IOWA GEOLOGICAL SURVEY

Volume XXXVII

Annual Reports, 1934, 1935, 1936, 1937, 1938, and 1939

with

Accompanying Papers

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IOWA GEOLOGICAL SURVEY
IOWA CITY, IOWA, DECEMBER 31, 1939

To Governor George A. Wilson and Members of the Geological Board:

GENTLEMEN:

Since the inception of the present Iowa Geological Survey in 1892 there have been but four directors and state geologists. With the exception of two years, 1904-1906, when Frank Wilder served, Professor Samuel Calvin by whom the Survey was founded directed the program from 1892 to 1911. Upon the death of Professor Calvin in April, 1911, Dr. George F. Kay became director and state geologist. In 1917, Dr. Kay accepted the Deanship of the College of Liberal Arts at the University. In 1934, desiring to devote more time to University administrative duties, he resigned as director and state geologist and upon his recommendation the Geological Board as then constituted appointed the undersigned in these positions. At the same time Dr. A. C. Tester was appointed assistant state geologist, to replace Dr. James H. Lees, retired, who had been assistant state geologist since 1906. The Geological Board accepted Dr. Tester's resignation in 1937 and appointed Dr. H. G. Hershey as assistant state geologist in 1939.

In 1933 the funds of the Survey were reduced, necessitating curtailment of staff, program and publications. The drouths of 1934 and 1936, the new demand for wells for air conditioning purposes, need for restudy of the limestones and shales of the state in a search for raw materials for the manufacture of rock wool insulation, and in 1938 a feverish new interest in the possibility of discovering oil and gas in Iowa so increased the duties of the officers and staff that until now the forty-third to forty-eighth administrative reports and accompanying papers have not been prepared for publication.

The following report for the years 1934 to 1939 and accompanying papers are submitted with the recommendation that they be published as Volume XXXVII.

During the years covered by this report and on this date, the main services rendered have been and are as follows:

Well Water

Although it is not possible to figure the value of water from wells in dollars and cents, it constitutes by far the most valuable geological resource in Iowa. Used for human consumption, watering livestock, air conditioning, and for various industrial purposes, it touches many phases of state and community life. More than half of the total budget and program of this Survey are devoted to studies and services related to water wells.

Cities, towns, schools, industrial plants, farmers, drillers, and other state departments ask for help in making locations for wells, for forecasts of the depths necessary to obtain a large enough quantity of water of the proper quality to meet their needs in given wells and of the rock formations to be drilled through, and for pumping tests and final checking before the wells are finally accepted and put into use. From 50 to 75 wells, projected or drilling, are continually being so serviced. Much of this work is done in cooperation with the State Department of Health. This work is based on the study of about 50,000 rock samples and more than 1,700 water analyses from more than 1,000 wells previously drilled, logged, and sampled. Taken over by Dr. A. C. Tester from Professor W. H. Norton who retired in 1933, this work is now done by Dr. H. G. Hershey assisted by W. C. Schuldt and M. M. Elias and several graduate students working part-time.

Through cooperative agreement and the matching of funds the work mentioned above has been supplemented since 1938 by the assignment to Iowa of T. W. Robinson, Associate Ground Water Engineer of the U. S. Geological Survey. This new work consists of state-wide studies of fluctuations in ground-water levels and their relation to periods of drouth and abundant rainfall, varying land use practice, heavy and light pumping, etc. More than 80 "observation wells" are now supplying water level records and this number will be increased. It is important that it be discovered whether water is being taken from underground faster than nature restores it, especially in some of our cities where more and more water is being used.

Knowledge of the permanency of the water supply is essential to the construction or expansion of any water supply system for any purpose.

Stream and Lake Gaging

Surface water in Iowa streams and lakes is also a valuable asset, although its monetary value cannot be determined. The use and conservation of this water involves certain problems. There is great need for continuous, long-time records of stream discharges during both low water stages and floods. The records are needed in designing bridges, dams, power plants, water supply systems, sewage disposal plants, etc.; and in planning for flood control, recreation lakes and prevention of soil erosion and the consequent silting of natural and artificial lakes, ditches and flood plains.

During the years covered by this report, the Iowa Geological Survey has been active, along with other interested state departments, in the promotion of a cooperative program of stream and lake gaging. Throughout the country, such work has for many years been done by the Surface Water Division of the Water Resources Branch of the U. S. Geological Survey in cooperation with the states. Until July 1, 1939, state funds for this purpose were contributed, in different amounts in different years, by several of the state departments including the Geological Survey and by the ad interim legislative Committee on Retrenchment and Reform. The 48th General Assembly made a direct appropriation of $4,500 a year to the Geological Survey in order that this program might be continued and put on a more permanent and less uncertain basis. Since 1932 the work has been directed by R. G. Kasel, District Engineer of the U. S. Geological Survey, stationed at Iowa City.

At the close of 1933 there were 28 gaging stations on Iowa streams and 4 on Iowa lakes; at the end of 1939, these numbers had been increased to 64 and 10 respectively. Stage readings are made at each station at least daily and some of the stations are equipped with automatic, continuous recorders. Discharge records are made for each station about once a month.

Oil and Gas

In spite of the drilling of numerous water wells, some of which have penetrated all possible oil and gas producing horizons all over the state and the drilling of a number of special oil and gas tests, Iowa has not so far produced oil or gas in commercial quantities. In 1920, the Iowa Geological Survey published a report entitled "Petroleum and Natural Gas in Iowa" in which the opinion was expressed that although no portion of the state could be considered as really promising "wild cat" territory, about twenty counties in south central and southwestern Iowa were more favorable than the remainder of the state. Later it was recognized that these same counties occupy a portion of the Forest City basin which extends northward into Iowa from northeastern Kansas, southeastern Nebraska and northwestern Missouri. Recently, large quantities of oil have been discovered and produced from an area in south central Illinois known as the Illinois basin. There is enough similarity in the geological conditions of the Illinois and Forest City basins to have created the present interest of oil companies in the Forest City basin. In 1938 and 1939 there was an active leasing campaign not only in the Iowa portion of the Forest City basin but outside of this basin to the north and east. A number of tests have been planned and three are now being drilled.

The policy of the Iowa Geological Survey in regard to the search for oil and gas in this state has always been conservative. The financial risks in any wild cat area are great. It does not seem wise to raise false hopes and to overencourage or overstimulate expensive preliminary surveys and drilling campaigns, especially on the part of local, inexperienced, and under-financed groups. On the other hand this basin should and will be tested. Our policy still is to be conservative, but to be as helpful as possible to all companies, groups and individuals, both inside and outside of Iowa, who really try to bring in oil in the state. Purely promotional schemes are discouraged, but even these are given advice and help once they are under way.

In harmony with this policy the Geological Survey has gladly made available published and unpublished geological data on which the more promising areas can be located, the probable maximum drilling depth in each location can be determined, the thicknesses, depths and characters of possible producing formations can be forecast, "key beds" for core drilling can be selected, etc. Hundreds of requests for reports, maps, sections, logs and samples have been filled. There is also much correspondence and conference in which direct opinions, advice and help are called for and given.

The geological sections of Senate File 328 enacted by the 48th

General Assembly are being administered by the Geological Survey, according to law. The Act which is designed to safeguard the state's interests without putting severe restrictions of any sort upon the oil companies or obligating the Survey seriously, appears to be serving the purposes for which it was intended.

It may be a year or several years before Iowa will be either proven to be commercially productive or can safely be condemned as a non-producing state.

Coal

The Iowa coal industry is not healthy. This is due partly at least to new competition from oil, gas and hydroelectric power. The problems with which the industry is faced, which are applicable to other states as well as to Iowa, are difficult of solution. Although many of these problems are not geological, the Survey does what it can to improve the coal industry in this state.

In 1936 the Geological Survey published Technical Paper No. 3, Iowa Coal Studies, in which H. L. Olin, University Professor in charge of Iowa Coal Utilization Research and some of his graduate students demonstrated that Iowa coal, if well prepared and properly burned, is not inferior to competing out-of-state coals in b.t.u. content, ash and smoke content, storage qualities, and coking properties.

Beginning in 1932 and continuing through the whole period covered by this report, geological field and laboratory work on the coal beds of the state and the associated clays, shales, sandstones and limestones has been pushed. The coal-bearing formations are being mapped. This work is not only valuable from the standpoint of coal, but its results are extremely useful in the search for oil. This project has been carried on by Professor A. C. Tester, Professor L. M. Cline of the Iowa State College, and a number of graduate students at the University, including M. L. Thompson, D. W. Stookey and E. H. Wenberg. Much progress has been made but the work will be continued for at least a year or two.

The Director of the Survey, Professor Olin and Professor Cline, were members of the Iowa Coal Committee appointed in 1938 by the Iowa State Planning Board at the request of the Governor, the Greater Iowa Commission and the Iowa Coal Institute and participated in the preparation of "Some Aspects of the Iowa Coal Industry," Iowa State Planning Board, 1939.

The history of coal production in Iowa since 1895, and especially since 1932, is tabulated in papers by H. G. Hershey that appear on pages 375 to 474 of this volume.

New Geologic Map of Iowa

The most important and useful basis for geological investigations and services of all sorts in any area is the geologic map. Such a map of Iowa by T. E. Savage published in 1905 has long since been out of date and for some years out of print. The most difficult and important task of this Survey administration has been the preparation and publication (1937) of the "Geologic Map of Iowa Showing Distribution of Outcrops of the Indurated Rocks" by Allen C. Tester.

This map on a scale of about 8 miles to 1 inch is lithographed in 7 colors and 26 patterns. It shows the rock formations exposed or immediately underlying the glacial, alluvial and other mantle rock deposits.

Picturing as it does the several sequences, systems, series, groups and formations of rocks in the state and their relation one to another, this map is almost indispensible not only for all the work of the Survey but to all others, inside and outside the state, who are interested in the geology and actual or potential mineral and rock resources of Iowa.

Glacial Studies

Iowa has long been a classic area for the recognition and interpretation of glacial and interglacial deposits. Prior to his death in 1911, Professor Calvin had contributed notably in this field. For 25 years, Dean Kay with the assistance of his graduate students, has been carrying the work forward and is now recognized as a world authority on the Pleistocene or Glacial period. An exhaustive treatise on glacial and interglacial gravels of Iowa by G. F. Kay and P. T. Miller is published in this volume.

The Thirty-seventh Annual Report of the State Geologist, Volume XXXIV, published in 1929, contained as the main paper of the volume, Part I of a monograph on the Pleistocene Geology of Iowa, entitled "The Pre-Illinoian Pleistocene Geology of Iowa," by G. F. Kay and E. T. Apfel. Part II to be entitled "The Illinoian and Post-Illinoian Geology of Iowa" is nearing completion and should be ready for publication in 2 or 3 years.

It should not be understood that this work has no great practical value. On the contrary it is necessary to an understanding of the many wells producing water from the drift, to the discovery and development of valuable deposits of sand and gravel, and to the classification and mapping of Iowa soils. In these studies also is found the explanation of the predominantly different topographies in different parts of Iowa and corresponding differences in problems of soil erosion, flood control, recreation, etc.

County Reports

By the close of 1933, all but 7 of the 99 Iowa counties had been surveyed and reports and maps on the geology and mineral resources of each of the 92 counties had been published in volumes of the Annual Reports. Prior to his death in 1935, Dr. James H. Lees had spent considerable time in Adams county, but had not completed the field work or written up the results for publication. This report has now been completed by L. W. Wood of the Iowa State Highway Commission and is published in this volume. In 1938 Audubon county was surveyed by W. H. Yoho, Floyd county by P. H. Nelson, Greene county by W. B. Tapper and Union county by J. H. Russell. These were graduate students who used the results of the surveys as theses at the University. These four county reports await revision, editing and publication.

Only two counties, Calhoun and Shelby, remain unsurveyed.

Rock Wool

Since 1935 when important interest in the manufacturing of rock wool for insulating purposes first appeared, the Geological Survey has been searching for suitable raw materials in this state. The work is done on a state-wide basis and is not yet complete. Special reports have been prepared for the areas around Dubuque, Clinton, Cedar Rapids, Des Moines, Sioux City, Burlington, Missouri Valley, and Council Bluffs, these being the most favorable places found so far, and for the territory served by each of five of the main Iowa railroads. One plant has already been located and is in operation at Dubuque. Several others should be located in Iowa.

Agricultural Lime

There is a large and growing need in Iowa for limestone of sufficient purity to be crushed and used as agricultural lime. Although

Iowa limestones have been studied and mapped in the past, there has been no special survey made by counties, geological formations or otherwise, with this special product in mind. There is known to be an abundance of suitable limestone in many portions of the state.

In connection with the operation of the "liming law" passed by the 47th General Assembly as House File 147, there is need for special geological information concerning outcrops of limestone, its lime content, the thickness of overburden at operating or prospective quarries, etc. County Boards need such data if they are to operate their own quarries and contractors need them in making bids on agricultural limestone for sale to the counties and resale to cooperating farmers.

Current service in this field by the Geological Survey has not been extensive; more of it should be given in the future. In cooperation with the State Planning Board, Appanoose, Clarke, Decatur, Lucas, Monroe and Wayne counties were surveyed for agricultural lime by J. H. Russell and the results were published under the title, "Agricultural Limestone Deposits in the Chariton Basin Counties in Iowa." Outcrops of limestone were located and sampled, samples were analyzed for lime content at the Agricultural Experiment Station at the Iowa State College, the amount of overburden was estimated, and sites were condemned or recommended. Such work as this should be done on a state-wide basis.

Mineral Production

Cooperation with the U. S. Bureau of Mines and the National Bituminous Coal Commission in the assembly of annual mineral production statistics has been continued. Figures for cement, clay and clay products, coal, gypsum, limestone, and sand and gravel for the years 1933-38, inclusive, are published in this volume, and also a general summary of mineral production in Iowa from 1895 to 1938, both by H. G. Hershey.

Respectfully submitted,

ARTHUR C. TROWBRIDGE,
Director and State Geologist

THE PLEISTOCENE GRAVELS OF IOWA

by

GEORGE F. KAY AND PAUL T. MILLER

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THE PLEISTOCENE GRAVELS OF IOWA

INTRODUCTION

The State of Iowa is located near the middle of the North American continent. It is in the upper Mississippi Valley, its east boundary being the Mississippi river, its west boundary the Missouri river. Iowa's greatest length, east and west, is about 335 miles, its width 208 miles. Fenneman [1] includes this state within the Central Lowland physiographic province.

Although considerable information about the Pleistocene gravels of Iowa is available in published reports, chiefly in the many county reports of the Iowa Geological Survey, it has been recognized for some time that a comprehensive report on the gravels of the state, based upon extensive field and laboratory studies, would be of distinct value not only to the citizens of Iowa but to all persons interested in the scientific and economic aspects of gravels of glacial and of interglacial ages. This paper has been prepared to meet this need.

The distributions, characteristics, relationships, origins, and ages of the gravels of the state have been determined in the light of our most recent investigations and interpretations of the Pleistocene deposits of Iowa, the area in which the records of the Pleistocene glacial and interglacial ages have been preserved more satisfactorily for study than in any other known area.

During the past twenty-five years the senior author has been interested in the study of the glacial deposits of the state in all their aspects. The junior author has assisted in the field studies and has had charge of investigations in the sedimentation laboratory. In the field, hundreds of exposures of gravel and associated materials were studied in detail, and from many of these exposures samples were collected and studied later in the laboratory.

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1 Fenneman, Nevin M., Physiography of Western United States, McGraw Hill Book Co., Plate I, 1931.

THE CLASSIFICATION AND SIGNIFICANT FEATURES OF THE PLEISTOCENE DEPOSITS OF IOWA

Kay's Recent Classification of the Pleistocene

A fairly comprehensive history, accompanied by references, of the investigations and classifications of the Pleistocene deposits of Iowa up to the year 1929 is available.[2] Since then the senior author [2a] has proposed some distinct revisions of previous classifications. His most recent classification for Iowa is as follows:

Period (System)	Epoch (Series)	Age (Stage)	Substage
		Recent	
	Eldoran	Wisconsin	Mankato Peorian Iowan
Pleistocene or Glacial	Centralian	Sangamon Illinoian	
	Ottumwan	Yarmouth Kansan	
	Grandian	Aftonian Nebraskan	

In this classification the Pleistocene is given the rank of period (system), and the period (system) is divided into four epochs (series), each of which is further subdivided into ages (stages). In figure 1 an attempt has been made by means of diagrammatic sections of glacial and interglacial materials to represent the present-day interpretations of the relationships of the Pleistocene materials of the different stages in Iowa.

Nebraskan Drift and Related Materials

The oldest of the epochs (series), the Grandian, began with the advance of the Nebraskan ice sheet and ended with the oncoming of the Kansan ice sheet. It includes the Nebraskan glacial age (stage) and the Aftonian interglacial age (stage).

In Iowa and border districts, the first ice sheet, the Nebraskan, came from the Keewatin center and covered a large area in the Mis-

2 Kay, G. F., History of Investigations and Classifications of the Pleistocene Deposits of Iowa: Iowa Geol. Survey, Vol. XXXIV, pp. 70-133, 1929.

2a Kay, G. F., Classification and Duration of the Pleistocene Period: Bull. Geol. Soc. of America, Vol. 42, pp. 425-466, 1931.

Kay, G. F., and Leighton, Morris M., Eldoran Epoch of the Pleistocene Period: Bull. Geol. Soc. of America, Vol. 44, pp. 669-674, 1933.

