by analysis a higher carbon content, indicating an old soil horizon	3
1.	Kansan till, leached, yellow, pebbly, top 2 feet oxidized to a deep brown	6

The top of the section is at approximate elevation 1290. The till is sharply set off from the overlying silt and loess by its greater toughness and plasticity, and its development of shrinkage cracks and starch-like fracture.

A somewhat different succession, developed on flat land under a condition of restricted surface drainage, is shown in a test hole at the west quarter-section corner of section 29, Grant township, as follows:

		Feet
5.	Loam, derived from loess, black and granular at the top, lighter colored and heavier below	2.6
4.	Loess, clayey, rather tough and plastic, mottled gray and brown by uneven distribution of iron compounds	8.9
3.	Loess or silt, similar to the above but with higher moisture content. The top of this member is marked by a 6-inch oxidized layer of darker color	2.5
2.	Gumbotil, gray, tough, plastic, very little sand. This shows to the eye an identical texture, and color not much different from the material above, but is distinguished in the laboratory by its higher colloidal content, and in the field by its greater resistance to penetration of moisture	13.6
1.	Till, grayish-brown, sandy, lower 3 feet unleached and with calcareous concretions, upper part grading to gumbotil	11.2

Top elevation here is 1292. Nos. 1 and 2 are Kansan till and gumbotil, No. 3 may represent the Loveland, and Nos. 4 and 5 are the Peorian loess. The unusual thickness of gumbotil is notable, but may be expected in such an area, to which erosion has not yet reached. A carbon determination at the top of No. 3 does not indicate a soil horizon, but the dark oxidized layer is evidence of a time interval before deposition of the Peorian loess. The whole section differs from that which may be found in natural exposures, as these are necessarily located where there has been free surface drainage and some erosion.

Loess appears in many of the cuts along the newly graded road north of Prescott, a maximum thickness of 10 feet being observed. This figure includes 2 or 3 feet of mottled gray and brown partly sandy material, evidently the Loveland silt and loess, but not sharply set off from the Peorian loess as is the case in some exposures. Lees' manuscript mentions at the railroad viaduct on the county line in section 12, Union township, 10 feet of loess, "gray and buff above, gray and brown below," evidently representing both Peorian and Loveland. His section shows below the loess, 6 feet of Kansan gumbotil, grading down into 6 feet of Kansan till.

Loess is shown in previously described sections in section 10, Washington township, and section 22, Lincoln township. The 5 feet next above the till at the former location may represent the Loveland. Loess 12 feet thick lies on gumbotil in a new road cut 1/4 mile east of the center of section 16, Carl township.

A previously described section west of the north quarter-section corner of section 29, Jasper township includes 10 feet of loess. At a level from 1 to 3 feet above the bottom of the loess is an irregular but persistent thin dark-colored zone below which the material is sandy, evidently representing the Loveland.

A good loess section in the southwest part of the county is the following, in a road cut in SE 1/4 SE 1/4 section 32, Douglas township:

	Feet
3. Peorian loess, light buff, grading to dark brown at top by addition of organic matter	10
2. Loveland loess or silt, mottled tan and brown by uneven distribution of iron compounds, top marked by a thin dark-colored ferruginous layer	6
1. Gumbotil, iron-gray, leached, a few quartz pebbles	5

The top of this section is at elevation 1245. The unusual thickness of the Loveland is notable, although total thickness of that formation plus Peorian does not exceed that observed at points farther east.

Post-Yarmouth History

Following the formation of Kansan gumbotil, and its later erosion in Yarmouth time, Adams county received the Loveland deposits, laid down largely by water but probably in part also by wind. These beds correspond in age with the Illinoian and Sangamon in areas farther east. Following their deposition a soil was formed on them and they were partly eroded away, events believed to have taken place in late Sangamon and early Iowan time. On this modified and eroded surface the Peorian loess was then deposited by the great dust storms during and following late Iowan time.

It is possible that loess deposition was slow enough and erosion vigorous enough, so that in some areas the new deposit was swept away by water as fast as it was laid down by wind. Whether this was the case, or whether there was at some time a complete blanketing of the surface by loess, is not certain. In any case, erosion continued long after deposition ceased or became so slow as to be negligible, and the result is now that the loess remains preserved only on the upland flats and the more gentle slopes. Such areas of more gentle slope are more extensive in the higher and less dissected townships, Carl, Colony, Union, Grant, and Mercer. They persist, however, in the more thoroughly eroded regions and in lower lands, notably on the terraces on East and Middle Nodaway rivers, bearing witness there to the great amount of pre-loess erosion. On any particular hill or ridge, the common condition is to find loess at the top, thinning as the slopes steepen on the sides, entirely gone where slopes are steepest, and modified to reappear at the foot of the hill as a belt of alluvium. Since loess deposition was relatively slow, and erosion well established before and uninterrupted throughout, there was probably little or no change in topography from that developed on the Kansan surface in Yarmouth time.

Much of the dark-colored silty material in the bottoms of the larger streams must have found its way there during and since loess deposition. This explains the lack of sandy or gravelly materials in the upper alluvium and their presence at greater depth.

It may be well at this point to discuss the conditions of preservation of the flat upland areas of southern Iowa to which the term "tabular divides" has been given. The general explanation for southern Iowa is that they are remnants of the original ground moraine plain left by the retreat of the Kansan ice sheet, untouched by Yarmouth erosion, and then covered by loess and preserved at the headwaters of drainage from later erosion. In a county like Madison where hard limestones are topographically high, they have resisted the headward extension of small streams, and have thus preserved large areas free from the stream cutting. On the other hand, in a county like Wayne or the southeastern part of Adams, where bedrock is largely a non-resistant shale, and where it is topographically so low as to have little effect upon stream development, the explanation lies in the relatively long distance of the divide areas from the master stream (Missouri River) and their lesser elevation above the master stream, as compared with divide areas farther north and west. For example, the only true tabular divides discovered in Adams county lie near the headwaters of Hundred and Two River, some 120 miles distant and 560 feet higher than the mouth of that river near Kansas City. The average slope of the Hundred and Two river basin may thus be expressed as 4 2/3 feet per mile. The uplands of northeastern Adams county drain to the East Nodaway river and lie only 90 miles distant and 520 feet above the mouth of that river north of St. Joseph. The average slope of the East Nodaway basin may thus be expressed as 5 7/9 feet per mile. This average slope seems to be enough higher to account for a more vigorous erosion by that river and a more rapid extension of its tributaries, so that in the same length of elapsed time the stream has been able more nearly to complete the work of reduction of the original upland plain. If the same comparison is extended into the central or west parts of the county, an even greater erosion capacity is indicated, and the almost total disappearance of upland flats is explained.

On the northeast part of Adams county are areas of upland divide, not so extensive as the true tabular divides of the southeast part of the county, but still nearly flat and untouched by erosion. These areas are underlain by a normal uneroded thickness of loess and Kansan gumbotil. They are not included with the true tabular divides for the reason that slope, though imperceptible to the eye, is sufficient for adequate surface drainage, thus precluding such modification of the underlying materials as has been observed at the west quarter-section corner of section 29, Grant township (see p. 341). Such pseudo-tabular divides evidently mark areas which escaped Yarmouth erosion but have been attacked by the headward extension of small streams since Peorian time.