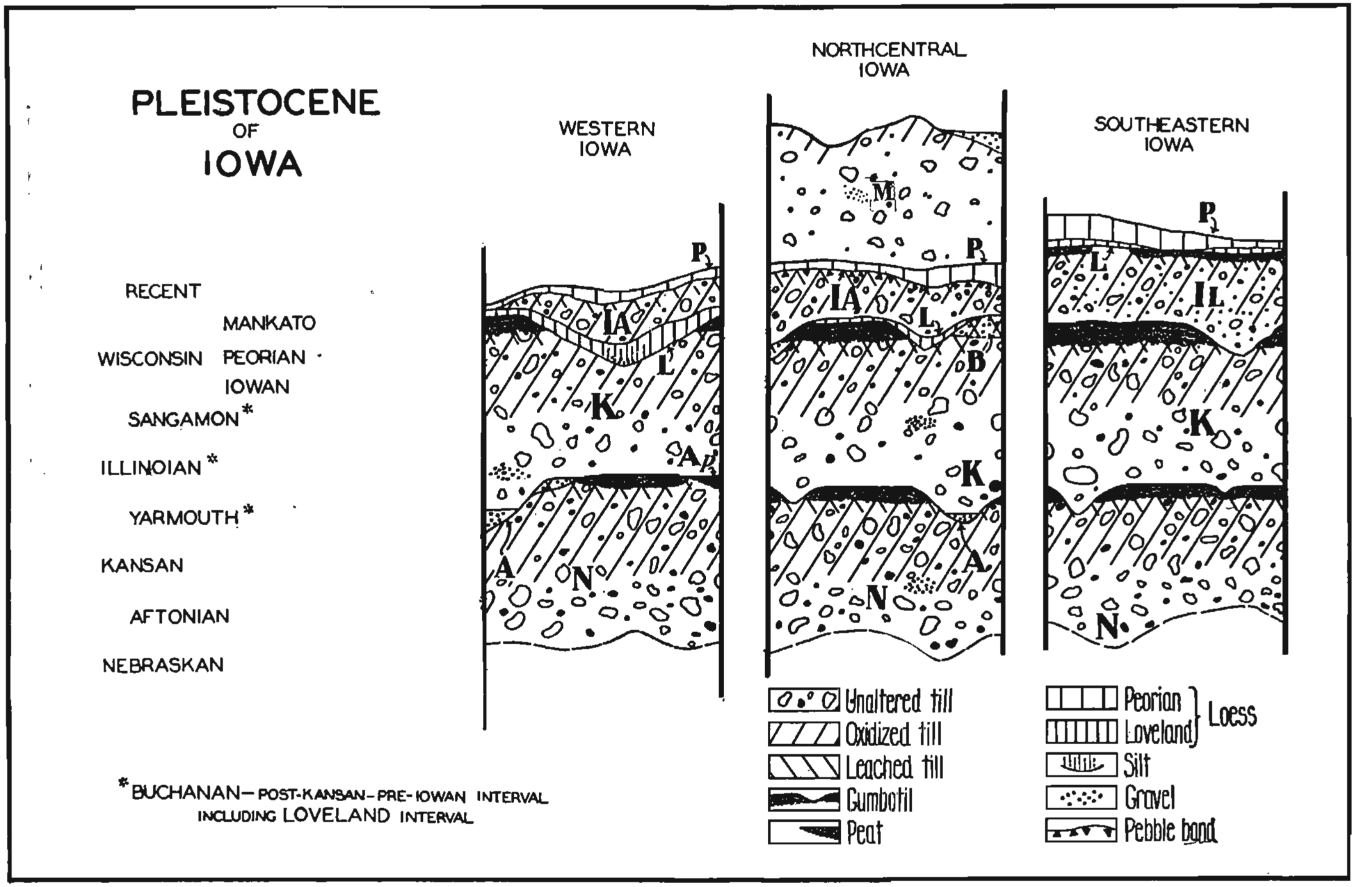


FIG. 1. — Diagrammatic sections of glacial and interglacial materials in the Pleistocene of Iowa.

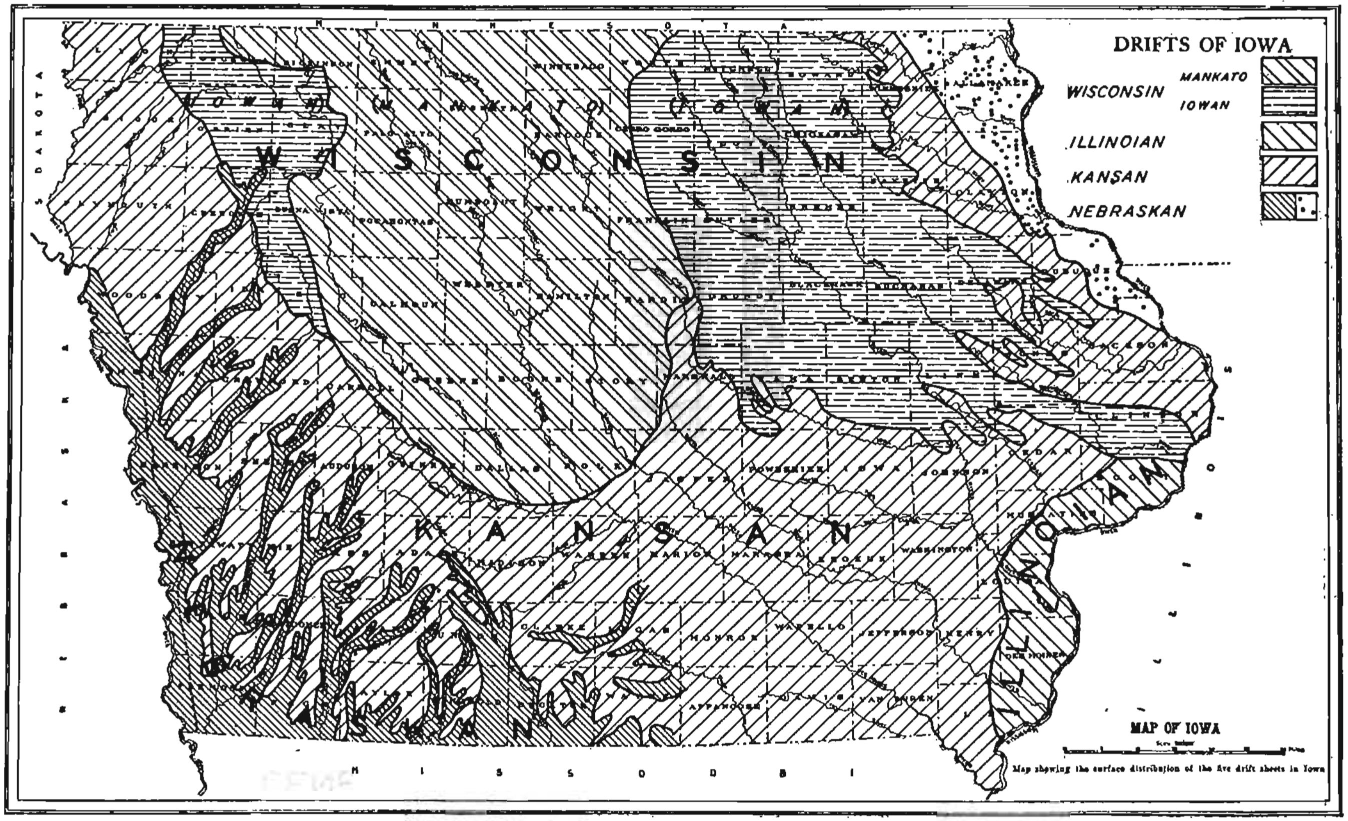


FIG. 2. — Map showing the surface distribution of the drift sheets of Iowa.

sissippi Valley. The evidence suggests strongly that this oldest ice sheet advanced over an area on which had been developed a topography characteristic of a mature erosional surface, with broad valleys, moderate slopes, and complete drainage systems. The drift left by this ice sheet has been estimated to have had a thickness of more than 100 feet, possibly as much as 150 feet. The drift consists of boulder clay or till with associated sands and gravels. This Nebraskan drift is at the surface in restricted areas only (see figure 2), as it is overlain in many places by younger drifts. The evidence as revealed in Iowa and adjacent states indicates that when the Nebraskan ice withdrew there was left over large areas a comparatively flat, poorly drained ground moraine plain. Till was the material left most widely at the surface of this plain; in places on the plain were sands and gravels. During the Aftonian interglacial age this drift underwent important changes. The unoxidized and unleached Nebraskan till, where so situated that chemical weathering was effective and erosion was negligible, was changed stage by stage until Nebraskan gumbotil was developed to an average thickness of more than 8 feet. Where gravels were subjected to weathering throughout Aftonian time — under topographic conditions similar to those under which gumbotil was developed from till — these gravels underwent great chemical changes also, changes comparable to those which the till underwent in the formation of gumbotil. In fact, in places in Iowa upland Nebraskan gravels are known which during Aftonian time were thoroughly leached of their calcium carbonate to a depth of 20 feet. Lenses and irregular masses of gravel incorporated in the Nebraskan till are only slightly weathered. In places peat instead of gumbotil was formed on the Nebraskan ground moraine plain. After the development of gumbotil much of the Nebraskan ground moraine plain was eroded, leaving only remnants of the former widespread Nebraskan gumbotil plain, and in places within the eroded areas sand and gravel were deposited.

The record of the weathering of the Nebraskan drift is well preserved in many places in Iowa because the gumbotil and related materials were covered by the drift of the second ice sheet, the Kansan. In the slopes of valleys, in road and railroad cuts, and in other excavations which go below the old Nebraskan surface, there are exposures of the Nebraskan gumbotil and underlying zones. In places the Nebraskan drift was all eroded before the coming of the Kansan ice sheet;

elsewhere the Kansan glacier removed only a part of the Nebraskan drift. Under such conditions the upper part of the Nebraskan drift is absent, and where the remaining Nebraskan drift is overlain by Kansan drift it is difficult to distinguish one drift from the other.

Kansan Drift and Related Materials

The second epoch (series), the Ottumwan, began with the advance of the Kansan ice sheet and ended with the oncoming of the Illinoian. It includes the Kansan glacial age (stage) and the Yarmouth interglacial age (stage). The Kansan drift sheet covered a large area in the Mississippi Valley. This drift has been estimated from field evidence to have had an average thickness, above the Nebraskan gumbotil plain, of about 50 feet. When to this figure is added the material necessary to fill the valleys cut in the Nebraskan drift the Kansan is seen to be also a massive drift to be ranked with the Nebraskan as one of the great drift sheets of the Pleistocene. During the Yarmouth interglacial age the Kansan drift underwent changes similar to those to which the Nebraskan drift was subjected in Aftonian time. That is to say, on the flat, poorly drained, Kansan ground moraine plain there was developed a gumbotil with maximum thickness of about 15 feet and average thickness of more than 11 feet. Gravels of Kansan age, where they were subjected to weathering under conditions similar to those under which Kansan till was being changed to gumbotil, became strongly oxidized and leached. In places, these upland Kansan gravels were leached to a depth of about 30 feet during Yarmouth interglacial time. As in the case of the Nebraskan, after the development of gumbotil and related weathered materials on the Kansan ground moraine plain, this plain was considerably eroded, leaving only remnants of the former widespread Kansan gumbotil plain, the largest of which are in southern Iowa and northern Missouri. In places within the eroded areas, sands and gravels were deposited, and in places loess was deposited before the deposition of the Illinoian drift.

In many places in Iowa and adjacent states, the Nebraskan and Kansan drifts closely resemble each other. Only locally can the Nebraskan drift be differentiated lithologically from the Kansan drift. In fact, the only satisfactory basis found thus far on which to decide definitely whether a pre-Illinoian drift is Nebraskan or Kansan is the relationship of the drift to interglacial materials whose age can be

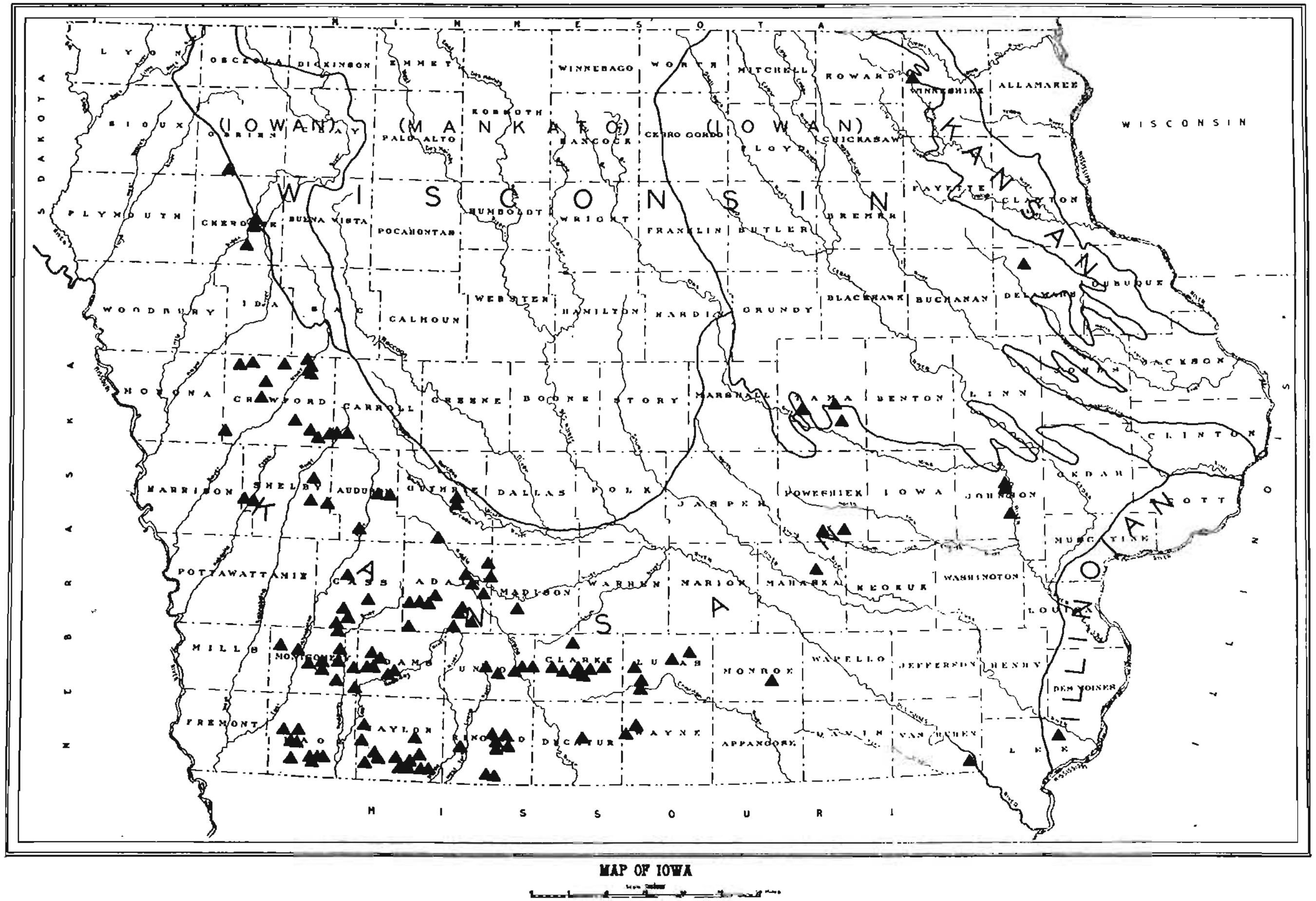
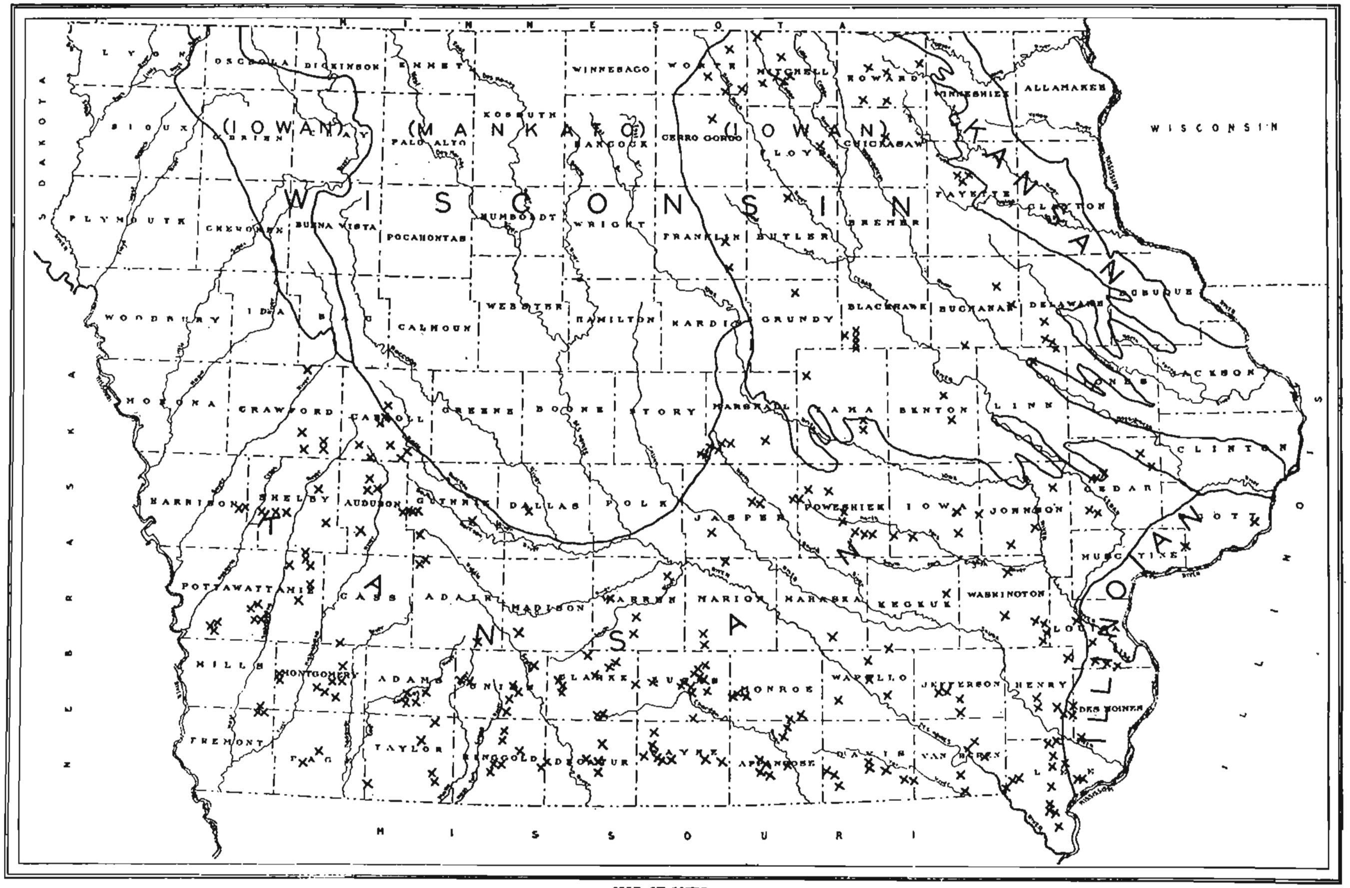


Fig. 3. — Locations of Nebraskan gumbotil outcrops in Iowa. The gumbotil, indicated by triangles, is the chief Aftonian interglacial horizon marker in the State.



MAP OF IOWA

FIG. 4.—Locations of Kansan gumbotil outcrops in Iowa. The gumbotil indicated by crosses, is the chief Yarmouth interglacial horizon marker in the State.

determined. Among the most widespread of interglacial materials separating Nebraskan from Kansan till is gumbotil. If a till is overlain by Nebraskan gumbotil or can be shown to be related to Nebraskan gumbotil, which in Iowa is found as remnants of a former extensive Nebraskan gumbotil plain, it is Nebraskan till. If, however, the till is overlain by a gumbotil which is known to be a remnant of the former extensive Kansan gumbotil plain the till is Kansan till. In fact, the gumbotils, on account of their distinctive characters, wide distribution, and topographic positions are the most satisfactory criteria that have been found for differentiating the older drifts. They have proved to be the most satisfactory Aftonian and Yarmouth horizon markers. They have been useful especially in differentiating and mapping the Nebraskan and Kansan drifts over wide areas. Figure 3 shows outcrops of Nebraskan gumbotil of Aftonian age separating Nebraskan till from Kansan till in Iowa, and figure 4 shows outcrops of Kansan gumbotil of Yarmouth age. From these outcrops it is possible to map areally the Nebraskan and Kansan drifts. Moreover, the Nebraskan gumbotil outcrops and the Kansan gumbotil outcrops mark the positions of the surfaces of the ground moraine plains on which the gumbotils were formed. From the altitudes of these outcrops it is possible also to construct maps to show the altitude of the Nebraskan and Kansan till surfaces during Aftonian and Yarmouth ages, respectively (see figures 5 and 6).