Beginning when loess deposition was completed, and continuing up to the present time, are those modifications of the surface materials by climate and vegetation (and most recently, by cultivation) known under the term of soil formation. These processes are described more fully in a later section of this report.

ECONOMIC GEOLOGY

Coal

Coal is an important mineral resource in Adams county, supporting an industry which employs about 250 workers.

A few mines were formerly worked in the Elmo seam in the adjoining edge of Montgomery county but all of those now in operation utilize the Nodaway. Following is a tabulation of statistics on the occurrence of the coal in those mines active during the 1938-39 season:

Name of Operator	Location		Shaft depth-Platform to base of coal Feet	Thickness			
	Section	Township		Caprock Feet	Slate or "bastard" Feet	Coal Inches	Under-Clay Feet
Henton Coal Co.	SE¼ NE¼ 29	Washington	41	1½	2	18	1½-2
Henton Coal Co.	NW¼ NE¼ 25	Lincoln	98	1	¼-2	12-17	1¾
Chatterton Coal Co.	Cen. NW¼ 7	Quincy	78				
Ruth Coal Co.	SE¼ SE¼ 2	Douglas	67	1¼	0-2	10-22	3
R. H. Gebbie	NE¼ NE¼ 2	Douglas	58	2¼	¼-1	10-20	2¼
Hendrickson Coal Co.	SE¼ NE¼ 4	Douglas	141	1½	1±	15-18	2
Dalgetty Coal Co.	NE¼ SW¼ 9	Douglas	123			18	
Wainwright Coal Co.	NW¼ SE¼ 9	Douglas	125	1½	1½	18	2
Franzine Coal Co.	SE¼ NE¼ 9	Douglas	138	1¾	0-2	17-19	1¾
Gale Coal Co.	SW¼ SE¼ 10	Douglas	78	1½	0-2	16	2¼
Albert Mack	NE¼ SW¼ 13	Douglas	85	1	½-2	14-18	2½
Boham Coal Co.	NE Cor. 13	Douglas	117	1	0-2	18-20	2¾
Cloyd Smith	SW¼ NW¼ 13	Douglas	51				
Drake Coal Co.	Cen. NW¼ 13	Douglas	116	1½	0-2	14-20	2½
Haley Coal Co.	NW¼ SW¼ 13	Douglas	69	½	0-2	18-22	2¼
Ed Thompson	NW¼ NE¼ 15	Douglas	38	2	½-1¾	16	1¾
Roy Thompson	NW¼ SE¼ 16	Douglas	60	1¾	0-½	16	2¼
Stern Coal Co.	SE¼ SW¼ 16	Douglas	63	2	¼-4	14-18	2½
Homer Lockwood	SE¼ NW¼ 26	Douglas	112	1½	0-2	18-22	2½
John Hunter	NW¼ NW¼ 26	Douglas	94	1¾	0-3	18	2
Acton Coal Co.	NE¼ SE¼ 29	Douglas	107	2	1±	18-20	4½-5½
Ruben & Anderson	SE¼ SE¼ 29	Douglas	180	1¾	½-3	18-24	2½-5
Linker & Landrus	NE¼ NE¼ 32	Douglas	174	1¾	1-2	14-24	5½
Ankeny Coal Co.	SW¼ NE¼ 19	Nodaway	184	2	1-4	16	3-4
Ankeny Coal Co.	SW¼ NE¼ 19	Nodaway	96			16	

This table shows the uniformity of the Nodaway coal and associated beds, the only significant change being the thickening of the underclay to the south.

Mining methods in the Nodaway coal are remarkably uniform. The longwall system is universally employed. A few inches of the underclay are first taken out, and the coal then broken down by wedging from the roof. With the coal comes most of the "bastard" or slate and this waste material, together with such underclay as has been removed, is piled in the tunnel or room back of the miner. The room is thus only about 3 feet high and miners work lying down. The roof is uniformly good enough so that timbering in the rooms is rarely necessary. Nearly all of the mines make very little water.

Rooms are too low to use horses and the loaded coal cars are pushed by hand to the foot of the shaft. A few of the smaller mines have used horse power for raising the cages, but most now have hoists operated by gasoline motors. The method of mining without blasting permits recovery of most of the coal in large chunks with little dust or dirt, and screening facilities are usually not provided, only mine-run being sold. None of the mines has rail connection, but the larger ones are on all-weather highways and coal is trucked to distances of 100 miles or more, in western Iowa and southeastern Nebraska.

There is no union organization among the miners, and earnings are in most cases rather low. The State Mine Inspector's regulations set up certain requirements as to ventilation, hoisting equipment, timbering, etc., so that working conditions are comparable with those in other mining districts of Iowa. The operation is seasonal and is carried on partly by farmers or farm laborers who work in the fields through the summer months. The State Mine Inspector's report shows a production of 31,367 tons from twenty-five mines in the county in 1937.

The following chemical and combustion test results on a face sample from a mine near Nodaway are quoted from Olin: [44]

[44] Olin, H. L., Iowa Coal Studies: Iowa Geol. Survey, Technical Paper No. 3, p. 10, 1936,

	Nodaway Coal	Average of 24 Iowa coals
1 Moisture, percent	21.7	18.1
2 Ash, percent	18.6	15.1
3 Sulfur, percent	6.6	6.0
4 BTU, per pound	11300	12013
5 Volatile, percent	37.8	38.5
6 Fixed Carbon, percent	43.6	46.4
7 Ash fusion temperature	2100°F	2187°F
8 Ignition temperature	257°F	287°F

Nos. 2 to 6, inclusive, are calculated on a dry basis.

These analyses show a quality comparable with other Iowa coals, or from ash and moisture tests, possibly a little lower. The somewhat lower quality is largely offset by the commonly cleaner product resulting from the longwall system of mining with little or no blasting. Consumer acceptance thus compares favorably with that of other Iowa coals.

Available information makes possible a reasonable estimate of the coal reserve in the Nodaway seam in Adams county. The area originally underlain is about 104 square miles. Mining operations to date have removed or made unavailable about 9 square miles. About 18 square miles additional is estimated to be unavailable because of poor roof and too great a depth for stripping. There remains some 77 square miles of available coal, which at an average thickness of 17 inches, contains about 121,600,000 tons. Of this amount, about 4 square miles containing 6,300,000 tons, in the bottomlands of Middle Nodaway River east and west of Carbon, and East Nodaway River northwest and northeast of Brooks, can be considered a possibility for strip mining. The remainder can be reached only by shafts, which in some cases must penetrate water-bearing beds above the coal, thus adding to the difficulty and expense of recovery. Of the 121,600,000 tons considered to be now available, not all will be recovered, as mining practice, even with the longwall system, involves some waste. With the most economical methods, such waste might be reduced to 20 per cent or less, leaving an estimated net recovery of at least 97,300,000 tons.