Peats and weathered gravels have been and will continue to be of value in interpreting Aftonian and Yarmouth interglacial history, but they have been found to be less serviceable than the gumbotils in areal mapping. Only a few good peat exposures of Aftonian age have been found in the Mississippi Valley and these are widely separated from one another. There are few known good exposures of peat of Yarmouth age. Moreover, since gravels differ in origin, in composition, in topographic position, in degree of weathering, and in other respects, their use in mapping is somewhat restricted. Much less reliance is now placed on interpretations of gravels and 'forest beds' penetrated in well drillings than was given to these materials in the earlier years of Pleistocene studies. Loess of late Yarmouth age is present in places in Illinois and Iowa.

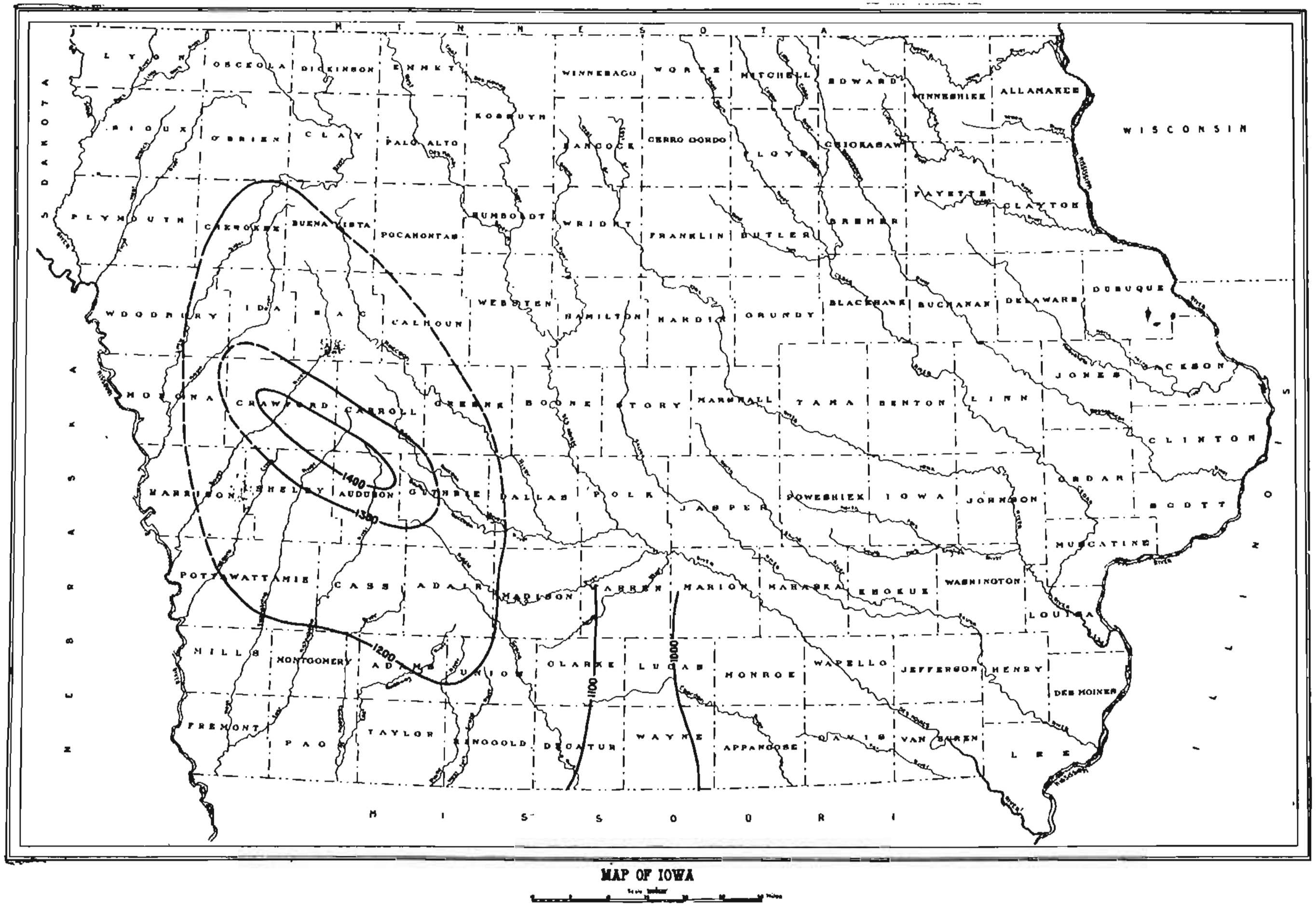


Fig. 5. — Contour map of Nebraskan plain, showing the surface of the Nebraskan plain in western Iowa on which gumbotil was formed during Aftonian time. Contour interval, 100 feet.

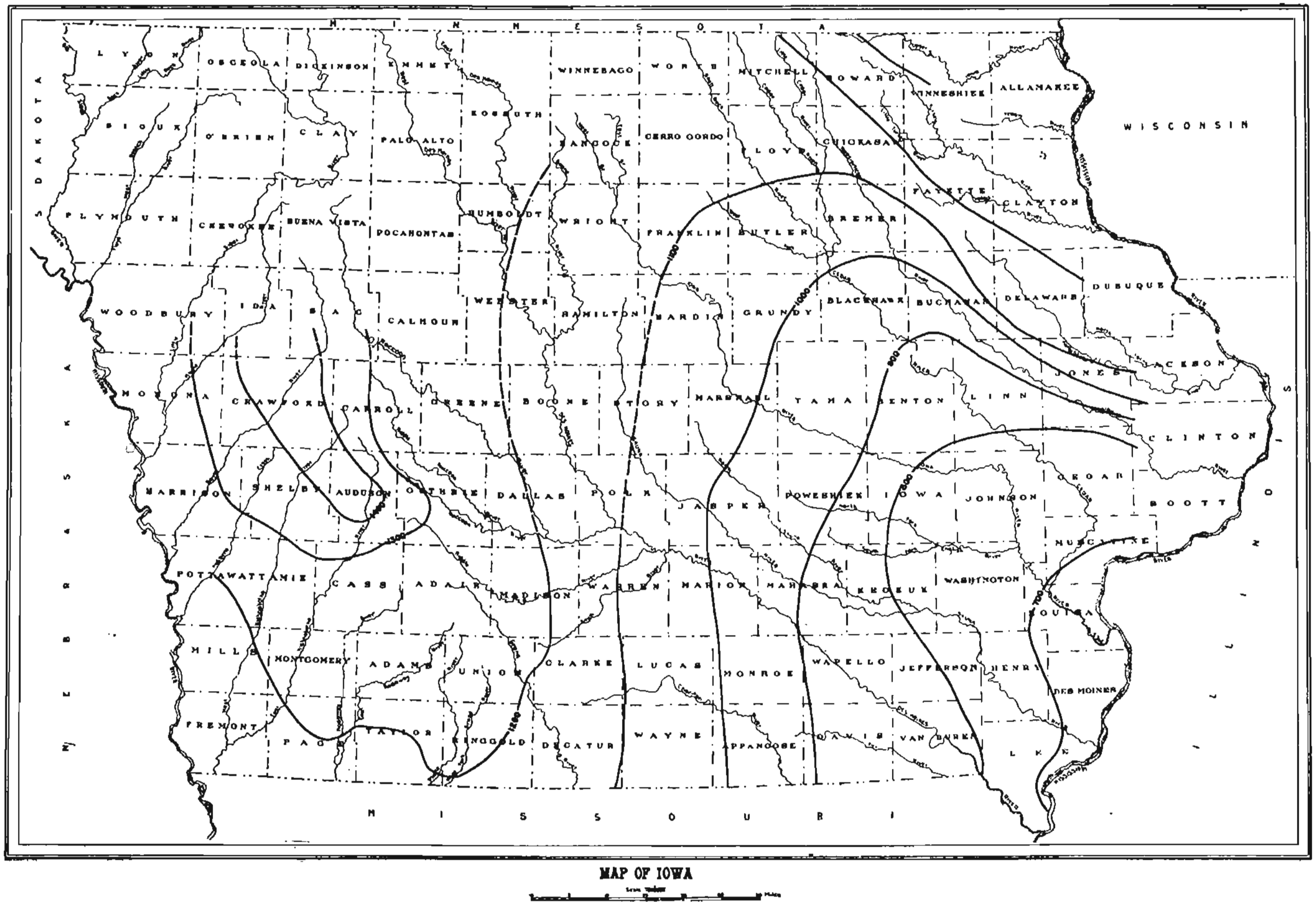


Fig. 6. — Contour map of Kansan plain, showing the surface of the Kansan plain on which gumbotil was formed during Yarmouth time. Contour interval, 100 feet.

Illinoian Drift and Related Materials

The third epoch (series), the Centralian, began with the recurrence of glacial conditions, which resulted in the third ice sheet and ended with the oncoming of the Iowan ice sheet. It included the Illinoian glacial age (stage) and the Sangamon interglacial age (stage).

The Illinoian ice sheet came into Iowa from the Labradorean center. The drift left by this ice sheet is exposed widely in Illinois, Indiana, and Ohio. A lobe of the Illinoian ice extended into southeastern Iowa, displacing the Mississippi river from its present location westward to a position where it remained until post-Illinoian time. The Illinoian drift, which has an average thickness of about 30 feet, has the same general characters as the Nebraskan and Kansan drifts. Extensive areas of its surface are flat and uneroded. In limited areas the topography is distinctly morainic. During the Sangamon interglacial age Illinoian till was weathered to a gumbotil to a depth of 4 to 6 feet where the topographic conditions were similar to the topographic conditions under which gumbotil was developed on the Nebraskan and Kansan tills.

Within the Illinoian drift area there are in many places two loesses on the Illinoian gumbotil and on eroded surfaces of Illinoian drift. The younger of these two loesses is the Peorian loess; the older loess has been correlated by the senior author with the widespread Loveland loess of western Iowa, which is later than the Kansan gumbotil erosion and is pre-Iowan in age. Leverett, however, correlates the Loveland loess of western Iowa with pre-Illinoian loess and questions the existence of a post-Illinoian, pre-Peorian loess. But in recent years this older loess on the Illinoian has been mapped widely by members of the Illinois and Iowa Geological Surveys. Although the Loveland loess of western, central, and southern Iowa outside the limits of the Illinoian area appears to be a single formation which was deposited in post-Illinoian, pre-Iowan time, the senior author has stated that in reality its lower part may be pre-Illinoian in age, and only its upper part post-Illinoian; and it may be that a part of the Loveland loess where it lies on drift older than the Illinoian was deposited during the Illinoian glacial age. The older of the two loesses on the Illinoian drift has been referred to late Sangamon time by the geologists of the Illinois Survey.

The Iowan Drift, the Peorian Loess, and the Mankato Drift

The youngest epoch (series), the Eldoran, began with the coming of the Iowan ice sheet and ended with the retreat of the Mankato. In Iowa it includes the Iowan glacial, the Peorian intraglacial, and the Mankato glacial substages of the Wisconsin age (stage).

The Iowan drift is limited in distribution and its characteristics are best known from studies in northeastern Iowa. The Iowan is thin, having an average thickness of less than 10 feet. Its topography is a drift-mantled, erosional type, although the mantle is in places thick enough to produce distinctly depositional features. In parts of the area the relief is very slight and the surface appears to the eye to be almost level. In Iowa, the Iowan was deposited on Kansan gumbotil, on the eroded surfaces of the Kansan drift, or on Loveland loess. Since the retreat of the Iowan there has not been sufficient time for the development of gumbotil. However, leaching of calcium carbonate has proceeded to a depth of somewhat more than 5 feet.

In recent years Leverett has contended that the Iowan is a Keewatin phase of the Illinoian. However, Kay, Alden and Leighton, and other geologists have presented evidence to show that the Iowan is much more closely related in age to the Wisconsin than to the Illinoian. Kay has contended also that the Sangamon interval, which separates the Iowan and the Illinoian glacial ages, was much longer than the Peorian interval — long enough for gumbotil more than 3 feet thick to have been developed on the Illinoian till, also for post-Illinoian gumbotil erosion, also for the deposition of a loess on this eroded Illinoian and for weathering of the loess all before the close of Sangamon time.

The Peorian intraglacial age was characterized by widespread loess deposition. This loess was apparently laid down shortly after the deposition of the Iowan drift. It varies in thickness from a few feet to nearly 100 feet adjacent to wide floodplains. In places, this loess is apparently genetically related to the Iowan. The senior author [8] has shown that the depth of leaching of the Peorian loess in Iowa where it is not overlain by Mankato drift is about the same as the depth of leaching of the Iowan till which has been subjected to leaching since the retreat of the Iowan ice sheet from Iowa. The presence of a pebble

8 Kay, G. F., The Relative ages of the Iowan and Wisconsin Drift Sheets: Amer. Journ. of Science, Vol. 21, pp. 158-172, 1931.

band on the Iowan drift beneath the Peorian loess is one of the arguments advanced by Leverett for the interpretation that the Peorian loess is much younger than the Iowan — the Iowan being considered by him to be comparable to the Illinoian.

The youngest of the drifts is the Mankato. It retains the distinctive features of youth such as moraines, eskers, kames, and lakes. The depth of leaching since the retreat of this ice sheet from Iowa has been determined to be about 30 inches.

PREVIOUS INVESTIGATIONS OF THE PLEISTOCENE GRAVELS OF IOWA

General Statement

As early as 1870, C. A. White referred to pockets of sand and gravel in till in Iowa.[4] Since that time many papers have been published in which sands and gravels of Pleistocene age have been described. The county reports of the present Iowa Geological Survey contain many general facts regarding the sands and gravels which are found in the different parts of the state. These sands and gravels have been described by Beyer [5] and by Wood [5a] also, but chiefly as economic materials. The two best known ages of gravels of the state are those described as Aftonian gravels of the Afton Junction-Thayer region and of western Iowa, and the Buchanan gravels of northeastern Iowa.

Chamberlin's Investigations at Afton Junction

In the year 1893, Chamberlin and McGee visited the Afton Junction-Thayer region in Union county, Iowa, where they examined the now famous exposures of tills and gravel. They interpreted the chief gravels to be kamelike deposits closely associated with the till upon which they lie.[6] Only at the Grand River pit was till exposed beneath these gravels. The till which lies on the gravels was considered by Chamberlin and McGee to have been deposited in connection with the second ice invasion. And now for the first time names were given to tills of different ages in Iowa. Chamberlin named the older of the two tills in the Afton Junction-Thayer region the Kansan, and the younger till the East Iowan. He believed that these two tills were of the same age as McGee's Lower Till and Upper Till, respectively, which had been mapped areally in northeastern Iowa. At this time no name was given to the gravel separating the Kansan till from the East Iowan till in the Afton Junction region or to the forest beds, peats, and soils, which in many places in Iowa were known to separate

4 White, C. A., Report on the Geological Survey of the State of Iowa: Vol. I, pp. 82-102, 1870.
5 Beyer, S. W., The Road and Concrete Materials of Iowa: Iowa Geol. Survey, Vol. XXIV, pp. 33-685, 1914.
5a Wood, L. W., The Road and Concrete Materials of Southern Iowa: Iowa Geol. Survey, Vol. XXXVI, 14-310, 1935.
6 Chamberlin, T. C., in James Geikie's The Great Ice Age, pp. 724-774, 1894.

two tills and were interpreted to be the products of the first interglacial age. But in 1895, Chamberlin again referred to the gravels and used for the first time the name Aftonian for the interglacial interval separating the Kansan till from the Iowan till.[7] His statement is as follows:

"Subsequent to the formation of the Kansan sheet of till and accompanying assorted deposits there was a notable retreat of the ice. . . . During this stage of retreat there were accumulations of muck and peat reaching a reported depth of twenty-five feet. One of the best exposures of this horizon is found between Afton and Thayer, Iowa, and from the former a euphonious name may be taken. Owing to the scarcity of gravel in the drift territory of southern Iowa the Chicago, Burlington & Quincy Railroad has made extensive excavations upon these gravel deposits lying between an upper sheet of till reaching a thickness of 40 to 60 feet and a lower till of less depth. The gravels appear to be kamelike accumulations, at least they are great lenses lying upon the surface of the lower till. This lower till is believed to belong to the Kansan stage and the upper to the Iowan. On the surface of the gravels there accumulated at points a deep mucky soil, in which occur considerable quantities of vegetable debris. This is believed to occupy the same horizon as the numerous peaty deposits described by McGee in eastern Iowa."

From this statement it is evident that the term Aftonian as first used was applied only to the horizon represented by soil bands, peat, and muck, and was correlated with the forest bed of McGee. According to the classification of Chamberlin's paper, the name Kansan was used for the lower till and the name Iowan for the upper till in the Grand River pit. The Aftonian beds proper were considered to have been deposited in the interval separating the two tills.

Calvin's Interpretations of Buchanan Gravels

In 1896, Calvin[8] published a paper on the Buchanan gravels. He stated:

"While, therefore, the gravels lie between two sheets of drift and for that reason may be called interglacial, probably Aftonian, they yet belong to the time of the first ice melting, and are related to the Kansan stage of the glacial series as the loess of northeastern Iowa is related to the Iowan stage."

7 Chamberlin, T. C., The Classification of American Glacial Deposits: Journal of Geology, Vol. III, pp. 270-277, 1895.

8 Calvin, Samuel, The Buchanan Gravels; an Interglacial Deposit in Buchanan County, Iowa: Amer. Geol., Vol. XVII, pp. 76-78, 1896.

About this time the classification of the Pleistocene deposits in the Afton Junction region was revised by naming the lower till pre-Kansan instead of Kansan and the upper till Kansan instead of Iowan. The reasons for these changes have been discussed fully in a paper by the senior author.[9]

Calvin soon recognized that the Buchanan gravels separated the Kansan till from Iowan till in northeastern Iowa, and hence were not Aftonian in age. In his report on Buchanan county, in Volume VIII of the reports of the Iowa Geological Survey, he described these Buchanan gravels. He referred to an upland phase in which the materials are relatively coarse and a valley phase in which they are composed largely of sand and fine gravel. In his report on Howard county, in Volume XIII, he referred again to the upland and valley phases of the Buchanan gravels and expressed the view that the upland gravels were deposited by streams flowing on the higher areas which had become bare while bodies of ice yet filled the valleys and lowlands. Then after the ice melted from the valleys the gravels there were laid down.

Calvin's Interpretation of the Gravels of the Afton Junction Region

Between the years 1900 and 1905 the Chicago, Burlington and Quincy Railroad made some important changes in the road between Thayer and Afton in Union county, in connection with which numerous deep cuts in drift were made, affording an unusual opportunity for the study of the glacial deposits. These new cuts as well as the Afton Junction, Grand River, and Thayer gravel pits were studied carefully by Calvin. The results of his investigations were given in a paper published by the Davenport Academy of Science.[10] In this paper, on page 21, he stated:

"There are three possibilities: (1) the gravels may have been laid down along drainage courses by waters flowing away from the melting and retreating margin of the pre-Kansan ice, upon a surface which but a short time before had been left bare by the gradually waning glaciers . . . (2) The gravels may have been deposited by waters flowing out in front of the advancing Kansan ice, in which case they were laid down upon the eroded and weathered surface of the pre-Kansan till. . . . (3) The gravels

9 Kay, G. F., History of Investigations and Classifications of the Pleistocene Deposits of Iowa: Iowa Geol. Survey, Vol. XXXIV, pp. 70-133, 1929. (Preprint 1928)

10 Calvin, Samuel, The Aftonian Gravels and their Relations to the Drift Sheets in the Region about Afton Junction and Thayer: Davenport Acad. Sci., Vol. X, pp. 18-31, 1905.

may have been deposited by floods which were in no way related to glacial conditions, and these floods may have occurred at any time during the long interval of mild climate which separated the pre-Kansan glacial stage from the Kansan."

In discussing these three possibilities, Calvin pointed out that the drift sheets related to the gravels differ in their petrological content. For example, the Kansan drift is much richer in quartzites and greenstones; the pre-Kansan is richer in granites. Furthermore, he stated, on page 22:

"The coarse feldspathic granites of the sub-Aftonian till are common among the cobbles and pebbles of the Aftonian deposit, while greenstones and basalts are relatively scarce. . . . Another fact of great significance is found in the highly ferruginous and profoundly weathered zone immediately below their contact with the overlying Kansan till."

Thus, the author concluded that the evidence supported the view that the Aftonian gravels were in place and profoundly weathered before the deposition of the Kansan drift, and hence the second hypothesis which would relate the gravels to the Kansan drift was untenable.

In discussing the third hypothesis he stated:

"It may be enough to say that, so far as relates to the interval between the complete melting of the pre-Kansan and the incursion of the Kansan ice, there is no way at present known to account for floods of volume and duration sufficient to transport and deposit the great beds which make up the Aftonian formation."

That Calvin considered the evidence conclusively in favor of the view that the Aftonian gravels were deposited in connection with the retreat of the pre-Kansan ice sheet is indicated in the following quotation:

"In the analogous case of the Buchanan gravels so extensively distributed throughout northeastern Iowa, there are indications which point unquestionably to their transportation and deposition by great floods liberated by the melting of the Kansan glaciers. The melting of the pre-Kansan glaciers certainly gave rise to similar floods, and it is safe to assume that these were the agents whereby the Aftonian gravels were carried and deposited."

In the concluding part of his paper, on page 29, Calvin made the following very definite statement:

"That the Aftonian was a real interglacial interval of mild climate and of long duration, is demonstrated by the evidence of extensive peat beds and forests which developed on the surface of the pre-Kansan drift, and were later overwhelmed and buried by the glaciation of the Kansan stage."

This conclusion, it will be noted, is based not upon the evidence furnished by the gravels, but rather upon the existence of peat and forest beds which had been found in other localities.

Although in the paper to which reference has just been made the judgment of Calvin is very positive with regard to the close relation of the gravels to the pre-Kansan drift, it will be found, if his subsequent papers are read, that he modified his view regarding the origin of the gravels. This change of view was not the result of further field study of the gravels in the Afton Junction-Thayer region, but of some interesting studies by Professor Shimek and himself of gravels in western Iowa and the fossils which they contain. Professor Shimek in the summer of 1908 found fossiliferous sands and gravels in western Iowa, chiefly in Harrison and Monona counties, which he classified as Aftonian gravels of strictly interglacial origin. In a paper in which he described the sands and gravels [11] he discussed their relations to the drifts as follows:

"(1) They are not sub-Aftonian because in every case examined they lie unconformably on the older drift, the old oxidized and weathered surface of which sharply marks the line of division between the two deposits. (2) They are not Kansan, for in nearly all the exposures Kansan is shown clearly resting unconformably on them, with calcareous plates (nodular) cementing sands and gravels, and strongly oxidized material sharply defining the line of division. Moreover, evidence is furnished by several exposures that the Kansan passed over the Aftonian beds while the latter were frozen, and plowed and tilted them in mass or disturbed and folded them in intricate fashion. (3) The sand and gravel beds are not glacial, but interglacial. That the materials were deposited in streams is shown by the fact that they are water-worn, cross-bedded with frequent interbedding of sand and gravel, the latter deposited by stronger currents, and that they contain fluviatile shells, with such intermingling of land shells as is common in the same region in modern alluvial deposits. That the climate was mild during this interglacial period is shown by the presence of the large numbers of herbivorous mammals which required a vigorous flora for their maintenance, and of fresh water and land mollusks, which are

11 Shimek, B., Aftonian Sands and Gravels in Western Iowa: Bull. Geol. Soc. of Amer., Vol. 20, p. 406, 1909.

identical with species now living in Iowa. The aquatic shells suggest the same biotic conditions as exist in the state today, and the land shells required plant-covered land surfaces on which they could find food and shelter, and these surfaces are not radically different from those which prevail in Iowa today, if we are to judge from the identity of the land forms."

Calvin studied the mammalian remains which were taken from the Aftonian gravels in western Iowa, and in one of his papers [12] he made reference to the gravels and their contained fauna as follows:

"The stratigraphic position is clear and well established; the gravels are Aftonian in age, but they contain evidence that they were not deposited until some time after the old pre-Kansan ice sheet had completely disappeared. The new evidence comes in the form of a fairly rich mammalian fauna that must have been contemporary with the deposition of the gravels, but which certainly did not live in the wet, chilly, verdureless region that co-existed with the melting of the pre-Kansan ice."

This same view was emphasized strongly in a paper by Calvin published in 1910.[13] Shimek also presented evidence for the view that the fossiliferous gravel and sand beds of western Iowa are Aftonian.[14]

These conclusions with regard to the gravels in western Iowa, and the fauna associated with them, naturally caused Calvin to be less sure than he previously had been regarding his interpretation of the origin of the Aftonian gravels in the Afton Junction, Grand River, and Thayer pits of Union county. In his Presidential address [15] read before the Geological Society of America he referred to the gravels of Union county as follows:

"The same gravels are exposed in a great ballast pit at Afton Junction, from which locality came the name 'Aftonian' given to the gravels as well as to the entire interval of which they form part of the record."

He called attention to Shimek's investigations in western Iowa, and stated that it might become necessary to modify the view expressed in 1905 in the Davenport Academy paper. He stated further that foot bones of a small, slender-limbed horse had been found in the Afton-Thayer deposits, and expressed the following judgment:

12 Calvin, Samuel, Aftonian Mammalian Fauna: Bull. Geol. Soc. of Amer., Vol. 20, pp. 341-356, 1909.

13 Calvin, Samuel, The Aftonian Age of the Aftonian Mammalian Fauna: Proc. Iowa Acad. Sci., Vol. XVII, pp. 177-180, 1910.

14 Shimek, B., Evidence that the Fossiliferous Gravel and Sand Beds of Iowa and Nebraska are Aftonian: Bull. Geol. Soc. of Amer., Vol. 21, pp. 119-140, 1910.

15 Calvin, Samuel, Present Phase of the Pleistocene Problems in Iowa: Bull. Geol. Soc. of Amer., Vol. 20, pp. 133-152, 1909.

"In the light of new finds in Harrison and Monona counties we may conclude that this beautiful little Equus was probably contemporary with the deposition of the gravels."

In this same paper, in concluding his discussion of the Aftonian, he stated:

"All lines of evidence now indicate that the beds in question record conditions which existed at some time during the progress of the interval, neither at its beginning nor at its close, but in the light of present knowledge the precise age of the deposits cannot be more definitely stated."

Kay's Interpretation of the Gravels of the Afton Junction Region

Kay after a detailed study of the sands and gravels in the Afton Junction region made the following statement: [16]

". . . The two tills of the region are now called the Nebraskan till and the Kansan till, and the gravels separating these tills have long been called the Aftonian gravels. It may be well to restate here that Chamberlin interpreted the chief gravels separating the two tills to be kamelike deposits on the surface of the lower till (present Nebraskan till) and related in age to this till. The gravels became much weathered during the Aftonian interval. Bain referred to evidence of lateral transition from gravels into boulder clay and suggested the possible contemporaneity of the gravels with the upper till (present Kansan till). Calvin, in 1905, interpreted these gravels to be deposits made by torrential floods during the retreating stages of the pre-Kansan ice. Later, in 1908, chiefly as a result of studies by himself and Shimek of gravels and their included fossil faunas in western Iowa, he suggested modification of his former view of the Aftonian gravels. He expressed the judgment that the most satisfactory interpretation of the gravels was that they are interglacial in age, having been deposited during the progress of the Aftonian interval, neither at its beginning nor at its end.

"Recent studies of the gravels and their relationships to the tills in the Afton Junction-Thayer region justify the statement that the chief gravels of Union county, which were thought by Calvin to have been deposited within the Aftonian interglacial epoch and to constitute a distinct stratigraphic horizon separating the Kansan till from the Nebraskan till, are not of this origin or age. Rather, the chief sands and gravels are lenses and irregularly shaped masses of gravels in the Nebraskan till and contemporaneous in age with that till. They are gravels not of Aftonian age but of Nebraskan age. They lie in large part below the level of the rem-

[16] Kay, G. F., History of Investigations and Classifications of the Pleistocene Deposits of Iowa: Iowa Geol. Survey, Vol. XXXIV, pp. 123-125, 1929. (Preprint 1928)

nants of Nebraskan gumbotil within this area. However, in a few places, as for example, in the Afton Junction pit close to Afton Junction station, the Nebraskan gravels in some places and the Nebraskan till in other places are at the surface of the Nebraskan drift. During the Aftonian interglacial interval the upper part of the Nebraskan till became weathered to Nebraskan gumbotil and the Nebraskan gravels which had a similar topographic relation to the Nebraskan till became weathered to highly oxidized and leached gravels. There are gradations laterally from typical Nebraskan gumbotil to gumboized gravels to thoroughly leached gravels. Later, both Nebraskan gumbotil and the oxidized and leached Nebraskan gravels were overlain by Kansan drift. Some of the Nebraskan gumbotil and some of the weathered gravels were picked up by the Kansan ice and are now inclusions in the Kansan till. Since the Nebraskan gravels which were weathered while at the surface and which now separate the Nebraskan till below from the Kansan till above underwent their great changes during the Aftonian interglacial epoch it may be considered proper to continue to call such gravels Aftonian gravels, but it is here suggested that the name Aftonian gravels be no longer used for the sands and gravels of Nebraskan age which were changed to their present condition in Aftonian time, but that they be called weathered Nebraskan gravels, just as the Nebraskan gumbotil is the name given to weathered Nebraskan till, the weathering having taken place in Aftonian time. The weathered Nebraskan gravels do in places separate Nebraskan till from Kansan till, and hence constitute the Aftonian stratigraphic horizon, just as peat does in some places in this area and in other areas. But Nebraskan gumbotil rather than gravels or peat is the most widespread evidence of Aftonian interglacial time in the Afton Junction-Thayer region. This Nebraskan gumbotil has been mapped over wide areas in southwestern Iowa and in other parts of the state and hence is the most significant Aftonian horizon marker which thus far has been found.

"The major interpretations of Chamberlin and McGee made many years ago in the Afton Junction-Thayer region have been strengthened by the recent studies, and this region will continue to be the classic area of Iowa for the investigation of the two oldest drifts, the Nebraskan and the Kansan, and of Nebraskan gumbotil, weathered Nebraskan gravels, and peat, which are the most distinctive evidences in support of the reality of the Aftonian interglacial epoch."

Kay's Interpretation of the Gravels of Western Iowa

In the year 1924, the senior author made the following statement regarding the sands and gravels of western Iowa:[17]

[17] Kay, G. F., Recent Studies of the Pleistocene in Western Iowa: (Abstract), Bull. Geol. Soc. of Amer., Vol. 35, pp. 71-74, 1924.

"The sands and gravels of western Iowa, which were described by Shimek and Calvin as being Aftonian interglacial gravels separating the Nebraskan till from the Kansan till and related in origin neither to deposits made during the closing stages of the Nebraskan glacial epoch nor to deposits made during the Kansan glacial epoch, are thought by the writer not to represent a distinctive stratigraphic horizon separating the Nebraskan till from the Kansan till. But instead they are interpreted as being lenses and irregularly shaped masses of gravels and sands within a single till; or, if in two tills, it is not possible to use the gravels and sands as evidence for differentiating these two tills. The gravels and sands are unleached and appear to be contemporaneous in age with the tills with which they are associated.

"Many mammalian fossils have been found in the sands and gravels associated with the tills of western Iowa. Calvin and Shimek believed that these remains were of animals which were living during the time of deposition of the gravels, which they interpreted as Aftonian and interglacial. But if the sands and gravels are lenses and irregularly shaped pockets related in age to the till with which they are associated, then a somewhat different interpretation of the age of the mammals becomes necessary. At the present time it is impossible to state whether the gravels in which the mammalian remains have been found are associated with Nebraskan till or with Kansan till, since, as stated previously, it has not been possible thus far to differentiate Nebraskan till from Kansan till except where the relationships of the till to gumbotil, the age of which is known, have been established. If the gravels in which the mammalian remains have been found should prove to be lenses and pockets in Nebraskan till, then the evidence would suggest that the animals are Nebraskan in age. It would be reasonable to assume that the animals were living in front of the advancing Nebraskan ice sheet, out from which sands and gravels were being carried. Remains of mammals became imbedded in the sands and gravels, which themselves later were overridden by or became incorporated in the onward moving Nebraskan till. If, on the other hand, the sands and gravels containing the mammalian remains should prove to be lenses and pockets in Kansan till, then the suggested interpretation would be that the mammals were living on the Aftonian surface during the advance of the Kansan ice sheet, out from which sands and gravels were being carried. After remains of mammals became imbedded in these sands and gravels the Kansan ice sheet advanced and incorporated in Kansan till these masses of sands and gravels in which the remains are found. If these conclusions are justified, then this mammalian fauna may not be a strictly interglacial fauna of Aftonian age. It is important to note, however, that the fauna is certainly early Pleistocene — that is, it was closely associated either with the advance of the Nebraskan ice or with the advance of the Kansan ice sheet, or it was associated with both as a result of having persisted on the adjacent plains from Nebraskan through Aftonian to Kansan time."

In 1929, Kay made a further statement with regard to the sands and gravels of western Iowa, as follows:[18]

"The sands and gravels in western Iowa which were interpreted by Shimek and Calvin to be Aftonian in age chiefly on account of the presence in the gravels of remains of mammals which they believed could have lived only in an interglacial epoch, are thought to be not interglacial but chiefly contemporaneous in age with the till with which the gravels are closely associated, the age of the till being probably Nebraskan but possibly Kansan. Some of the gravels may have been deposited in valleys in the Aftonian interglacial epoch, but their characteristics and their relationships to the till do not seem to support this view. Mammalian remains in the gravels do not of themselves determine whether the gravels are strictly interglacial in age or are of glacial origin, since vertebrate paleontologists are not in agreement regarding the climatic conditions under which mammals such as have been found in these gravels may live. Hay[19] is of the opinion that the mammals the remains of which have been found in the gravels of western Iowa could not have lived in the immediate vicinity of an ice sheet, but must have lived under interglacial climatic conditions. On the other hand, W. D. Matthew[20] believes that in determining the age of gravels and sands stratigraphic evidence can be more safely followed than fossil evidence. In a letter he stated:

> 'What actually seems to have happened in the Pleistocene was that glacial advances drove the boreal forms southward and compelled them to mingle temporarily with temperate faunas. . . . When the retreat of the ice opened up northern territory again, the boreal types were the first to extend their range northward, and then or later retreated from the southern territory they had invaded.'

"Matthew offers no adverse criticism to the view taken in this paper that the sands and gravels of western Iowa containing the remains of mammals were probably contemporaneous in age with the till with which they are apparently closely related in origin."

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18 Kay, G. F., History of Investigations and Classifications of the Pleistocene Deposits of Iowa: Iowa Geol. Survey, Vol. XXXIV, pp. 121-122, 1929. (Preprint 1928)
19 Hay, O. P., The Pleistocene of the Middle Region of North America and its Vertebrated Animals: Carnegie Institution, Washington, Publication 322A, 1924.
20 Personal communication.

Alden and Leighton's Interpretation of the Buchanan Gravels

As stated on page 25 of this report, Calvin recognized an upland phase and a valley phase of the Buchanan gravels in northeastern Iowa, both phases having been interpreted by him as being fluvioglacial deposits of Kansan age. Alden and Leighton,[21] after a careful study of the gravels within the Iowan drift area of northeastern Iowa, concluded that the Buchanan gravels of the valley phase are glacial outwash of Iowan age rather than of Kansan age, and that there are upland gravels of two phases, one phase of Kansan age as interpreted by Calvin and the other phase of Iowan age. They referred to the two phases of upland gravels as Kansan kames and Iowan kames.

Schoewe's Lake Calvin Sands and Gravels

Schoewe in his report on Lake Calvin[22] described three lake terraces: an intermediate, a high, and a low terrace. The structure and materials of each of these terraces are discussed. The materials of the low terrace in contrast to the materials of the intermediate and high terraces are coarser, contain more gravel layers, have a higher textural range, and consist predominantly of sands with extremely little silt or clay. "Whereas the high and intermediate terraces contain thinly and horizontally bedded deposits with minor cross-bedding, the prevailing type of structure of the low terrace is well developed cross-bedding and pocket-and-lens stratification."

Carman's Interpretation of the Gravels of Northwestern Iowa

Two comprehensive reports have been prepared by Dr. J. E. Carman on the Pleistocene deposits of northwestern Iowa.[23,24] Reference will be made here only to his discussion of the gravels and sands in the later of these two reports. In this report sands and gravels have been differentiated and described as follows:

1. *Interbedded Gravel and Till.* With reference to these deposits Carman states: "An interbedding of gravel and till characterizes several exposures within the Iowa region. These deposits were formed by oscillations

21 Alden, W. G., and Leighton, Morris M., The Iowan Drift, A Review of the Evidences of the Iowan Stage of Glaciation: Iowa Geol. Survey, Vol. XXVI, pp. 49-212, 1917.