Soils

Adams is now and will probably remain essentially an agricultural county. The fundamental capital stock of agriculture is the soil, and soils are thus properly considered as the county's most important natural resource.

In preparation of this report, the writer first consulted with the Agronomy Department of Iowa State College, and arrangements were made for field reconnaissance and office conference with their director of soil surveys, Doctor Roy W. Simonson. Much of the following material in this report is credited to the advice and assistance of Doctor Simonson.

Soil Formation

Three general phases of soil formation are recognized by soil scientists, in chronological order as follows: first, the breaking down of the parent material to small particle sizes so that external agencies may become effective; second, the development of organic matter (humus) in the surface soil; and third, zone differentiation, brought on by movement of certain constituents from one horizon to another. This chronological order does not imply that one phase ends before another starts; there is more or less over-lapping, or even existence of all three at once.

The great ice sheets which ground up the surface rocks, and the winds which transported and redeposited much of the finely divided material, effectively accomplished this first phase of soil formation, the reduction of parent material. The wonderful fertility of Iowa soils bears witness to the complete accomplishment of this task. Such reduction was uniformly complete throughout Adams county, and this phase of soil formation need be considered no further.

Most of the soil formation in this county may be included in the second phase, as it is in most places only this phase which takes place rapidly enough to keep pace with the reduction of the surface by erosion. As pointed out in the section on Topography, the great bulk of the area of the county is in slope. Where such slope is gentle and erosion slow, the depth affected by soil formation may be as much as 3 feet, but even so, with little horizon differentiation. On steeper areas organic matter may attain a depth of only a few inches, or under cultivation be entirely swept away. The Tama and Shelby soils of Adams county illustrate this phase of soil development.

In the flat areas still remaining from the original upland plain, soil formation is not partially nullified by the effects of erosion, and proceeds farther into the third phase, that of horizon differentiation. Run-off is less and percolation of rain water correspondingly more. Soluble constituents are carried down far below the soil horizon.

Those soluble only with difficulty, such as the iron and aluminum oxides, are leached down by the percolating waters, partly in solution, partly in colloidal form, and partly in suspension, to be redeposited in lower soil layers from 1 foot to 3 feet below the surface. The enrichment of these layers with this colloidal material gives them a heavier texture which hinders downward percolation and permits further enrichment from above until the supply of moveable colloids in the upper layers becomes largely exhausted. This process is slower under prairie conditions than under forest, and such horizon differentiation, even in the largest of the tabular divides of Adams county, is still incomplete. A soil of this kind, which owes its characteristics to the results of restricted surface drainage in a flat topography, is known by the term "Planosol" and is represented in Adams and adjoining southern Iowa counties by the Grundy series.

Soil Classification

The detailed soil survey of Adams county has not yet been made, and only the broader features of classification of its soils can be outlined.

Soils of Adams county belong almost entirely to the great Prairie Group of the north-central plains, as recognized by the United States Department of Agriculture. Four predominant series are present here, the Grundy or similar series of the flat tabular divides, the Tama and Shelby of the slopes, and the Wabash of the alluvial bottomlands.

Grundy Series

This series is of limited occurrence, being confined to the flat tabular divide areas of the southeast part of the county, as shown in figure 2. Surface drainage in such areas is greatly restricted and a large proportion of the rain water percolates slowly downward through the soil and its underlying parent loess. The amount of such water during the wetter seasons is enough to waterlog the soil and underlying loess and exclude nearly all of the air, so that oxidation is arrested and previously oxidized materials deoxidized or reduced. Dryer seasons permit the entrance of some air, so that partial and intermittent oxidation takes place along joints, root cavities, or other channels. This results in a gray color of reduced loess, mottled with irregularly distributed brown oxidized spots. The downward percolating water also accomplishes much along the lines of hydrolysis and solution, probably with an accompanying extensive change in the character of the clay mineral forms, so that the physical properties are further modified in the direction of greater plasticity or stickiness and greater volume change with varying moisture contents. The final result is a material derived from loess, but quite different in appearance and texture from the typical loess of natural exposure in the slope. Such modification takes place only on flat areas of no erosion, and there are thus no natural exposures of the modified material. It is known from artificial excavations, including wells, where it lies upon a gumbotil of almost identical physical properties, and separately recognizable sometimes only by laboratory tests.

The solum, or true soil horizon on such material is commonly about 3 feet thick. The surface soil to a depth of about 16 inches is a black friable silt loam high in organic matter. Lower layers are less friable, more plastic, and lighter in color, until at a depth of 20 to 24 inches there is a dark gray silty clay. Below this depth the mottling resulting from uneven oxidation becomes more pronounced and organic material is further decreased, so that at 36 inches depth the soil becomes indistinguishable from the underlying parent loess.

Studies now in progress by the Agronomy Department indicate that the soil on the tabular divides of Adams county shows some variations from the typical Grundy of southern Iowa, and it may be advisable to give a new series name to some parts of the area. It is, however, more closely related to the Grundy than to any other series now recognized in Iowa, and is therefore given that name in this report.

Grundy soil is very fertile and offers the added advantage of being free from erosion danger. Its restricted drainage makes it hard to handle in wet seasons, and the compact and impervious nature of the subsoil makes tile drainage commonly unsatisfactory.

Tama and Shelby Series

These may be considered together, as they are developed under like topographic, climatic and vegetative conditions, the Tama from loess, and the Shelby from till or gumbotil. On the slope areas, constituting nearly all the county, surface drainage is free, and a correspondingly smaller proportion of rain water percolates into the ground. Oxidation of the subsoil and parent material proceeds continuously, though slowly, and a more or less uniform yellow to buff color is attained. Original differences in plasticity and shrinkage characteristics between loess and till or gumbotil are preserved, and the loess is thus sharply set off in natural exposures from the lower materials. The true solum or soil horizon is fully developed on the more gentle slopes to a thickness of 3 feet. On steeper slopes, erosion materially reduces this thickness, in some cases to only a few inches.

The surface soil of the Tama series in Adams county is a mellow dark brown silt loam high in organic material. Where not truncated by erosion, this horizon is 12 to 18 inches thick. Below this is a brown and rather friable silt loam or silty clay loam, lighter colored at greater depth, and grading at about 36 inches into a tan loess.

The Tama, where not eroded, has a fertility comparable with that of the Grundy. Its surface drainage is good. It has a higher degree of permeability than the related Shelby, and consequently absorbs more rain water, with correspondingly less loss by erosion. It is also commonly found on more gentle slopes, where erosion is more easily controllable. It is not subject to overflow as are some of the bottom-land soils. Altogether, the Tama may be considered to be the most desirable agricultural soil in the county.

Areas of Tama soil follow the distribution of the loess, except in the case of the upland flats in the southeast part of the county where Grundy and similar series are found.

Soils developed from similar parent material and under environments similar to the Tama are in counties farther west commonly included in the Marshall series. The distinction between Tama and Marshall is not yet thoroughly understood and it may be that some areas in the west part of Adams county will eventually be included with the latter. This determination is left to the detailed soil survey of the county.