22 Schoewe, W. H., The Origin and History of Extinct Lake Calvin: Iowa Geol. Survey, Vol. XXIX, pp. 49-222, 1924.

23 Carman, J. Ernest, The Pleistocene Geology of Northwestern Iowa: Iowa Geol. Survey, Vol. XXVI, pp. 233-445, 1917.

24 Carman, J. Ernest, Further Studies of the Pleistocene Geology of Northwestern Iowa: Iowa Geol. Survey, Vol. XXXV, pp. 15-193, 1931.

of the ice front during the general stages of advance and retreat. By these oscillations, gravel deposited just beyond the ice edge may have been laid down on till only recently deposited and may soon have been buried by till. The freshness of the gravel and till of these layers shows that neither was exposed long at the surface before the next higher member was deposited."

2. *The Gravel Hills.* "The kamelike gravel hills of the Iowan region are interpreted as gravel masses deposited in moulins or other openings in the Iowan ice sheet. On the melting of the ice these masses were left on or in the upper part of the drift sheet."

3. *The Valley Gravels.* "The valley gravels of the Iowan region and of the valleys of the Kansan region that carried Iowan drainage are interpreted as outwash from the Iowan ice chiefly during the withdrawal of the ice sheet. The valley gravels in those valleys of the Kansan region that did not receive Iowan drainage are believed to have been released from the Kansan till during an especially active period of erosion, owing to the lack of vegetation during the Iowan ice age, and to have accumulated farther down the valleys."

THE DISTRIBUTION, CHARACTERISTICS, AND OTHER FEATURES OF THE PLEISTOCENE GRAVELS OF IOWA

General Statement

The Pleistocene gravels of Iowa are of both glacial and interglacial origin. Each glacier which advanced into the state left gravel deposits. Theoretically, gravels were deposited in three general positions by the water from the melting glaciers: (1) in front of the advancing glacier which later overrode those within the area of till deposition, reincorporating some of the gravels into the glacial load and leaving the remainder of the gravels at the base of the till; (2) within the till sheet during the deposition of the till; (3) as outwash on the surface of the newly deposited drift sheet during the retreat of the glacier. During the interglacial intervals, gravels were deposited along the courses of streams which were dissecting the drift plain. These gravel deposits differ from those of glacial origin primarily in their relations to the till sheets.

Gravel deposits, either glacial or interglacial, may be destroyed by interglacial erosion or by the corrasion of a younger ice sheet. Valley gravels may be reworked by post-depositional streams which occupy the valleys.

The Gravels of the Grandian Series — The Nebraskan and Aftonian Stages

The Nebraskan was the oldest of the Pleistocene glaciers. Studies of the deposits left by this glacier show that it passed over all of Iowa including the northeastern part which for many years was thought to be driftless. Outcrops of Nebraskan gumbotil have been studied at many places within the state (figure 3), and in some parts of the state its surface and distribution can be mapped. The Nebraskan drift contains sand and gravel as irregular masses as well as outwash on its surface. Both of these will be described as Nebraskan gravel.

The Distribution of the Gravel of the Nebraskan Stage

The Nebraskan gravels are found chiefly in two areas, eastern Iowa and southwestern Iowa. The locations of the exposures studied are

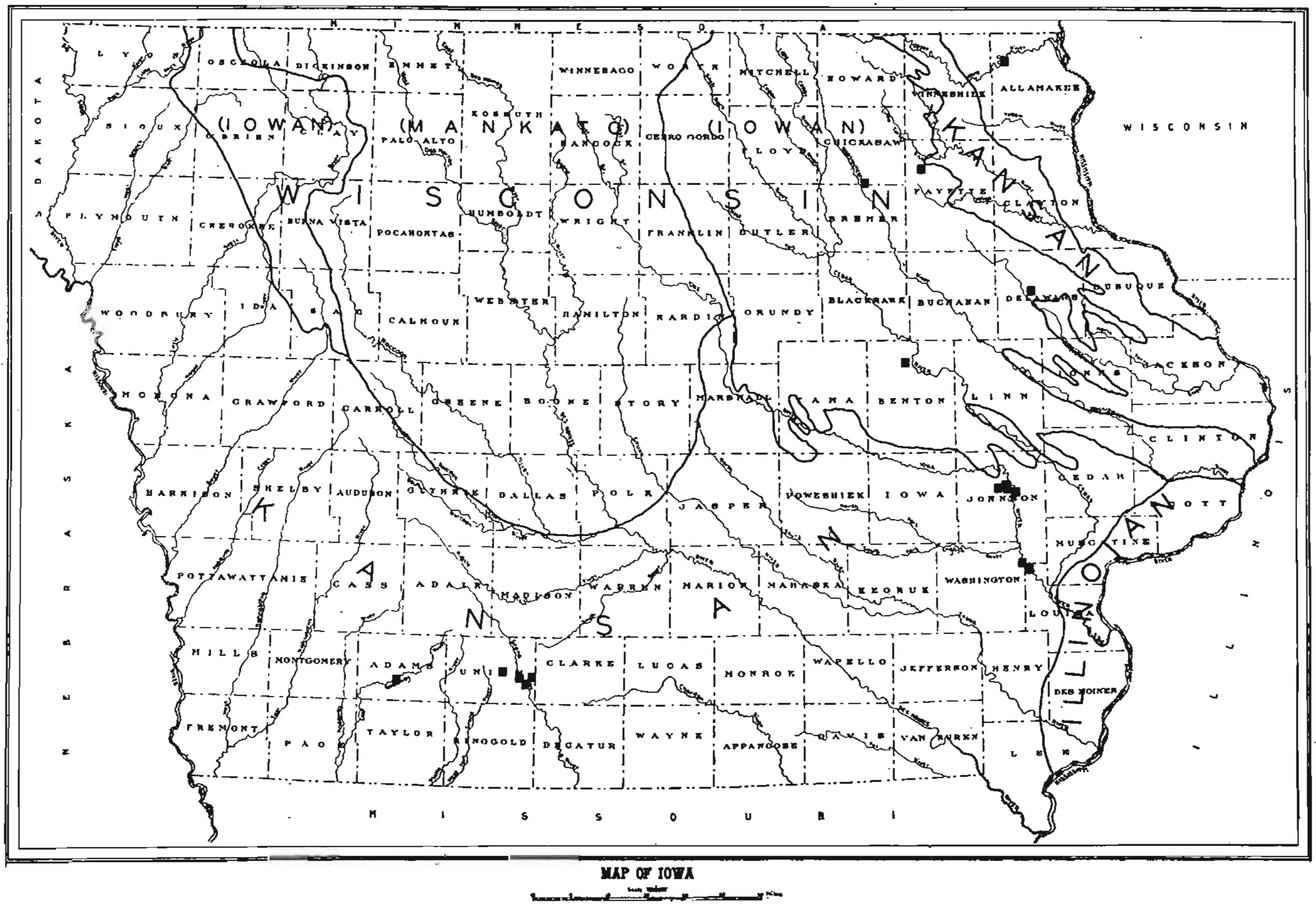


Fig. 7. — The squares show the locations of the Nebraskan gravel exposures in Iowa.

shown in figure 7. The limited number of exposures of Nebraskan gravel is due to the restricted area of exposed Nebraskan deposits. Throughout all of Iowa except a small portion of the northeastern part, covered only by loess, the Nebraskan deposits have been covered by one or more younger drifts. The Nebraskan deposits have not only been concealed by later deposition but much Nebraskan drift was removed by erosion, chiefly during the Aftonian interglacial interval. As a result of post-Nebraskan erosion which removed the younger overlying drift in some places good sections of Nebraskan drift have been made available for study.

The Characteristics of the Gravel of the Nebraskan Stage

General Characteristics:

The Nebraskan gravel occurs as pockets within the Nebraskan till and as outwash at the surface of the till. The gravel and the till have been subjected to weathering and have undergone comparable alterations. As soon as the drift was exposed after the retreat of the ice, chemical weathering began to act on the materials at and near the surface. This alteration continued over those wide areas where there was little, if any, erosion until the profile of figure 8 was developed. The alteration in the gravel, although comparable, was not to the same extent as that in the till, for within the more porous gravel the alteration extended to greater depths, unchecked by the formation of an impervious layer of gumbotil at the surface.

During the time that the till was being altered to the profile of figure 8, the gravels within the zone of weathering were being oxidized and leached. The oxidized iron compounds coated the grains, coloring the gravel to shades ranging from buff (15'i, Ochraceous-Tawny) [25] to highly ferruginous reddish-brown (11'k, Hazel), the average color being more nearly the reddish-brown extreme. The iron oxide coating the grains also acts as a cement which binds the gravel together into a firm mass which will stand in a vertical exposure. After the weathered gravel has been exposed to the atmosphere for a short time the cement hardens, beginning at the surface, and forms a friable conglomerate layer several inches thick. In the gravel deposits at and near the gumbotil horizon the oxidation extends to greater depths than in the more compact till. However, in the gravel deposits

25 The numerical and descriptive color terms within the parentheses are those used by Ridgeway. Ridgeway, Robert, Color Standards and Nomenclature, 1912.

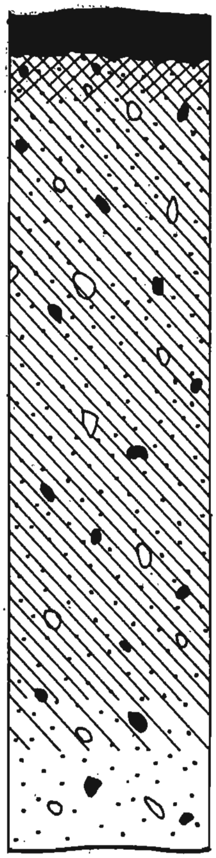


FIG. 8. — Diagram showing profile of weathered Nebraskan till.

located lower down in the Nebraskan till profile, in the oxidized and unleached and the unoxidized and unleached zones, the oxidation is much less to almost absent.

The processes of chemical weathering have leached also the more soluble substances such as carbonates from the upper portion of the drift and its associated gravel. However, the gravel masses enclosed in the lower unleached part of the Nebraskan profile contain their original rocks, many of which are calcareous, also lime concretions, molluscan shells, and numerous fossils of different species of vertebrates.

The deposits are generally well stratified in beds having a general horizontal position, but lenses, pockets, and cross-bedding are very

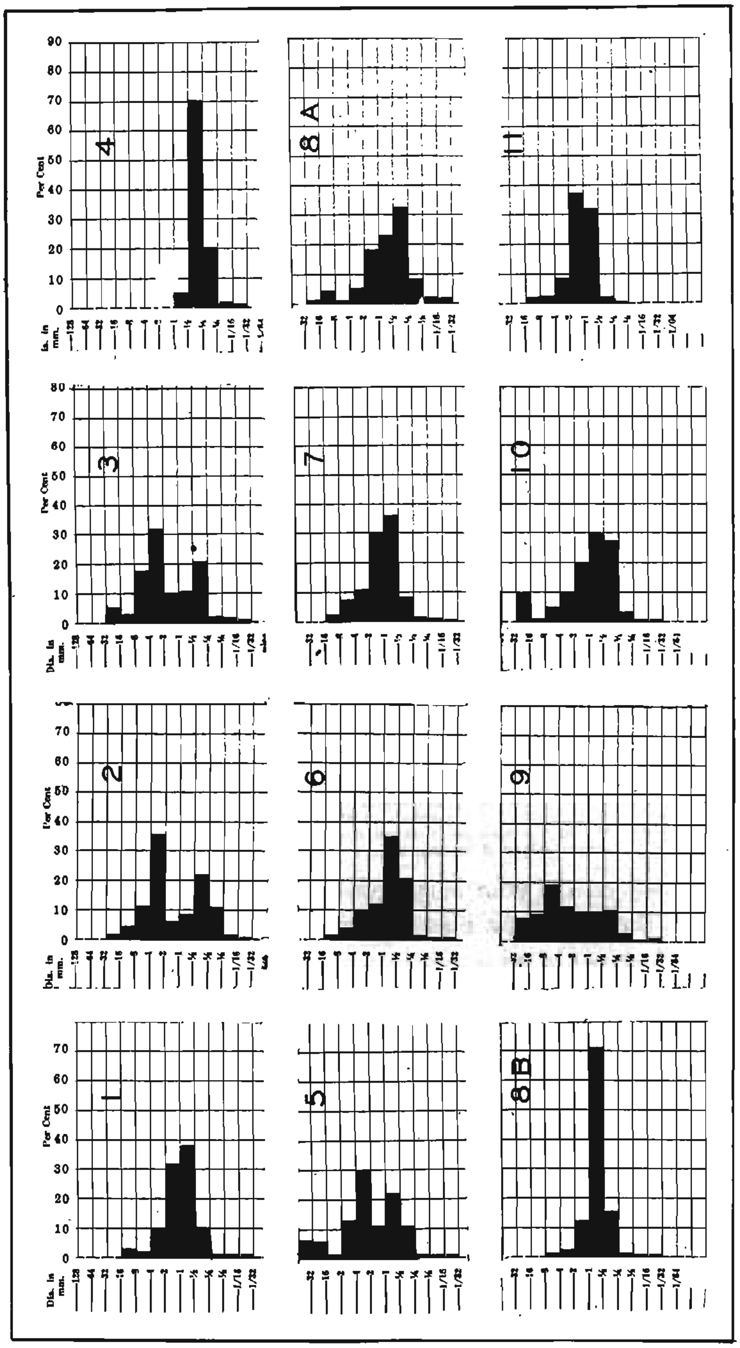


FIG. 9. — Graphs showing mechanical analyses of the Nebraskan gravel.

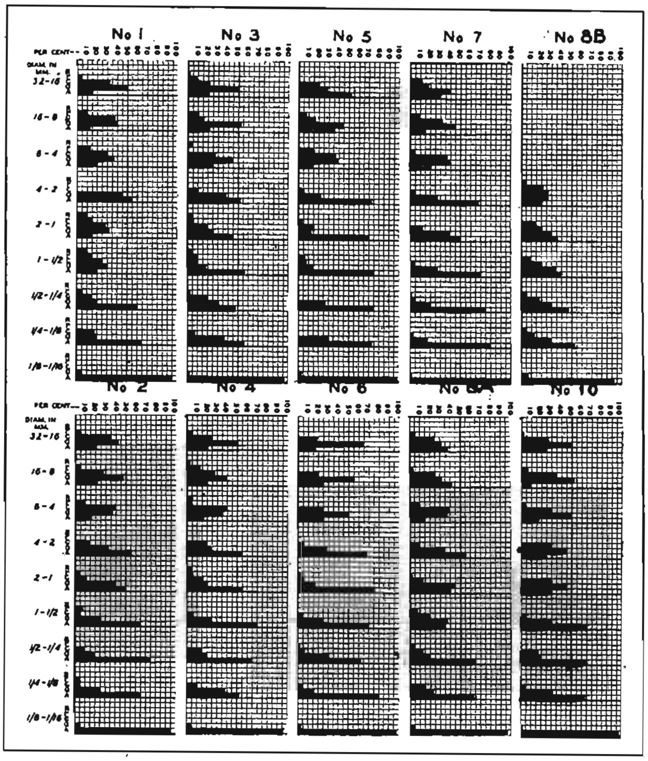


FIG. 10. — Graphs showing shape analyses of size grades between 1/16 and 32 millimeters in diameter. The numbers of these analyses correspond to the numbers of the mechanical analyses of figure 9. R = rounded; r = sub-rounded; C = curvilinear; a = sub-angular; A = angular.

common. However, the poor sorting and the high degree of alteration give some of the deposits a massive, poorly stratified appearance.

The gravel shows a wide size range both within single exposures and in different exposures. Most of the gravel is below one centimeter in diameter, although there are beds which consist almost entirely of pebbles between one and three centimeters in diameter. Still larger than the pebbles are cobbles and boulders distributed throughout the finer material and bearing no relationship to the stratification. These boulders have been observed to have a maximum diameter of about 75 centimeters. The percentage of each of the different size grades, determined by mechanical analyses, is shown graphically in figure 9 for the exposures later described. The percentage of rounding, as defined and named by Tester [25a] of each size grade between 1/16 and

[25a] Tester, A. C., The measurement of the shapes of rock particles: Jour. Sed. Petrol., Vol. 1, pp. 3-11, 1931.

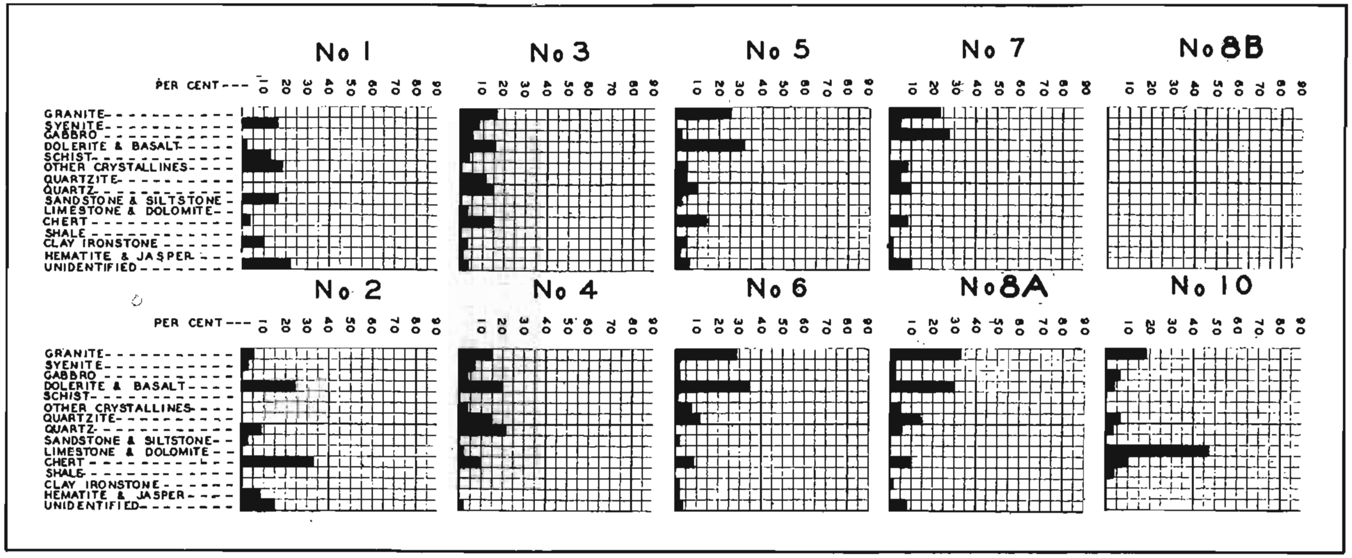


FIG. 11. — Graphs showing lithology of pebbles between 16 and 32 millimeters in diameter. The numbers of these analyses correspond to the numbers of the mechanical and shape analyses of figures 9 and 10.

32 millimeters in diameter is given in figure 10. The lithology, determined by an analysis of pebbles between 16 and 32 millimeters in diameter, is shown in figure 11.

There is a wide range in the thickness of the deposits of Nebraskan gravel. At some locations they are a bed only a few inches thick while at others they are as much as 30 feet thick.