The surface soil of the Shelby in Adams county is a dark-brown loam, in many cases somewhat sandy, extending to about 10 inches depth where uneroded. It is underlain by brown, granular, clay loam, which becomes lighter in color with greater depth and finally grades at 36 inches or less to the ordinary yellowish-gray sandy or pebbly glacial till. Where the soil develops on gumbotil the sandy characteristic is absent, and the greater impermeability makes the whole profile shallower; these areas are not extensive or important, as loess is usually found above the till in those flatter topographic situations where gumbotil has been formed.

Shelby soil is rich in plant foods, and where erosion can be sufficiently checked, it will produce good crop yields.

Wabash Series

The dark-colored topsoils of the Tama and Shelby series are eroded from the upland slopes and redeposited as the black alluvium of the lowlands. A large part is carried only a fraction of a mile, to the nearest small branch, but some finds its way to the major river valleys in or beyond the more remote parts of the county. Since the upland surface material of Adams county is almost entirely loess and till, silt and clay particle sizes predominate in the alluvium, and sand and gravel are relatively rare. The Wabash series of soils is developed from this silty or clayey dark-colored alluvium.

The surface soil of the Wabash is black mellow loam, in places slightly sandy. This grades at about a foot depth to heavy black silt loam or silty clay loam, which at depths of about 25 inches becomes a little lighter in color, grading to the typical dark-gray alluvium. Since many of these lowlands are subjected to overflow at irregular intervals, the whole solum or soil horizon may have less depth than the figures given; or may be repeated as a whole or in part at one or more lower levels. Wabash soils are obviously very fertile. In spite of their low topographic situation, drainage is commonly sufficient, or if not, is susceptible to definite improvement by tiling. Where overflows are not too frequent, these are some of the most valuable agricultural soils in the county.

Other Soils

Such terraces as are found in Adams county seem to be largely erosional remnants rather than of alluvial origin. The surface materials are commonly loess or till, and soils developed are for the most part referable to the Tama or Shelby rather than to any of the alluvial terrace series. Some small low terraces are of colluvial origin, derived from slope wash from the adjacent hills; these are composed of materials like those of the bottom lands and soils developed on them are similar to the Wabash, though possibly referable to another series on account of their topographic position.

Relatively small forested upland areas show Clinton soils formed on loess, and Lindley on till, as contrasted with the Tama and Shelby series of the prairie upland. Forest conditions permit a more rapid and complete differentiation of separate horizons within the solum than is the case in prairie, and the Clinton and Lindley soils are included in the Gray-brown Podzolic Group so extensively represented in eastern Iowa and adjoining states. Areas in Adams county which were once forested but are now cleared are in most cases so eroded that the original podzolic soil is largely removed.

A few small areas of slope in the south part of Douglas township have shale and sandstone so near the surface as to require mapping of what little soil is present in one of the residual series. These slopes are not extensive, and patches of till cover parts of them, so that residual soils are of little or no importance.

Soil Erosion

The soils of Adams county are the fundamental capital stock of the county's most important industry. This capital is seriously menaced by the destructive effects of erosion. Of the soil series described, probably none except the Grundy is entirely free from erosive effects; even the Wabash soils of the lowlands may be periodically buried by new materials brought down by floods from the upland slopes. The Shelby soils, by virtue of topographic position and relative impermeability, are especially susceptible.

Soil erosion depends upon a number of factors. Of these, nature of soil material and slope on which the soil occurs are geological, while others are climatic or cultural and thus not included in a report of this type. For a more extended discussion of these factors, the reader is referred to the Iowa State College publication, "Soil Erosion in Iowa".

Adams county soil materials which are present on erodible slopes may be classed as of limited permeability. This is particularly true of the gumbotil and till. The loess here includes a higher content of clay and colloids than is found farther west, and while more permeable than the till, does not absorb water fast enough to permit much absorption, except on the flatter slopes. Adams county soils materials are thus of more than average susceptibility to surface erosion.

A most important factor in soil loss by erosion is the degree of slope on which it occurs. For example, the Agronomy Department of Iowa State College[45] gives the opinion from their experience in erosion control that slopes up to 2 per cent in the Adams county soils

45 W. H. Pierre, Oral Communication, 1939.

need no protection; slopes from 2 to 9 per cent should be cultivated only with proper rotation and fertilization, and by such special treatment as contour plowing or strip cropping; slopes from 9 to 15 per cent require some such construction as terracing; and slopes greater than 15 per cent should be retired from cultivation; and put into permanent pasture or forest.

Examination of road profiles in Adams county shows that 61 per cent of the mileage examined has original ground slope greater than 2 per cent. Since the roads in many cases quarter or even run perpendicular to the direction of steepest slope, this means that something more than 61 per cent of the land in the county must have special handling of some kind to remain in cultivation without destruction of the soil by erosion. Few indeed are the farms in Adams county which do not have an erosion problem.

Soil erosion may take the form of surface or sheet wash, reducing the original soil thickness to as little as a few inches, or the more spectacular form of gullying. It is hard to say which form is more destructive, as sheet wash ruins the crop-producing ability of the land just as surely, if not as spectacularly, as gullying. Sheet wash commonly comes first, and if it is recognized in its early stages, preventive and reconstructive methods are much easier than with gullying.

Methods of erosion control include choice of crops and tillage methods, addition of lime or fertilizer, contour cultivation, strip cropping, terracing, and installation of temporary or permanent dams in gullies. These methods have only unimportant geological aspects and will not be discussed in this report. Readers interested in further information are referred to the 1938 yearbook of the United States Department of Agriculture, "Soils and Men," to the handbook "Soil Erosion in Iowa" published by the Iowa Agricultural Experiment Station, or to the several offices and camps of the United States Soil Conservation Service throughout the state. One such office is located at Greenfield, and the workers there are familiar with erosion control methods on soils similar to those of Adams county.

Water Supply

Adams county is notable for the almost complete absence of deep drilled wells. The usual farm well is dug by hand or bored with a large auger, and is located in a slough or small branch, or in the creek or river bottomland, if available. Such wells penetrate the upper alluvium, and if located in a small slough obtain a moderate supply of water from sandy beds not far above the underlying till. In the larger valleys, the sandy beds may yield water anywhere below the level of the nearby stream. In either case, the depth of the well is commonly between 15 and 30 feet. Only in a few places are sand beds sufficiently coarse or pervious to give satisfactory results with a driven point.

Shallow wells in the uplands find some water at the base of the loess in the flatter areas, or in sand and gravel pockets in or upon the tills on the slopes. Such supplies are commonly small and the average is not quite as reliable as the ordinary slough well. Depths up to 60 feet are common.

In many Iowa counties the base of the glacial drift is a reliable aquifer, and there are a few wells in Adams county, mostly in the high uplands of the southeast townships, which find such a supply. The depth is commonly around 200 feet, or locally less. Where the bedrock surface is higher, in the western part of the county, there seems to be ample relief on that surface to drain off any water-bearing bed of this type which may be present. The few drilled wells in the west part of the county get their supply from the Cretaceous or Pennsylvanian.

The Dakota sandstone of Cretaceous age is an excellent source of many public water supplies in western and northwestern Iowa. Attenuated and eroded remnants of this formation are present in the extreme western part of Adams county, but these are usually too high in elevation and too well drained to yield much water. A few exceptions may be made. The Septer well in SW 1/4 NW 1/4 section 10, Lincoln township, is reported to obtain a good supply of water from a thick bed of sand lying above the bedrock at elevation 1110 (160 feet depth), the sand probably representing the Dakota. Good springs issue from sand which may be Dakota at several points in the slopes in the southwest part of Douglas township, and these are used in part for domestic supply or for stock watering. There is believed to be a good chance of the Cretaceous being low enough to be water-bearing over much of the west part of Lincoln township and perhaps also locally in the northwest part of Douglas township.

Deeper drilled wells in and near Adams county have been singularly unsatisfactory. A recent test in SW 1/4 NW 1/4 section 25, Douglas township, reached the Pennsylvanian at 200 feet and continued to 336 feet without finding an adequate water supply. The deep test at Lenox was a failure as a source of water for public use. Other unsuccessful tests in the Pennsylvanian have been reported near Carl, east of Prescott, and at a few places in the west part of the county. An attempted well in SW 1/4 NW 1/4 section 18, Washington township, is reported to have penetrated 135 feet of glacial materials and 565 feet of rock, but no satisfactory water supply.

A few Pennsylvanian wells have been more successful. The Fees well in SW 1/4 SW 1/4 section 11, Washington township, penetrates 125 feet of clay with some gravel, and 33 feet of rock, and yields an ample supply of good quality. The Great Lakes Pipeline Company obtains for their booster station in NW 1/4 NW 1/4 section 15, Quincy township, (see figure 24) a satisfactory supply from

FIG. 24. — View of Great Lakes Pipeline Company Booster Station near Corning.

an 85-foot well penetrating 10 feet of rock. A few other wells, for which logs are not available, are of enough depth to penetrate the Pennsylvanian.

Both the Pennsylvanian and the Upper Mississippian in Adams county include sands and sandy beds which are thick enough and persistent enough to be good prospects for water supply. The lithologic nature of the beds is not such as to cause excessive mineralization. Should these sandstones fail to yield water, as at Lenox, there are still possibilities in the massive Mississippian limestones. It is believed that previous failures to obtain a yield from these horizons should not be allowed to obscure their possibilities over the area in general. The top of the Maple Mill shale is estimated to occur at elevations from minus 400 at the northeast to minus 700 at the southwest, corresponding to depths below the surface from 1550 to 1950 feet, and a test to that horizon may be expected to pass through several possible aquifers.

The only public water supply in the county is that used by the town of Corning. It consists of a reservoir of about 15 acres area impounding surface water behind a dam across a small branch about a mile northeast of the town. The drainage area is 290 acres and is not restricted as to cultivation or other use. A supply of this size was insufficient in 1934, and almost gave out in 1936, and plans have been proposed for a larger reservoir with 2200 acres of drainage area. The water, although palatable, is subject to all kinds of pollution, but is safe when chlorinated. It should be possible to set aside a watershed of 2 or 3 square miles area near Corning which could be closely restricted as to land use, thereby minimizing surface pollution and loss of capacity by silting as a result of erosion.

A natural supply which has had semi-public use is a spring at the base of the bluff east of Middle Nodaway River in SW 1/4 section 12, Douglas township. This was formerly a flowing spring, but the water level in late years has been lower, so that it is now a shallow well. It is reported that the supply has never failed. The source of the water is apparently in gravelly or sandy beds just above the Pennsylvanian surface to the east.

The Burlington Railroad has only one locomotive water supply in the county, at Corning. This is pumped from a small basin made by a low dam in East Nodaway River south of the depot, and stored in an elevated tank nearby. Stockyard supplies at Prescott, Brooks, and Nodaway, are from wells 25 to 34 feet deep in drift and alluvium.

Looking at future water supplies in general, it appears that private needs can best be served as at present, from shallow wells in the lowlands. Widespread erosion control should reduce runoff and increase percolation, thus making supplies of this type more dependable. Public needs will have to be met largely by surface water, but there is a possibility of obtaining satisfactory supplies from wells up to 1500 or 2000 feet deep. If surface water is used, the reservoir must be of ample size and the catchment area should be proportionately large and also restricted as to land use to protect the quality of the water. Considering the cost of a deep well and the possibility of failure, and the certainty of supply from an adequate surface reservoir, the surface water alternative may be preferable.

Road and Concrete Materials

With respect to supplies of road or concrete materials, Adams is one of the more barren counties of southern Iowa. Exposed rock includes the thin limestones of the Virgil series along East and Middle Nodaway Rivers in the western half of the county, and the Dakota sandstone at a few points in Lincoln and Douglas townships. The eroded slopes of Nebraskan and Kansan till show the usual outcroppings of gravelly beds, and a number of prospects have been investigated; these have shown little or no available material.

Limestone

The Deer Creek limestone is naturally exposed only in the banks of East Nodaway River near Corning, but it extends out from the bluffs and underlies extensive areas of bottomland nearby. The section at the Adams County Limestone Company quarry indicates its character. Higher Pennsylvanian beds given in that section are commonly absent in this area, the overburden consisting of 10 to 15 feet of alluvial silt with sand layers, or at the foot of the upland slopes, 10 feet or more of glacial till. Quarries have been or are being worked in SE 1/4 NE 1/4 section 3, SE 1/4 SW 1/4 section 3, SE 1/4 NW 1/4 section 3, and SW 1/4 NW 1/4 section 2, all of Jasper township. Quarry areas at these places are limited in extent by increasing overburden on the land side and eroded areas refilled with silt on the river side. Most of the available rock at the locations mentioned has been removed, but systematic prospecting in the lowlands in sections 3 and 2, or perhaps a mile or so farther up or down stream, should reveal others. The rock will be found to lie partly or entirely below water level, and quarrying will be the more difficult on that account. The whole thickness of ledge is probably usable for road surfacing work, and some of the upper layers may make satisfactory concrete aggregate.

The interval above the Deer Creek as far as the Nodaway coal includes a number of limestones, which in counties farther west are thick enough to support quarry operations covering the whole interval. A similar operation would be of great interest in connection with coal stripping possibilities in the lowlands in the west part of Adams county; it is feared however that those limestones are here too thin and of too poor quality to warrant such a development. The same difficulty arises in quarrying any of the Topeka limestones where they crop out in Washington and Jasper townships, with the hope of extending the operation to enough depth to include the Deer Creek. The Topeka limestones individually are considered to be too thin to be worth developing, except for very small quantities of stone for private use.

Limestones above the Nodaway coal are likewise too thin to be worth quarrying except on a small scale for private use.