Characteristics of the Nebraskan Gravel of Eastern Iowa

The exposures of Nebraskan gravel within Iowa, as shown in figure 7, include those which have been called Aftonian in previous reports; but as stated by Kay and Apfel,[26] the name Aftonian refers to the time of alteration of the gravel rather than to the time of deposition.

One of the best-known places within the state of Iowa to study these profoundly altered deposits is in the vicinity of Iowa City, in Johnson county. Here within a limited area, shown in figure 12, ten Nebraskan exposures can be definitely correlated and half of them contain gravel.

The weathered gravel is well exposed in the east central part of section 9, West Lucas township (T. 79 N., R. 6 W.), Johnson county, along both sides of the interurban railway cut just west of the Iowa river at Iowa City, at G in figure 12. The gravel is exposed also in small masses in the quarry one block south, and again in a road cut two blocks south of the interurban cut. This same type of gravel has been reported at the same elevation along the east side of the valley in the basement of the Women's Gymnasium. These gravel deposits are at an elevation of about 670 feet above sea level, about 30 feet below the upland and an equal amount above the Iowa river, in a region of loess mantled erosional topography.

Along the north side of the interurban railway cut just west of the Iowa river at Iowa City, the following section is exposed:

	Feet
4. Loess, buff colored, minimum leaching 8 feet, contains fossils (Peorian)	25
3. Loesslike material, light reddish-brown, all leached (Loveland)	2
2. Gravel, highly oxidized and leached (Nebraskan)	8
1. Till, dark gray, unoxidized and unleached (Nebraskan)	1

The gravel is colored reddish-brown (11'k, Hazel) by the iron oxide which coats the grains and cements them into a compact mass

26 Kay, G. F., and Apfel, E. T., The Pre-Illinoian Pleistocene Geology of Iowa: Iowa Geol. Survey, Vol. XXXIV, p. 182, 1929.

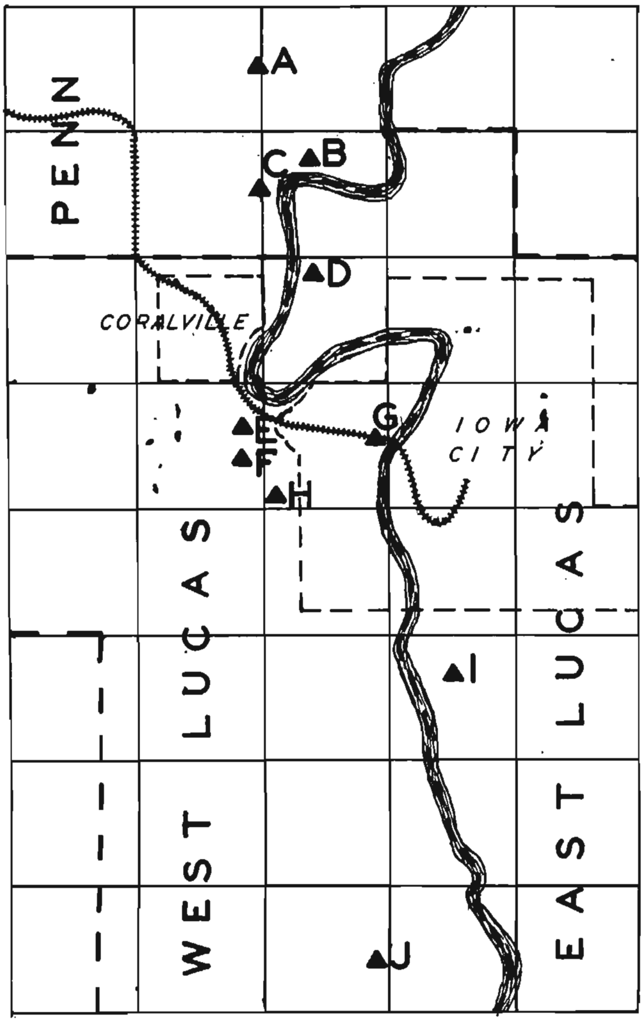


FIG. 12. — Map showing the locations of the Nebraskan exposures in Johnson county.

which case-hardens on exposure to the atmosphere so that it maintains a vertical face, and requires the use of a pick to obtain a sample. The entire section of gravel has been leached of its carbonates and many of the pebbles are extremely weathered, as shown in figure 13. Some of the granites and other igneous rocks fall to pieces during collection and others are cracked so that they can be broken between the fingers. The gravel is well sorted and stratified in thin layers which are separated in places by a thin bed of finer sand or a bed of small pebbles

FIG. 13. — Weathered pebbles from the Nebraskan gravel.

or granules, but in no place was cross-bedding observed. The gravel is very uniform in clastic texture; nothing coarser than three centimeters in diameter was observed and anything larger than one centimeter in diameter is only in the thin beds which are interstratified with the finer material. A mechanical analysis of a sample of average material is given in No. 4 of figure 9. The shape of the various size grades between 1/16 and 32 millimeters in diameter is shown in No. 4 of figure 10, and the rock content, determined by an analysis of pebbles between 16 and 32 millimeters in diameter, is shown in No. 4 of figure 11.

Another exposure of Nebraskan gravel is in the southwest quarter of section 22, East Lucas township (T. 79 N., R. 6 W.), Johnson county, at I in figure 12, along the east side of the Iowa river valley, one mile south of Iowa City. The best exposure is in a gravel pit, but the gravel is exposed also in a ditch a short distance to the north and in a gully east of the pit. All of these exposures are at the same elevation, 650 feet above sea level.

In the best exposure there is 15 feet of gravel, highly oxidized and leached of its carbonates. The gravel is overlain by 6 feet of Peorian loess and there is some evidence of a thin band of Loveland loess separating them.

In general this exposure is similar to that of the interurban cut. The beds are highly oxidized to a dark reddish-brown (11'i, Hazel), the iron oxide forming a mass more compact than that in the interurban cut exposure, since material has been recently removed and very little case-hardening has developed. A comparison of the analysis No. 3 and No. 4 of figure 9 shows that this exposure has a greater size range than No. 4. The exposure contains a greater percentage of material between 4 and 16 millimeters in diameter and also six large boulders between 25 and 40 centimeters in diameter within the gravel and unrelated to the stratification. A shape analysis is shown in No. 3 of figure 10, and a rock analysis in No. 3 of figure 11. The gravel is well stratified, the lower half being in a horizontal position, truncating the upper half, which dips at an angle of about 45 degrees.

Another interesting exposure of Nebraskan gravel is in the southeast quarter of the northeast quarter of section 8, West Lucas township (T. 79 N., R. 6 W.), Johnson county, in a ravine along the south side of the Finkbine golf course, at F in figure 12.

This gravel is at an elevation of 665 feet above sea level in a region of loess mantled erosional topography. The upper surface, which is at the Nebraskan gumbotil horizon, is about half way between the valley bottom and the divide. Here the section is as follows:

	Feet
4. Loess, buff, leached (Peorian)	7
3. Gumbotil, gray, containing more gravel with increase in depth until it grades into gravel (Nebraskan)	5
2. Gravel, well stratified, slightly oxidized, leached (Nebraskan)	12
1. Gravel, well stratified, slightly oxidized, unleached (Nebraskan)	3

The gravel of this exposure differs from that of the exposures previously described chiefly in the limited amount of alteration which it has undergone. The iron oxide colors it to a light-buff (15'1, Hazel), but is not sufficient to form a cement. Thus the uncemented beds slump readily and conceal the lower portions of the cut. Disintegration has not been as effective as in the other exposures described, and leaching has removed the carbonates below the gravelly gumbotil to a depth of only 12 feet, below which the gravel effervesces freely from both primary and secondary calcium carbonate. Since the other exposures of Nebraskan gravel show greater alteration, it seems probable that the impervious layer of overlying gumbotil has checked the descent of ground water, and thus has lessened the amount of chemical weathering. The gravel shows good horizontal stratification with some cross-bedding. The size, shape, and rock analysis are shown in No. 2 of figures 9, 10, and 11, respectively.

There is another exposure of Nebraskan gravel on the Finkbine golf course at E in figure 12, in the northeast quarter of section 8, West Lucas township (T. 79 N., R. 6 W.), Johnson county.

This exposure it at the same elevation as the exposure described above, 665 feet above sea level. The material resembles that which has been previously described, and the analysis of the size, shape, and rock content are shown in No. 1 of figures 9, 10, and 11, respectively. The gravel exposed is 8 feet thick, leached and highly oxidized. It is overlain by Peorian loess.

During excavation for the new football stadium, at H in figure 12, the Nebraskan gumbotil surface was exposed in several places. The relationship between the till and gravel was similar to that of other exposures. At some places the gumbotil occupied the surface, at others the gravel, and between there was generally a narrow gradation zone from one to the other. This exposure shows the relation of the till to the gravel on a horizontal surface. The elevation of the Nebraskan surface at this location is 665 feet above sea level. This section has been fully described by Kay and Apfel.[27]

A small pocket of gravel in the Nebraskan till occurs at Lovers Leap, D in figure 12. Slumping and vegetation have made a study of the exposure impossible.

In Delaware county, Nebraskan gravel is exposed 1 1/4 miles north of Manchester, in the northeast quarter of section 17, Delaware township (T. 85 N., R. 5 W.), in the valley of Honey Creek.

This is a region of gently rolling Iowan drift topography and the gravel occurs 15 feet above the level of Honey Creek, at an elevation of 985 feet above sea level, the same elevation as the Nebraskan gumbotil exposed in a road cut one-eighth mile farther north.

The gravel is colored to a dark reddish-brown (11'i, Cinnamon-Rufous) by the extreme oxidation of the iron compounds, which coat the grains and cement them into a compact mass which hardens on exposure to the atmosphere and maintains a vertical face. Leaching has removed the carbonates from the entire 15 feet of gravel, and many pebbles are extremely weathered. The exposure shows a wide size range in the material; most of the gravel is below 2 centimeters in diameter, although there are thin beds which consist almost entirely of pebbles ranging between 2 and 10 centimeters in diameter. Pebbles, cobbles, and boulders are distributed throughout the mass with no relation to the stratification. A mechanical analysis of a sample of average material is shown in No. 5 of figure 9. The material is well stratified in a general horizontal bed. Although no cross-bedding is present, the absence may be due to the extreme oxidation and leaching which tends to obliterate the finer structure.

27 Kay, G. F., and Apfel, E. T., The Pre-Illinoian Pleistocene Geology of Iowa: Iowa Geol. Survey, Vol. XXXIV, pp. 153-154, 1929.

The percentage of rounding of the grains in the different size grades is shown in No. 5 of figure 10, and the rock content, determined from a pebble count, is shown in No. 5 of figure 11. Stratigraphically, the gravel lies above limestone and below leached till.

Another exposure of Nebraskan gravel is in a pit in the southeast quarter of the southwest quarter of section 8, Windsor township (T. 94 N., R. 9 W.), Fayette county, about 6 miles west of West Union. The exposure occurs within the Iowan drift area, in which there is a relief of more than 100 feet, the upper one-third the result of irregular distribution of the Iowan drift and loess. The Nebraskan gravel deposit is only a few feet above the valley bottoms, at an elevation of 1050 feet above sea level.

This gravel is very much like that previously described. It is colored to a dark reddish-brown (11'i, Cinnamon-Rufous) and cemented into a compact mass by the iron oxide. The carbonates have been leached from the entire 10 feet of gravel exposed, and weathering has disrupted many of the rocks. Size, shape, and rock analysis are given in No. 7 of figures 9, 10, and 11. The overburden consists of Iowan till about 30 inches thick. No contact at the base of the gravel was exposed.

In Chickasaw county the Nebraskan gravel is exposed in the northeast quarter of the southwest quarter of section 31, Dresdon township (T. 94 N., R. 12 W.), along the east side of primary number 59 and of the valley of the Wapsipinicon river.

The gravel occurs only a few feet above the valley flat of the river, at an elevation of 1045 feet above sea level, in a region of gently rolling Iowan drift topography.

The gravel is highly colored to the usual reddish-brown (11'k, Hazel) by the extreme oxidation, which also cements the grains into a compact mass. Leaching has removed the carbonates from all of the 12-foot exposure. Many of the rocks such as granite are weathered so that they crumble readily by slight pressure, and others are cracked so that they can be broken between the fingers. The deposit consists of two members, both the same age, separated by a pebble band which consists of a layer of pebbles. The upper 4-foot member consists entirely of sand, well stratified in horizontal beds. The lower member resembles more nearly the other exposures of Nebraskan gravel. It is 8 feet thick, well stratified, and contains a small amount of cross-bedding. Aside from the 20 boulders which lie in the bottom of the pit there is practically nothing coarser than 3 centimeters in diameter, and the pebbles are all within the pebble band and the lower member of the deposit. A size analysis of the average material of each member is given in No. 8 of figure 9; (A) represents the lower member and (B) the upper member. The shape of each size grade of the upper and lower beds is shown in figure 10, number 8A the lower bed, and 8B the upper bed. The shape analyses of the size grades coarser than 4 millimeters in diameter in 8B are missing, since there was no material of these size grades in that bed. A rock analysis, determined by a pebble count, is shown in No. 8 of figure 11. This analysis is for the lower member only.

Weathered Nebraskan gravels are exposed in Washington and Louisa counties at locations about 2 miles apart. Within this area there are also several exposures of Nebraskan till by which Schoewe [28] has determined the elevation of the old Nebraskan gumbotil plain to be between 620 and 640 feet above sea level. The first of these two exposures of gravel is located in the extreme southeast quarter of section 36, Iowa township (T. 77 N., R. 6 W.), Washington county. The second exposure is in the northwest quarter of the southwest quarter of section 8, Union township (T. 76 N., R. 5 W.), Louisa county. Neither of the exposures is more than one-half mile from the Iowa river and both are only a few feet above the level of the stream.

Schoewe [29] states that the two gravel sections are very much alike, differing only in a few minor details. He describes the section in Washington county as follows:

	Feet
3. Light ash-colored drift	10
2. Leached and oxidized sands and gravels	20
1. Dark bluish calcareous drift; compact, unoxidized, and containing small pebbles	4

"Towards the base of the sand and gravel deposit, the gravels predominate. The textural range of the gravels is rather high, the pebbles varying from small fragments the size of a pea to pieces several inches in diameter, the finer material, however, being in excess. The gravels are cross-bedded.

"The sands are highly oxidized and have a brownish color, are fairly fine and have a low textural range. In structure they are highly contorted,

28 Schoewe, W. H., The Origin and History of Extinct Lake Calvin: Iowa Geol. Survey, Vol. XXIX, pp. 49-222, 1924.

29 Schoewe, W. H., Interpretation of Certain Leached Gravel Deposits in Louisa and Washington Counties, Iowa: Proc. Iowa Acad. Sci., Vol. XXVI, pp. 393-398, 1920.

dip at high angles, are cross-bedded and at places, especially in the middle of the deposit, are more or less horizontal. A lens and pocket structure is conspicuous throughout the exposure in which occasionally leached mud or clay balls are found.

"Although but ten feet of the ash-colored drift is exposed, the slope of the hill is covered by drift to a height from forty to fifty feet above the section. The exposed portion of the till contains limestone pebbles and is filled with many concretions. Higher up the slope of the hill, the drift is leached. The entire outcrop is from 150 to 250 feet long.

"The other section differs but little from the one just described, except that it contains less gravel and no drift is exposed beneath the sands. However, it contains near the base several thin leached layers of till from one to two feet thick. Here and there, a well weathered limestone pebble occurs in it, nor are lime concretions entirely wanting.

"On the whole, the stratification of the sands and gravels of the exposure in Louisa county is more horizontal than that of the one in Washington county. Barometric readings show that the two sections lie approximately at the same elevation, namely, from 620 to 630 feet above sea level. The length of the second outcrop is the same as that of the first and the exposure is forty feet high."

A mechanical analysis of an average of the material from the exposure described above, in Washington county, shows that the percentages of the different size grades are very similar to those in the exposure at F in figure 12, on the south side of the Finkbine golf course (No. 2 of figure 9). Like the other exposures of extremely weathered gravel there is considerable rounding of the grains by solution; also many of the rocks such as granites are so weathered that they crumble easily, and others when broken show a weathered band at the surface. All of the limestones and dolomites have been removed by solution.

Gravels in the Afton Junction-Thayer Region

Until the importance of Nebraskan gumbotil as an Aftonian horizon marker separating the Nebraskan till from the Kansan till was recognized a few years ago, other materials were emphasized as bases for separating the Nebraskan till from Kansan till. Chief among these criteria were weathered sands and gravels and peats lying between the two oldest tills. Type sections of the two oldest tills separated by gravel are in the region of Afton Junction and Thayer in Union county in southwestern Iowa, the location of which is shown in figure 8. In fact, the Aftonian gravels in this part of the state are so well known by students of Pleistocene geology that one hesitates to state that a restudy of these famous exposures and other exposures in the same region has revealed evidence which seems to justify further discussion of the origin and relationships of these gravels, and to warrant questioning some of the former interpretations.

From the time the gravel pits of this area were opened more than 35 years ago and their interesting characteristics revealed, they have been visited by many glacial geologists of America and of Europe. Some persons have come merely to see the type sections of the two oldest tills, now known as the Nebraskan and the Kansan, separated by the gravels which for many years have been called the Aftonian interglacial gravels; others have come to study carefully the characteristics of the tills and gravels and their inter-relationships. The most important contributions dealing with these gravels and associated deposits have been made by Dr. T. C. Chamberlin, Dr. H. F. Bain, and Dr. Samuel Calvin.

The chief gravels are exposed in three gravel pits in Jones township and a gravel pit in Union township, Union county, figure 14. One

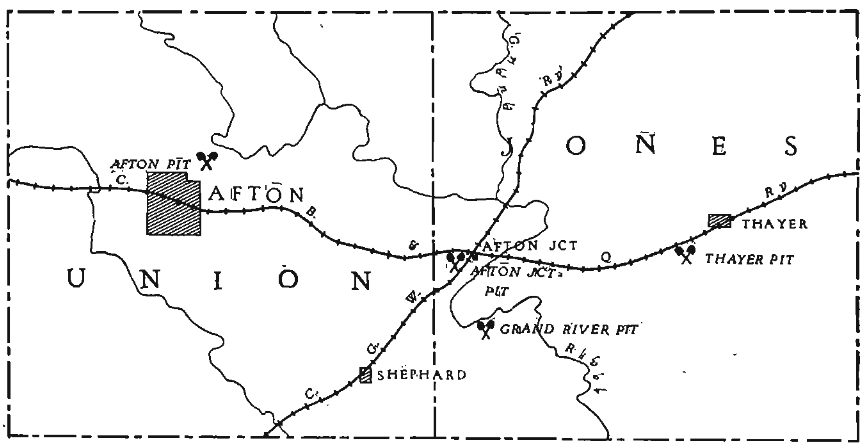


FIG. 14. — Map showing locations of Nebraskan gravel exposures of the Afton Junction-Thayer region in Union county.

pit, known as the Afton Junction pit, is about 200 yards west and somewhat south of Afton Junction station on the Chicago Great Western railway, and of the Great Western Crossing on the Chicago, Burlington and Quincy railway; a second pit, called the Grand River pit, is on the south bank of Grand River more than a mile southeast of Afton Junction station; the third pit in Jones township, the Thayer pit, is about three-fourths mile southwest of Thayer station. All of these pits have been abandoned for more than 30 years. Northeast of Afton, Union township, a pit was opened only recently and from it gravels are still being taken. This will be called the Afton pit.