Shale

Where the Nodaway coal is mined in the west part of the county there are dumps of waste shale or clay which in some cases have included enough coal to burn them more or less thoroughly. Such

FIG. 25. — Shale dump and headworks at Linker and Landrus mine.

burned shale in other counties where dumps are large is a valuable source of low-cost road surfacing material. In Adams county the mines are not so large and much of the waste is left underground, so that such dumps are small and unimportant. These smaller dumps commonly do not reach such a high temperature in burning, and the quality of the burned material is correspondingly lower. One of the larger dumps is at the Linker and Landrus mine in NE 1/4 NE 1/4 section 32, Douglas township, shown in figure 25. This dump contains possibly 1000 cubic yards.

Sand and Gravel

Adams county, being less dissected by stream action than are others in that part of the state, has fewer exposures of sand or gravel associated with glacial drift. All known prospects, some thirty in number, have been investigated by the State Highway Commission, and none found to have available more than 1000 cubic yards of material. Locations of the more important of these are shown on the sketch map, figure 22. It is probable that other small pockets of sand or gravel will be found, and not impossible that one or more of large size are present. Information now available indicates little likelihood of the latter possibility.

Where the Dakota sandstone appears in the west part of the county, it offers limited quantities of sand ranging in particle size from coarse to the very finest. Partial cementation of this material makes its recovery somewhat difficult. The best exposures now known are in SW 1/4 SW 1/4 section 32, Douglas township, and NW 1/4 SE 1/4 section 5, Lincoln township.

Alluvial materials consist almost entirely of silt or very fine sand. Soundings by the State Highway Commission for bridge foundations on East and Middle Nodaway rivers indicate the presence of sand or fine gravel in the deeper alluvium, but such materials have not thus far been found available under moderate overburden.

Riprap and Masonry Stone

Some of the better layers in the upper part of the Deer Creek limestone are suitable for riprap, or if properly dressed, for masonry. The county jail at Corning is built from this material, and the walls are still in good condition after more than sixty years. Some portions of the Coal Creek limestone, and the lower layer of the Burlingame are also suitable for these purposes. Stone from any of these horizons lies under extremely heavy overburden and is thus very difficult and expensive to recover, and it does not seem probable that it will have any widespread use. So far as is now known, the Dakota sandstone is not well enough indurated to serve for such purposes.

Agricultural Lime

Use of ground limestone as a soil amendment has an important part in the soil conservation program so greatly needed in Adams county. It may indeed be said that such sources of agricultural lime as are present in the county should be conserved for that purpose, rather than used as surfacing material spread upon the roads, valuable as that use undoubtedly is. The section on limestone in the foregoing discussion of road and concrete materials gives the occurrence of limes which might be quarried for agricultural use. Some ledges, as for instance those in the upper part of the Deer Creek, are of purity comparable to that of the best in the state (90 to 95 per cent), and have already had limited use near Corning. Others, in the lower part of the Deer Creek, the Coal Creek, and the lower Burlingame, include shaly or sandy material reducing purities to figures between 80 and 90 per cent. The shales associated with or lying above the Nodaway coal in the west part of the county are non-calcareous, and of little value for this purpose.

Limestone Mining

It may be worthwhile at this point to call attention to the possibility of mining for limestone to be used either in road work or for agricultural lime. Shaft mining is unquestionably expensive, but it is already in operation on a commercial scale at depths of about 100 feet at Douds and Fort Dodge, Iowa, and exhaustion of surface supplies may force its adoption in southwestern Iowa before very many more years. The Deer Creek could be thus obtained in the west part of the county at depths as little as 75 feet. Lower ledges of greater thickness can be found at greater depth in the east part of the county. The Oread at New Market is 70 feet thick and includes two beds of 12 to 15 feet thickness which are chiefly limestone. Its top lies in the east half of Adams county at about elevation 1000, or 200 to 300 feet below the surface. A deeper horizon, but probably of better quality, is the Winterset limestone, recognized at Lenox and expected to be present in 20 to 25 feet thickness at about 500 feet depth in the lower lands in eastern Adams county. Prospecting may show some available stone at the Stanton, Plattsburg, or Wyandotte horizons or perhaps at some other horizon between the Oread and the Winterset.

Petroleum

At a time like the present, when oil geologists are actively engaged in structural mapping in southwestern Iowa, it seems unwise to venture much prediction as to oil possibilities in Adams county. The main features of the Pennsylvanian in the west half of the county are explained in an earlier section of this report. Little or nothing is known of the character of older beds here, or of any of the beds in the east part of the county, except by deduction. A few comments may be made.

If oil is to be found, it must have been derived from some deep-seated formations, migrating thence through porous beds to some point where it is trapped and may be recovered by drilling. Too little is known of the character of the deeper formations of Adams county to say whether or not oil may have been derived from them. Porous beds suitable for reservoir rocks are present at several horizons at Clarinda, Lenox, and Greenfield, and this condition is probably fulfilled in Adams county as well. Assuming that circumstances have at one time favored oil formation and migration, the next requirement is a suitable structural or stratigraphic condition to trap the oil. Such a condition may be in the bed from which the oil was first derived or in some other bed, and, since oil may originate in rocks as old as the Cambrian, the condition may be looked for anywhere in or above the Cambrian section.

The age of the deformations now observed in the Pennsylvanian of western Adams county is almost certainly post-Pennsylvanian, but there is every reason to believe that older beds were affected by those same movements. Disturbances of this kind originate at points deep in the earth's crust, and deeper beds are the most profoundly affected. Thus, the deformation which produced the terrace and monocline structure in the Pennsylvanian of western Adams county may be expressed in the deeper beds as a series of unsymmetrical anticlines of which the west flank is the higher. It is probable that the steep southward dip along the north edge of Lincoln township is the south flank of such an unsymmetrical anticline, here expressed in beds as high as the Pennsylvanian, and perhaps more pronounced in deeper strata.

None of the foregoing arguments for the presence of anticlines proves that these include domes with sufficient closure to permit accumulation of commercial quantities of oil. Such may, of course, be present, especially in the deeper beds.

Changes in dip, such as are implied by terrace and monocline structure, may, even without closure, trap oil which can move through beds of limited permeability only if inclined to a certain degree of slope; such oil may be arrested at or near places where that critical slope is not attained. If sediments are deposited on a surface made irregular by previous erosion, those coarser and with higher porosity will tend to accumulate in areas of greater steepness, grading to those finer and more impervious in the flatter areas; such variation in porosity in a single bed may trap oil. Porous beds deposited on an irregular surface may also pinch out or be overlapped by impervious strata, and thus hold any oil which reaches them. All these possibilities are included under the general term of "stratigraphic trap," as contrasted with the structural trap or dome caused by deformation. Commercial production of oil from stratigraphic traps is rather rare.

Summing up all these points, it is admitted that there is little or no evidence, either positive or negative, on the possibility of finding commercial quantities of oil in Adams county. Probably the best statement that can be made at this time is that drilling on carefully selected (from stratigraphic and structural studies) locations will be necessary to indicate what that possibility is.

APPENDIX A

Driller's Log of New Market Core Drilling

Coal prospect hole by the H. R. Ameling Prospecting Company for the New Market Coal Company in section 33-69-35, Taylor county, Iowa, elevation unknown.

Formation	Thickness	Depth
Top soil	4′	4′
Sand	16′	20′
Gumbo-Boulders	40′	60′
Gumbo-Boulders	41′	101′
Gravel	2′	103′
Limestone	12′ 10″	115′ 10″
Fire clay	0′ 9″	116′ 7″
Coal	1′ 9″	118′ 4″
Fire clay	1′ 8″	120′
Fire clay	10′	130′

Formation	Thickness	Depth
Limestone	6′	136′
Black shale	4′	140′
Gray shale	3′	143′
Limestone	1′	144′
Green shale	2′	146′
Blue shale	8′	154′
Sandy shale	3′	157′
Blue Shale	5′	162′
Coal	0′ 3″	162′ 3″
Sand-limestone	21′ 9″	184′
Black shale	8′	192′
Soft shale	6′ 6″	198′ 6″
Blue shale	3′ 6″	202′
Limestone-partings	27′	229′
Blue shale	5′	234′
Limestone-shale	2′	236′
Blue shale	10′	246′
Soft blue shale	5′	251′
Limestone	4′	255′
Shale-limestone	21′	276′
Gray shale	9′	285′
Limestone-shale	4′	289′
Limestone-gravel	11′	300′
Sand	5′	305′
Black shale	4′	309′
Green shale	19′	328′
Limestone-shale	6′	334′
Red shale	16′	350′
Green shale-soft	10′	360′
Dark Gray shale	2′	362′
Green shale-lime	2′	364′
Blue shale	36′	400′
Blue shale	41′	441′
Decomposed lime	1′	442′
Black shale	2′	444′
Blue shale	15′	459′
Blue shale-lime	8′	467′
Green shale-lime	5′	472′
Shale-lime-soft	11′	483′
Gray limestone	11′	494′
Dark shale	4′	498′
Lime-shale	7′	505′
Red shale	3′	508′
Blue shale	13′	521′
Lime-shale	2′	523′
Soft blue shale	11′	534′
Blue shale	2′	536′
Red shale	3′	539′
Shale and limestone	20′	559′
Shale-lime	8′	567′
Limestone	3′	570′
Gray lime	10′	580′
Dark lime	2′	582′
Blue shale	6′	588′
Black shale	1′	589′
Shale-lime	2′	591′
Blue shale	6′	597′
Light gray lime	4′	601′
Lime-shale	22′	623′
Dark shale	10′	633′

Formation	Thickness	Depth
Shale-lime	13′	646′
Limestone	19′	665′
Dark shale	5′	670′
Soft shale	5′	675′
Decomposed S. & L.	2′	677′
Limestone	25′	702′
Shale-lime	8′	710′
Lime-flint	3′	713′
Limestone	4′	717′
Soft shale	1′	718′
Lime-flint	3′	721′
Loose flint	1′ 2″	722′ 2″
Soft shale-lime	0′ 9″	722′ 11″
Soft lime	1′ 7″	724′ 6″
Gray limestone	5′ 6″	730′
Black shale	3′	733′
Soft shale	2′	735′
Coal	0′ 2″	735′ 2″
Soft shale	3′ 10″	739′
Decomposed lime	8′	747′
Green shale	6′	753′
Light gray limestone	4′	757′
Black shale	1′	758′
Soft red shale	11′	769′
Blue shale	6′	775′
Light gray lime	9′	784′
Lime-gravel	2′	786′
Sand-shale	30′	816′
Soft sand	6′	822′
Blue shale	7′	829′
Soft shale	3′	832′
Dark shale	1′	833′
Lime-shale	5′	838′
Lime-shale very soft	10′	848′ (bottomed)

Driller's Log of Farm Well Near Villisca

Drilled by the Thorpe Well Company for the Equitable Life Insurance Company in NE 1/4 NE 1/4 section 14-70-36, approximate elevation 1270.

Formation	Thickness	Depth
Yellow sand clay	70′	70′
Sand sea mud	6′	76′
Blue clay hard gummy	49′	125′
Sand and sea mud	40′	165′
Yellow sand	5′	170′
Sea mud	30′	200′
Gray shale	12′	212′
Dark shale, hard bands	28′	240′
Gray shale	12′	252′
Coal and slate, dark shale	33′	285′
Limestone gray hard	14′	299′
Dark gray shale	3′	302′
Limestone, hard	3′	305′
Gray shale	2′	307′
Limestone, hard	6′	313′

Formation	Thickness	Depth
Gray shale	2′	315′
Limestone	12′	327′
Gray shale	8′	335′
Limerock	15′	350′
Gray shale	7′	357′
Limerock	8′	365′
Dark shale	8′	373′
Limerock, soft	7′	380′
Gray shale	2′	382′
Limestone?	13′	395′
Brown limestone	30′	425′
Dark shale, gummy	10′	435′
Brown limestone	5′	440′

APPENDIX B

Comments on Tests

These tests are run in the Ames Laboratory of the Highway Commission, on samples selected to represent the general character of the various materials. Mechanical analysis is determined by screening down to the 0.053 millimeter size, and from rate of settlement in a suspension for the smaller sizes. Particle sizes above 1.981 millimeter are known as gravel, above 0.053 millimeter as sand, above 0.005 millimeter as silt, above 0.001 millimeter as clay, and below 0.001 millimeter as colloids. Lower plastic limit is the percentage moisture content at which the material assumes plastic instead of elastic properties. Lower liquid limit is the percentage moisture content at which the material passes from the plastic to the liquid state. The range between the two is the plasticity index, which may thus be considered a measure of the water-holding properties. A rather close correlation between colloidal content and plasticity index will be noted.

The first two samples are for the most part similar to those of Peorian loess following. The second shows the increase in colloidal content and in plasticity as a result of weathering in the very flat areas where surface drainage is poor and percolation correspondingly greater.

The first four samples of Peorian loess are from Adams county, and show much the same characteristics, with perhaps slightly greater colloid content and plasticity to the east. The almost complete absence of sand is typical. The fifth sample is from a location near Portsmouth in the west part of Shelby county, and the sixth near Little Sioux, in the northwest part of Harrison county. This last is taken from the bluff fronting the Missouri river bottomland, while the Shelby county sample is about 20 miles inland. Comparison of clay