In an earlier part of this report there is a discussion of these most interesting gravels, including the evidence upon which they were differently interpreted by different authors. Here it is sufficient to say that Chamberlin interpreted the gravels to be kame-like deposits on the surface of the Nebraskan drift and related in age to this drift. Bain referred to evidence of lateral transition from gravels into boulder clay and suggested the possible contemporaneity of the gravels with the Kansan till. Calvin, in 1905, interpreted these gravels to be deposits made by torrential floods during the retreating stages of the pre-Kansan ice. Later, in 1908, as a result of studies by himself and Shimek of gravels and their included fossil faunas in western Iowa, Calvin suggested a modification of his former view regarding the origin of the Aftonian gravels in the Afton Junction-Thayer region. He expressed the judgement that the most satisfactory interpretation of the gravels is that they are strictly interglacial in age, having been deposited during the progress of the Aftonian interval, neither at its beginning nor at its end.

Recent extensive studies of these type sections of gravels and tills in Union county and studies also of the relations of gravels to tills and gumbotils in several other counties in southwestern Iowa have shown clearly that these gravels were not deposited within the Aftonian interglacial epoch to constitute a distinct stratigraphic horizon separating the Nebraskan till from the Kansan till. Although some of the gravels do lie on the surface of the Nebraskan till and are related in age to this till the gravels as a whole are not limited to the surface of the Nebraskan till. There are lenses and irregularly shaped masses of gravels in the Nebraskan till and these gravels are comtemporaneous in age with the Nebraskan till. Moreover, there are many inclusions of the Nebraskan gravels in the overlying Kansan till, and it is thought that some gravels in the Kansan till are contemporaneous in age with that deposit.

Three sections in the Afton Junction region show clearly the relationships of the Aftonian gravels to the Nebraskan till. The sections are located as follows:

1. In the Afton Junction pit in the northwest quarter of the southwest quarter of section 19, Jones township (T. 72 N., R. 28 W.), Union county. This pit is about 200 yards west and somewhat south of Afton Junction station on the Chicago Great Western railway, and of the Great Western crossing of the Chicago, Burlington and Quincy railway.

2. A road cut in the southwest quarter of section 7, Union township (T. 72 N., R. 29 W.), Union county.

3. In the Afton gravel pit in the northeast quarter of section 16, Union township (T. 72 N., R. 29 W.), Union county, northeast of Afton.

A section in the southwest corner of the old Afton Junction pit shows till and related materials. The section is about 200 yards south of a railroad cut in the base of which, many years ago, Aftonian gravels were exposed and were described by Calvin. With reference to the Aftonian gravels in this railroad cut it is worthy of note that Frank Leverett reports that more than 25 years ago he and Douglas Johnson found near the west end of the cut some carbonaceous material overlying the gravels and underlying 30 feet or more of Kansan till. The elevation of the surface of these gravels, it is well to emphasize here, is less than 10 feet lower than the top of the section in the Afton Junction pit. The elevation at the top of the section to be described is about 1120 feet above sea level. The section in the southwest corner of the Afton Junction pit is as follows:

	Feet
4. Loess, leached	11
3. Gumbotil, Nebraskan, compact, dark drab to chocolate color, reddish on dry surface, few siliceous pebbles, leached	6
2. Till, Nebraskan, gray to drab, leached, compact, grading below into less compact, more yellowish colored till and gravelly till	5
1. Gravelly till, oxidized, leached	3

Below the lowest part of the section there is considerable slump, but the chief gravel which was taken from this pit years ago was below the base of the above section.

Only about 50 yards to the east of this section there is a steep slope in the south part of the pit. Here the following section was taken. The top of the section is at the same elevation as the top of the section which has just been described:

	Feet
4. Loess, leached	10
3. Till and gravelly till, Nebraskan, the gravel highly oxidized, upper three feet very gravelly and chocolate-colored, leached	13
2. Till and gravelly till, Nebraskan, unleached, the till in part oxidized and in part unoxidized, many concretions	6
1. Gravel, Nebraskan, highly oxidized, many concretions, unleached, in places cemented; exposed	5

The leached and gravelly till in the upper part of this section is related closely to the gumbotil of the adjacent section and to the Aftonian gravel horizon in the railroad cut a short distance to the north. All are at the surface of the Nebraskan drift and are Nebraskan in age. The changes of the original Nebraskan till to gumbotil and of the sand and gravel to its present highly oxidized and leached condition took place during the Aftonian interglacial age and before the Kansan drift was deposited upon them. The chief gravels are at the surface of the Nebraskan till and in lenses and irregularly shaped masses in the Nebraskan till. In quantity the lenses and irregularly shaped enclosed masses of sand and gravel are far more extensive than the masses of sand and gravel at the surface of the Nebraskan till. Only those weathered sands and gravels which separate the Nebraskan till from the Kansan till can be used stratigraphically in differentiating these tills. It is interesting that the gumbotil and the leached gravel at the same elevation as the gumbotil are at approximately the same elevation as an exposure of Nebraskan gumbotil underlain by Nebraskan till and overlain by Kansan till in a road cut between sections 17 and 20, Jones township (T. 72 N., R. 28 W.), on the east slope of Grand River valley, about 1 1/2 miles northeast of Afton Junction. It is interesting also to note that the gravels in the Grand river and Thayer pits have approximately the same elevation as the gravel in the Afton Junction pit.

The second section showing clearly the relationships of the Aftonian gravel to the Nebraskan till is in a road cut about 3 1/2 miles west of Afton and about 1/2 mile southeast of Union County Poor Farm. It is in the southwest quarter of section 7, Union township (T. 72 N., R. 29 W.), Union county. The elevation of the base of this cut is about 1145 feet or 50 feet below the Kansan drift uplands. The cut is more than 100 yards long and is about 18 feet deep in its deepest part. The lower part is in Nebraskan gumbotil and the upper part is in loess. To the south of the road-cut and at a lower level is a stream-cut bluff exposing oxidized drift and gravelly drift. From the top of the road cut down to the level of the stream the section is as follows:

	Feet
4. Loess, yellowish to brownish in color, leached	8
3. Gumbotil, Nebraskan, gray color, few siliceous pebbles, leached	7
2. Gravel and sand, oxidized and leached	10
1. Till, and gravelly, Nebraskan, oxidized and unleached	5

A short distance to the east is a similar section, but here some of the unleached till in the lower part is unoxidized and the gumbotil zone has in it gravelly leached till.

In these sections the sand and gravel are pockets in the Nebraskan till and are of the same age as the till. During the time that the surface till was becoming gumbotil the sand and gravel intimately associated with it underwent extensive oxidation and leaching and became the "Aftonian gravels."

The third section which is to be described and which shows the relation of the Aftonian gravels to Nebraskan till is in the Afton gravel pit in the northeast quarter of section 16, Union township (T. 72 N., R. 29 W.), Union county, northeast of Afton. This pit was opened recently to secure road-making material and is still being used. The pit is at the end of a spur which extends into the flood-plain of Three Mile Creek. This spur has a gentle slope and the gravel is close to the surface. Above the gravel is about 3 feet of oxidized and leached till. The gravel in the deepest part of the pit is between 20 and 25 feet thick. The section exposed is as follows:

	Feet	Inches
9. Till, oxidized and leached	3	
8. Gravel, colored brown (15'i) by iron oxide, leached to a depth of about 18 inches, below which it is highly calcareous, good stratification, within which are cross-bedding, lens and pocket structures. Average thickness	5	
7. Silt, gray (17"b), unleached, well stratified	1	2
6. Silt, gray (17"b), unleached well stratified	1	4
5. Silt, buff like that of No. 7; contact with the underlying gravel is horizontal		10
4. Gravel, stratified in horizontal beds about one-half inch thick, an alternation of oxidized and unoxidized beds	2	
3. Gravel like that above, No. 4, but all dipping at a high angle toward the southeast; contains coarser material, some as large as three centimeters in diameter. Exposed	5	
2. Slumped material which conceals gravel	10	
1. Gravel like that of No. 3	3	

There is very little material in the pit larger than 2 centimeters in diameter except a few cobbles and boulders, the largest having an average diameter of about 35 centimeters. A few clay-balls are found within the coarser gravel. The clastic texture of a sample of average material from the gravel zones is given in No. 9 of figure 10. The perçentage of rounding is shown in No. 9 of figure 11. The lithology, of pebbles between 16 and 32 millimeters in diameter, is shown in No. 9 of figure 12. The elevation at the top of the gravel is about 1130 feet above sea level. About one mile north of the gravel pit in the northwest quarter of section 10, Union township (T. 72 N., R. 29 W.), is an exposure of Nebraskan gumbotil underlain by Nebraskan till and overlain by Kansan till. The elevation of this Nebraskan gumbotil is about 1170 feet above sea level. A similar Nebraskan gumbotil outcrops about one mile south of Afton, also at an elevation of about 1170 feet. This evidence indicates that before erosion of the Nebraskan gumbotil plain began in this area the elevation of the gumbotil plain was about 1170 feet above sea level. This is 40 feet higher than the elevation of the gravel and on this evidence the gravel is interpreted to be part of the Nebraskan drift. In no sense is the gravel Aftonian as previously interpreted.

By way of summary, it may be stated that a study of the relationships of the gravel to tills in the Afton Junction region indicates that most of the gravel deposits of Union county which have been thought by some geologists to have been deposited during the Aftonian interglacial stage and to constitute a distinct stratigraphic horizon separating the Nebraskan and Kansan tills are not of this origin or age. Rather, the chief sand and gravel deposits are lenses and irregularly shaped masses of gravel in the Nebraskan till and contemporaneous in age with the Nebraskan till. They are not of Aftonian age but of Nebraskan age. They lie largely beneath the level of the Nebraskan gumbotil. However, in a few places, as for example in the Afton Junction pit, the Nebraskan gravel, as well as the Nebraskan till, were at the surface of the Nebraskan drift plain during the Aftonian interglacial interval. The surface Nebraskan till became weathered to Nebraskan gumbotil and the surface Nebraskan gravel became weathered to highly oxidized and leached gravel. Later, both oxidized and leached gravel and Nebraskan gumbotil were picked up by the Kansan ice and became inclusions in the Kansan till. Since the Nebraskan gravel which was weathered at the surface and which now separates the Nebraskan till below from the Kansan till above was altered during the Aftonian interglacial age, it may be thought proper to continue to call such deposits "Aftonian gravels," but it is here suggested that the name "Aftonian gravels" be no longer used for the sand and gravel which are of Nebraskan age but which were changed in Aftonian time, but that they be called weathered Nebraskan gravel just as Nebraskan gumbotil is the name given to weathered Nebraskan till, the weathering having taken place in Aftonian time. The weathered Nebraskan gravels do in places separate the Nebraskan till from Kansan till, and hence constitute an Aftonian stratigraphic horizon. But gumbotil, peat, and related materials, rather than gravel, are the most widespread evidence of Aftonian interglacial time.

Other Gravels in Western Iowa

Not only in the Afton Junction-Thayer region but farther north in Western Iowa, gravel and sand have been interpreted to have been deposited in Aftonian interglacial time, and thus to constitute a stratigraphic horizon separating the Nebraskan till from the Kansan till. In recent years the senior author has restudied this area, particularly Pottawattamie, Harrison, and Monona counties and the adjoining counties on the east. The chief purpose of the investigation was to determine whether a restudy of the tills, gravel, and related deposits of the area would permit, in the light of our most recent knowledge of the Pleistocene of southern, southwestern, and northwestern Iowa, a more satisfactory interpretation of the relationships and origins of these glacial materials than was possible when previous studies were made. Considerable additional field work will be necessary before final conclusions can be reached, but thus far the evidence warrants the following tentative statements:

1. The oldest known tills, the Nebraskan and the Kansan, separated in many places by Nebraskan gumbotil of Aftonian age, have been traced as far west as the western parts of Crawford and Shelby counties, less than twenty-five miles from the Missouri river, the western boundary of Iowa. The evidence in hand indicates clearly that both of these old tills formerly extended to the Missouri river and beyond into the state of Nebraska. If it were not for the thick deposits of loess overlying the tills in this region no doubt many additional good sections of them could be seen.

2. In western Iowa it has not been possible to distinguish the Nebraskan till from the Kansan till by differences in color, texture, lithologic composition, or degree of weathering. Only when it is possible to establish the relationship of an outcrop of till and associated gravel to gumbotil or other interglacial material the age of which is known can the definite age of the till and gravel be determined. When the till is overlain by Nebraskan gumbotil or can be shown to lie lower topographically than nearby remnants of the eroded Nebraskan gumbotil plain, then the till generally may be interpreted as being Nebraskan till. If, however, an outcrop of till is overlain by Kansan gumbotil, or if the till has the proper relation topograph-

ically to remnants of the eroded Kansan gumbotil plain, the till may be interpreted as being Kansan till.

3. The sands and gravels of western Iowa have been described by Shimek and Calvin as being Aftonian interglacial deposits separating the Nebraskan till from the Kansan till and related in origin neither to deposits made during the closing stages of the Nebraskan glacial epoch nor to those made during the Kansan glacial epoch. These sand and gravel deposits are thought by the present writers, however, not to represent a distinctive stratigraphic horizon separating the Nebraskan till from the Kansan till, but instead to be lenses and irregularly shaped masses of gravel and sand within a single till, or in two tills or between two tills and to be of no value as evidence for differentiating the two tills. The gravel and sand deposits are unleached and appear to be contemporaneous in age with the tills with which they are associated.

4. Many mammalian fossils have been found in the sand and gravel associated with the tills of western Iowa. Calvin and Shimek believed that these remains were of animals which were living during the time of gravel deposition,which they interpreted as Aftonian and interglacial. But if the sand and gravel deposits are lenses and irregularly shaped pockets related in age to the till with which they are associated, then a somewhat different interpretation of the age of the mammals becomes necessary. At the present time it is impossible to state whether these deposits in which the mammalian remains have been found are associated with Nebraskan till or with Kansan till, since, as stated above, it has not been possible thus far to differentiate Nebraskan till from Kansan till except where the relationships of the till to gumbotil — the age of which is known — have been established. If the gravel deposits in which the mammalian remains have been found should prove to be lenses and pockets in Nebraskan till then the evidence would suggest that the animals are Nebraskan in age. It would be reasonable to assume that the animals were living in front of the Nebraskan ice sheet, which was sometimes advancing and somtimes retreating and out from which sand and gravel were being carried. Remains of mammals became imbedded in the sand and gravel, which later were overridden by or became incorporated in the onward-moving Nebraskan till. If, on the other hand, the sand and gravel containing the mammalian remains should prove to be lenses and pockets in Kansan till, then the suggested interpretation would be that the mammals were living on the Aftonian surface during the advance of the Kansan ice sheet, out from which sand and gravel were being carried. After remains of mammals became imbedded in these sand and gravel deposits, the Kansan ice sheet, which was sometimes advancing and sometimes retreating, incorporated in the Kansan till these masses of sand and gravel in which the remains are found. If these con-

clusions are justified, then this mammalian fauna may not be a strictly interglacial fauna of Aftonian age. It is important to note, however, that the fauna is certainly early Pleistocene — that is, it was closely associated either with the advance of the Nebraskan ice or with the advance of the Kansan ice or with both, as a result of having persisted on the adjacent plains from Nebraskan through Aftonian to Kansan time.

Mammalian remains in the gravel do not of themselves determine whether the gravel is strictly interglacial in age or is of glacial origin, as vertebrate paleontologists are not in agreement regarding the climatic conditions under which mammals such as have been found in these deposits may live. Dr. O. P. Hay is of the opinion that the mammals, the remains of which have been found in gravel deposits of western Iowa, could not have lived in the immediate vicinity of an ice sheet, but must have lived under interglacial climatic conditions. On the other hand, W. D. Matthew believes that in determining the age of gravel and sand stratigraphic evidence can be more safely followed than fossil evidence. In a letter he stated:

"What actually seems to have happened in the Pleistocene was that glacial advances drove the boreal forms southward and compelled them to mingle temporarily with temperate faunas . . . When the retreat of the ice opened up northern territory again, the boreal types were the first to extend their range northward, and then or later retreated from the southern territory they had invaded."

Matthew offers no adverse criticism to the view taken in this paper that the sands and gravels of western Iowa containing the remains of mammals probably were contemporaneous in age with till with which they are apparently closely related in origin.

Relations of the Nebraskan Gravel.

The waters from the melting Nebraskan glacier deposited gravel at the base, within, and at the surface of the till. Following the retreat of the ice, during the early part of the Aftonian interglacial interval, the processes of weathering brought about many changes in those materials at and near the surface; the till was changed to a mature weathered profile (see figure 8). Comparable changes within the gravel are recorded in the leaching of the carbonates, the weathering of many of the igneous rocks such as granites and greenstones, and the high degree of oxidation of the iron compounds. After these changes had taken place and preceding the advance of the Kansan glacier, the old Nebraskan plain was thoroughly dissected by erosion. The gumbotil which had before covered the Nebraskan till surface now remained only on the divides to mark the horizon of that pre-existing surface. The erosion was checked by the advance of the Kansan glacier, which covered the Nebraskan glacial deposits with a thick layer of till, which during the Buchanan interval underwent changes similar to those the Nebraskan had undergone during the Aftonian interval. It is apparent that, undergoing similar histories, the deposits should likewise bear marked resemblances. The only unquestionable method of differentiating the tills and gravels is their relations to the gumbotil plain which at present occupies the uneroded divides of the old erosional surfaces. Since the only deposition on the Kansan in the areas studied is the thin Iowan till, Peorian loess, Loveland deposits and Illinoian till and these are thin and may occupy separate areas, the Kansan gumbotil horizon is near the tops of the present day hills. Likewise, the Nebraskan gumbotil horizon is about 50 feet (the thickness of the Kansan till) lower, generally only a few feet above the valley flats.

Throughout most of the state the correlation of the gravel is simplified to a certain extent because of its tendency to occur at or near the gumbotil horizon, which is relatively flat, dipping gently toward the south. However, in western Iowa the absence of gumbotil exposures and the indistinct relation to the drift sheets make impossible definite correlation by these methods.

Since the Nebraskan gravel deposits are exposed in widely separated areas, it will be necessary to discuss separately the relations of each area.