Physical Tests on Adams County Soil Materials by Iowa State Highway Commission

Laboratory Number AAD-	Source of Sample: Section		Source of Sample: Township	Material Represented	Mechanical Analyses — Percent Particles smaller than 1.981mm	0.417mm	0.147mm	0.053mm	0.005mm	0.001mm	Lower Liquid Limit	Lower Plastic Limit	Plasticity Index
9-281	NW¼SW¼	29	Grant	Soil from loess	100	100	99	99	35	20	48	26	22
9-283	NW¼SW¼	29	Grant	Modified loess	100	100	100	100	39	24	53	20	33
8-3192	SW¼NW¼	25	Grant	Peorian loess	100	100	100	99	38	22	48	22	26
8-3187	SW¼NW¼	25	Carl	Peorian loess	100	100	100	99	40	21	52	22	30
8-3198	NW¼NW¼	22	Lincoln	Peorian loess	100	100	100	100	36	18	45	22	23
8-3195	SW¼SW¼	19	Nodaway	Peorian loess	100	100	100	99	34	22	44	22	22
7-1453	NE¼NW¼	20	79-40	Peorian loess	100	100	99	98	28	13	43	23	20
8-1577	NW¼SW¼	8	81-44	Peorian loess	100	100	100	97	13	6	30	24	6
9-316	SE¼SE¼	32	Douglas	Loveland loess	100	100	100	99	30	19	41	20	21
8-3193	SW¼NW¼	25	Grant	Loveland silt	100	98	86	78	29	13	27	15	12
8-3189	SW¼NW¼	25	Carl	Kansan gumbotil	100	100	99	98	53	31	63	23	40
8-3190	SE¼NE¼	35	Carl	Leached Kansan till	97	95	78	66	37	18	39	15	24
8-3196	SW¼SW¼	19	Nodaway	Leached Kansan till	99	96	82	73	39	23	43	18	25
8-3191	SE¼NE¼	35	Carl	Unleached Kansan till	97	94	77	65	34	20	35	15	20
9-290	NW¼SW¼	29	Grant	Unleached Kansan till	98	94	79	70	39	23	46	16	30
8-3197	SW¼NE¼	5	Nodaway	Nebraskan gumbotil	100	100	99	97	53	26	66	24	42

and colloid content between these two and the Adams county samples lyng from 45 to 65 miles inland, shows a marked absence of fines at Missouri River, with a proportionate increase greater in the first 20 miles than in the next 25 to 45 miles. The absence of sand, even at Missouri River, is noted. Earlier investigators, without means for carrying mechanical analysis to particle sizes smaller than those which can be screened, have reported the loess to be uniformly fine from Missouri River eastward, but the present analyses show its relative coarseness to the west.

The loess sample from section 19, Nodaway township, is on the rather narrow ridge separating the valleys of East and Middle Nodaway rivers. Its close agreement in particle sizes with other Adams county loesses is evidence of the minor part played by these smaller valleys as sources of loess.

Both loess and silt phases of the Loveland are shown. The silt is unique among Adams county materials, having too much fine sand to be a loess, and too little colloidal material to be a till or gumbotil. This is evidently an alluvial sandy silt.

Both gumbotil samples are characterized by almost complete absence of sand, and extremely high colloid content and plasticity index. This is typical of gumbotils from other counties.

The tills show small amounts of gravel and a larger proportion of sand. At the same time, colloid contents are as high as those of the loess which contains almost no sand. In other words, when the sand is removed from till, the residue is much finer than even the clayey loess of Adams county. Some till samples show as much as 50 per cent sand and gravel, but the figures given in the table are more typical of southwestern Iowa. No significant difference between leached and unleached tills is noted.

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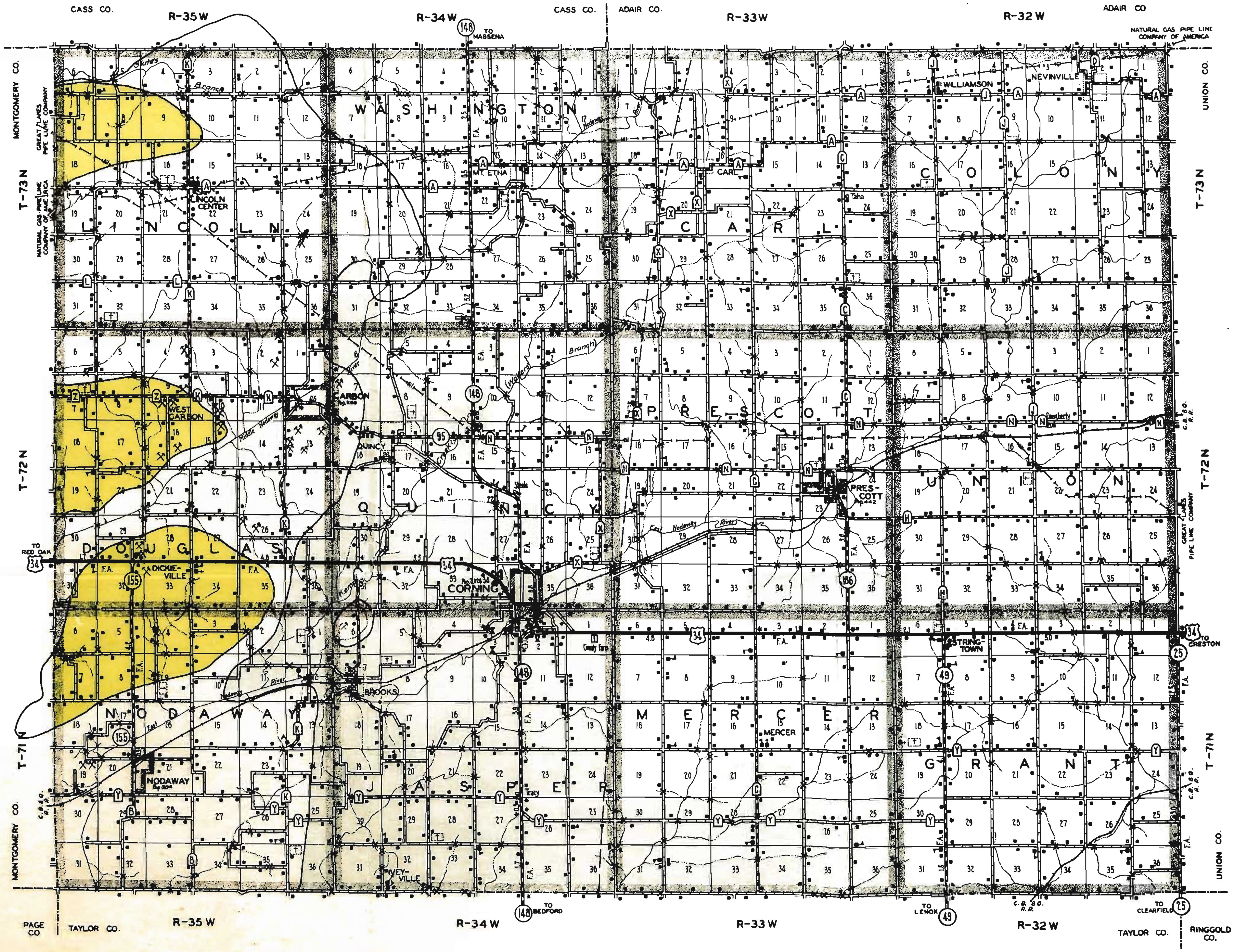

IOWA GEOLOGICAL SURVEY

Geological Map of ADAMS COUNTY IOWA

By L. W. WOOD

Scale: ½ Inch 1 Mile

1941

LEGEND

Cretaceous
Dakota

Pennsylvanian
Virgil
Wabaunsee
Shawnee

Approximate eastern edge of Deer Creek limestone

Coal Mine

Quarry

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