The type locality within Iowa in which to study the relations of the Nebraskan gravel to the other deposits is in Johnson county, near Iowa City. The relations of the ten exposures shown in figure 5 are given in the following table:

Location	*Elev. above S. L.*	*Material Exposed*
A. Section 29, Penn township	660	Peorian loess Nebraskan gumbotil
B. Quarry north of Coralville	660	Peorian loess Iowan terrace gravel Nebraskan gumbotil with gravel inclusions. Devonian limestone.
C. Between Coralville and Quarry	660	Peorian loess Kansan till Nebraskan gumbotil Nebraskan till Devonian limestone.

D. Lover's Leap	665	Nebraskan gravel Devonian limestone.
E. North side of Finkbine golf course	665	Peorian loess Nebraskan gravel
F. Finkbine golf course 500 yards south of E.	665	Peorian loess Nebraskan gumbotil Nebraskan gravel.
G. Interurban cut west of the Iowa river at Iowa City	670	Peorian loess Loveland loess Nebraskan gravel Fresh Nebraskan till.
H. New University Football stadium	665	Peorian loess Loveland loess Nebraskan gumbotil and Nebraskan gravel Nebraskan till.
I. South of Iowa City, section 22, East Lucas township	640	Peorian loess Nebraskan gravel Devonian limestone.
J. Indian Lookout south of Iowa City	660	Peorian loess Kansan gumbotil Kansan till Nebraskan gumbotil.

As shown by the elevations given in the preceding chart, the surface of the old Nebraskan gumbotil plain was approximately 660 feet above sea level with but little relief. The exposures of gravel are at about the same elevation as the gumbotil, the greatest difference in elevation being 25 feet. If the old Nebraskan plain were reconstructed, using the elevations of the ten locations of the Nebraskan exposures shown in figure 13, the maximum slope required would be 12 1/2 feet per mile or about one-third of one per cent grade.

Since the surface of the Nebraskan drift was a plain, it might be concluded, that the gravel deposits previously described belonged to the same deposit as the gumbotil, if one considered elevation alone; but more conclusive evidence is available. In the exposure F, along the south side of the Finkbine golf course, the gravel lies below and grades upward into a thin bed of Nebraskan gumbotil. In the base of the new University football stadium at H, there is a lateral gradation from the gravel through gravelly gumbotil into gumbotil. As previously stated, whether the surface of the drift be gravel or till, it was subjected to the same processes of weathering which would form comparable changes within them. In exposures such as G and I, in which the gravel occupies a surface position, they are entirely leached of their carbonates, a maximum depth of 16 feet being observed. But in exposure F, where the gravel was overlain by till which probably retarded the chemical action of the ground water, it is leached to a depth of only 12 feet and oxidation is slight. These contacts of the gravel with the gumbotil, both lateral and vertical, eliminate all possibilities of any time of deposition other than that of the deposition of the till.

That the till with which the gravel deposits are associated is Nebraskan and not Kansan is proven by the occurrence of a younger till above the Nebraskan gumbotil. At Indian Lookout, J, there are two gumbotils, the lower one, the Nebraskan, 660 feet above sea level, and the upper, the Kansan, 700 feet above sea level. North of Coralville, at C, the lower gumbotil, the Nebraskan, is overlain by a younger till, exposed for 25 feet, above which it is concealed by vegetation. Thus it may be concluded that the Kansan gumbotil plain was 40 feet higher than the Nebraskan gumbotil at J, and more than 25 feet higher at C.

If the gravel deposits which occur on the surface of the lower till were to be correlated with the younger till, it would necessitate postulating considerable relief on the Kansan gumbotil surface which was not the case, or a minimum leaching of the carbonates to a depth of 30 feet and a maximum of 80 feet. But these postulated depths of leaching are far greater than any observed.

The Nebraskan gravel deposits in Delaware county occur in the valley of Honey Creek at an elevation of 985 feet above sea level, at the same elevation as the Nebraskan gumbotil exposed along the west side of the road one-eighth mile north. Another exposure of Nebraskan gumbotil occurs in the same valley 3 1/2 miles farther north, at about the same height above the stream level as the first exposure of Nebraskan gumbotil and the Nebraskan gravel. If the surface of the Nebraskan gumbotil plain were reconstructed from these exposures it would have a gentle slope to the south almost equal to that of Honey Creek,

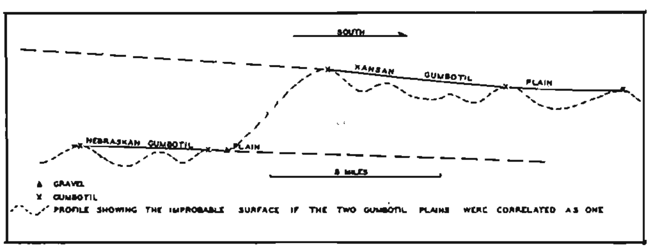


FIG. 15. — Diagrammatic profile showing the relation between the Nebraskan and Kansan gumbotil plains in Delaware county.

which is flowing at grade. Like the gravel, the gumbotil exposure farthest north lies upon the bedrock surface.

Differing in position from the Nebraskan gumbotil deposits previously described which occur in the valley north of Manchester, the Kansan gumbotil occurs on the divides south of Manchester. The relations of the two gumbotil surfaces are shown graphically in figure 15. It is evident from these relations that there are two separate gumbotils and that the gravel deposits are associated with the lower one.

The Nebraskan gravel deposits in Benton county are about 50 feet below the Kansan till surface but no exposures of Nebraskan gumbotil were observed with which to correlate them.

The Nebraskan gravel deposits of Fayette county are below the upland in a region of about 120 feet of relief, the upper one-third a result of irregular distribution of the Iowan till and loess. The Kansan gumbotil is at an elevation of 1110 feet above sea level in comparison with that of the Nebraskan gumbotil at 1040 feet above sea level, and that of the Nebraskan gravel at 1050 feet above sea level. These three exposures are within a radius of half a mile, as shown in figure 16.

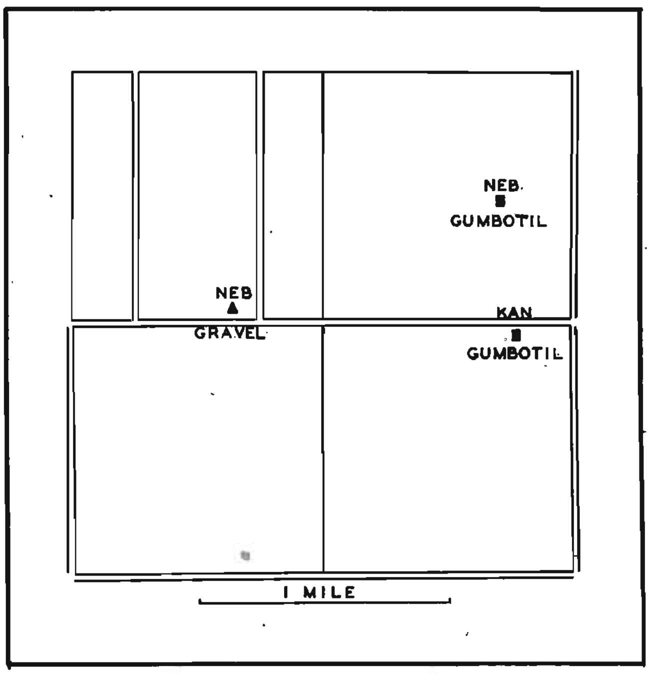


FIG. 16. — Sketch map showing locations of Nebraskan and Kansan exposures.

If the gumbotils were essentially horizontal or sloping slightly, the differences in elevation of the two gumbotil exposures would allow a thickness of about 70 feet for the Kansan drift. Since the gravel occurs at the same elevation as the Nebraskan gumbotil it may be assumed that the two are parts of the same plain. But correlating this gravel mass with the Kansan till would necessitate postulating either a minimum slope on the Kansan gumbotil surface of about 75 feet per mile or, if the surface was a plain as under normal conditions, leaching of the carbonates from 75 feet of overlying material and the 10 feet of gravel. The characteristics of the gravel show that it was deposited at the surface of the till, which would be in harmony with the correlation with the Nebraskan gumbotil plain.

The relations of the Nebraskan gravel of Chickasaw county are similar to those of the preceding exposures. It occurs in the valley, 55 feet lower than the level of the Kansan gumbotil plain which is on the divides. The physical characteristics of the gravel indicate that it was deposited at the surface of a till sheet which would logically be the Nebraskan.

The relations of gravel to associated deposits in western Iowa have been included in the general discussion of these deposits on pages 49 to 58. However, the interpretation of the age of these deposits is based entirely on their relation to the Nebraskan gumbotil plain.

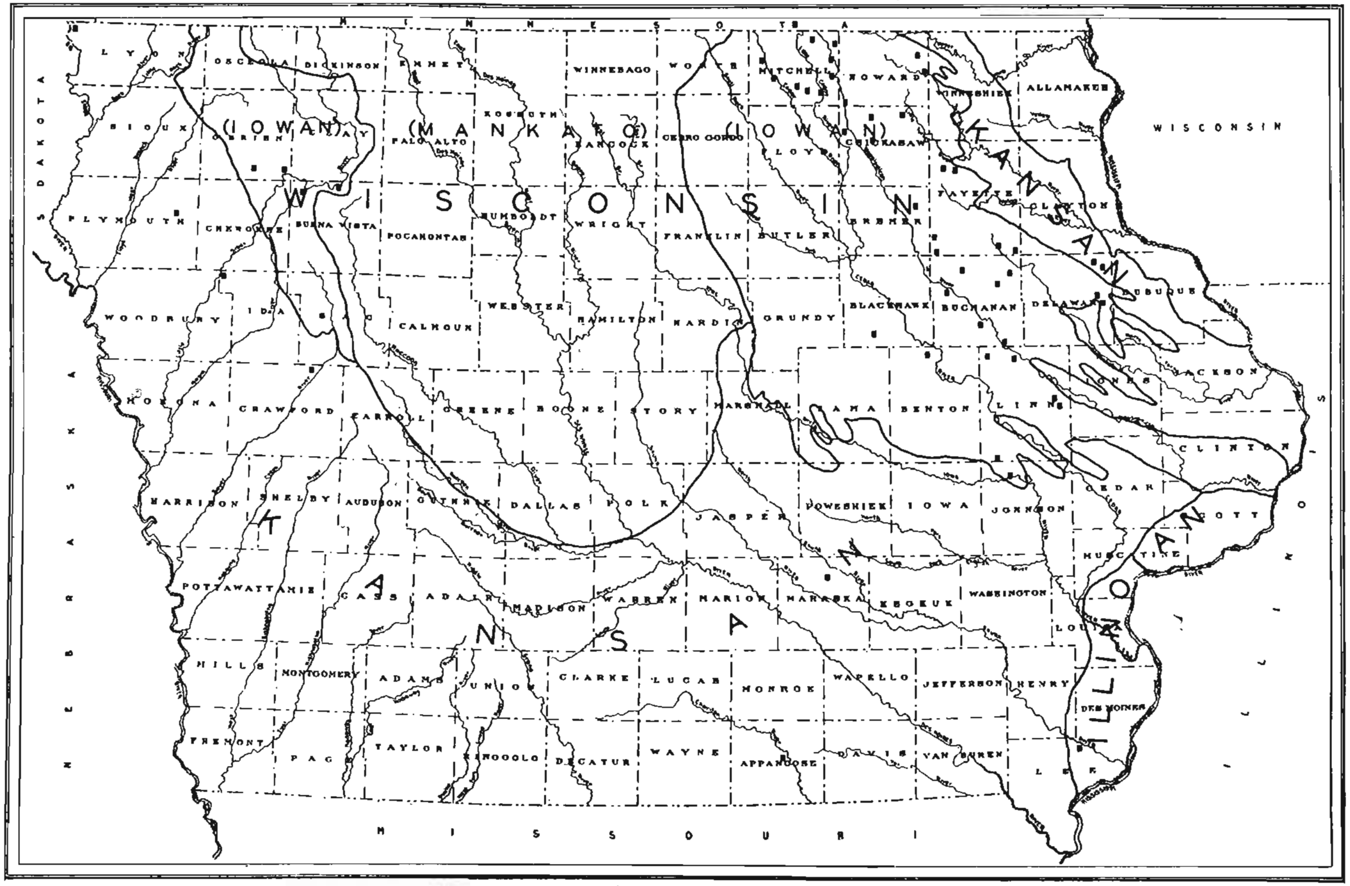
The Gravels of the Ottumwan Series — The Kansan and Yarmouth Stages

The gravels of the Ottumwan series include those deposited during the Kansan glacial age and the Yarmouth interglacial age. In almost all previous discussions these gravels have been referred to as Buchanan gravels.

Calvin,[80] who was the first to use the name Buchanan, made the following statements regarding the term:

"The use of the term Buchanan as a name for an interglacial stage is open to criticism. It came into use tentatively before the recognition of the Illinoian drift as a stage distinct from either Kansan or Iowan had been published, and when the whole period of time between the retreat of the Kansan and the invasion of the Iowan ice was supposed to be a single, uninterrupted, interglacial interval. It was first used in the precise sense

80 Calvin, S., The Interglacial Deposits of Northeastern Iowa: Iowa Acad. Sci., Vol. V, pp. 64-70, 1898, and American Geologist, Vol. XXI, pp. 251-254, 1898.



MAP OF IOWA

FIG. 17. — The squares show the locations of Nebraskan and Kansan exposures.

in which the term Aftonian was originally used, and as a substitute for that term when it was shown that the Aftonian soils and gravels preceded the Kansan stage. Since the recognition of the Illinoian glacial stage the term has been used for the interval following the Kansan in publications by Chamberlin, Calvin and Scott. No great objection to its continued use can be urged; in fact, it is much to be desired that names once introduced should remain undisturbed, but it may after all be a decided gain to Pleistocene geology to select a name for the interval between the Kansan and Illinoian from some locality where true interglacial deposits are clearly intercalated between the Kansan and Illinoian sheets of drift."

It is evident from the preceding reference that as early as 1897 Calvin realized that the old term should be replaced by new terms. In present usage, Buchanan represents that time interval between the retreat of the Kansan glacier and the advance of the Iowan.

The term was originally applied to gravels deposited during the retreat of the Kansan glacier. It did not include those gravels deposited during the Yarmouth interglacial age or the Buchanan interval. Furthermore, more recent investigations reveal that many of the gravel deposits called Buchanan in some of the early reports belong in reality to other ages of deposition. In this paper the "Buchanan gravels" will be described under their time of deposition.

The Distribution of the Gravels of the Kansan Stage

The Kansan gravels in Iowa are distributed throughout the area of Kansan glaciation. Most of the exposures are in gravel pits, but a few are in road cuts or in natural exposures along streams. As shown in figure 17, most of the exposures are in northeastern Iowa. Their absence in certain parts of the state is not always indicative of the absence of the gravel, but may be due either to the overlying material, which is too thick to permit the gravel to be profitably removed, or to the diminutive size of the gravel masses which renders them too small to be of commercial value. However, these small deposits are sometimes exposed in fresh road cuts or along streams. In northwestern Iowa many deposits near the surface of the drift must have been removed by erosion during the Loveland interval.

The Characteristics of the Gravels of the Kansan Stage

General Characteristics:

The Kansan gravels were deposited either as pockets within the till or as outwash at the surface of the till. Most of the exposures studied were deposited either at the surface or as pockets only a few feet below the surface, in either case having the same topographic position as the Kansan gumbotil. However, a few exposures are masses of gravel which were deposited lower down within the drift sheet.

Following the retreat of the Kansan glacier the Yarmouth interglacial age began, during which time the newly exposed drift surface was subjected to the modifying agencies of weathering. The atmosphere and ground water began altering the drift by oxidation and leaching, the oxidation taking place more rapidly and extending deeper than the leaching. In areas which were so situated topographically that there was little if any erosion, the zones shown in figure 8 were developed — namely, gumbotil, oxidized and leached till, oxidized and unleached till, and unoxidized and unleached till. The Kansan till was altered to gumbotil to an average depth of 11 feet. Leaching removed the carbonates from the till to an average depth of about 5 1/2 feet below the gumbotil, and the iron compounds were oxidized to still greater depths. While the till was being altered as described above, the sands and gravels within this zone of weathering were subjected to the same processess and underwent comparable alterations. The coarse texture of the gravel and sand in comparison with the till allowed oxidation to continue more rapidly and to greater depths, and the action of ground water in leaching was not disturbed by the formation of an impervious layer of gumbotil at the surface. The present altered condition of the gravel depends upon its relation to the original till surface.

Most of the exposures occur at and near the Kansan gumbotil plain, and show extreme alteration by both oxidation of the iron compounds and leaching of the carbonates; but the few exposures which occur as masses buried deeply within the till are unleached and may or may not be colored by the extreme oxidation of the iron compounds. The general characteristics will be given separately for each of the above types of gravel.

In the Kansan gravels which are at and near the Kansan gumbotil surface, the iron oxide forms a hard, harsh coating on the grains, colors the gravel to a dark reddish-brown (15'i, Ochraceous-Tawny to 15"i Sayal Brown), and cements it into a compact mass which will stand in a vertical section. After exposure to the air the iron oxide in the outer few inches hardens, making that part of the deposit more coherent. Extreme oxidation of the iron compounds within separate layers cements them more firmly into a weakly coherent conglomerate which can be broken into blocks. Leaching processes have removed the carbonates from all exposures of Kansan gravel of this type. Only those exposures buried deep within the till are unleached. The greatest depth to which the leaching within the Kansan gravel has been observed is about 55 feet. In addition to the complete removal of the more soluble rocks such as limestone and dolomite, many of the granites, greenstones, and other igneous rocks are disintegrated or weathered beyond identification.

The beds of gravel are well stratified in a general horizontal position but include irregularities in the form of lenses, pockets, cross-bedding, clay-balls, and masses of till. Although most of the exposures are well stratified, the poor sorting, the leaching, and the high degree of oxidation give some of them a massive, poorly stratified appearance. The deposits show a wide clastic textural range both within the separate exposures and in the group as a whole. Most of the gravel is smaller than 1.5 centimeters in diameter, although there is also a high percentage between 1.5 and 5 centimeters in diameter. Still larger than the pebbles are cobbles and boulders distributed through the finer material and seldom bearing any relationship to the stratification. Boulders having a diameter between 45 and 60 centimeters are not uncommon, and some have been observed with diameters as great as one meter. The percentage of the different size grades as determined by mechanical analyses is shown graphically in figure 18, each sample used represents an average of the exposure from which it was taken. The exposures represented in figure 18 are the type exposures described later in this report and other exposures included merely for comparison. The shape analyses of the different size grades of the first eight samples given in figure 18 are shown in figure 19. The rock content, determined from pebble counts made from the same exposures as represented in figure 18, is given in figure 20.

The type area in which to study the Kansan gravel is in Mitchell county, Iowa. In no other part of the state are their relations to the Kansan and Iowan tills so well shown. Kansan gravel underlying Illinoian till is best represented in Lee county, and the masses of Kansan gravel which were deposited deep within the Kansan till are exposed in the loess-mantled Kansan area in northwestern Iowa.

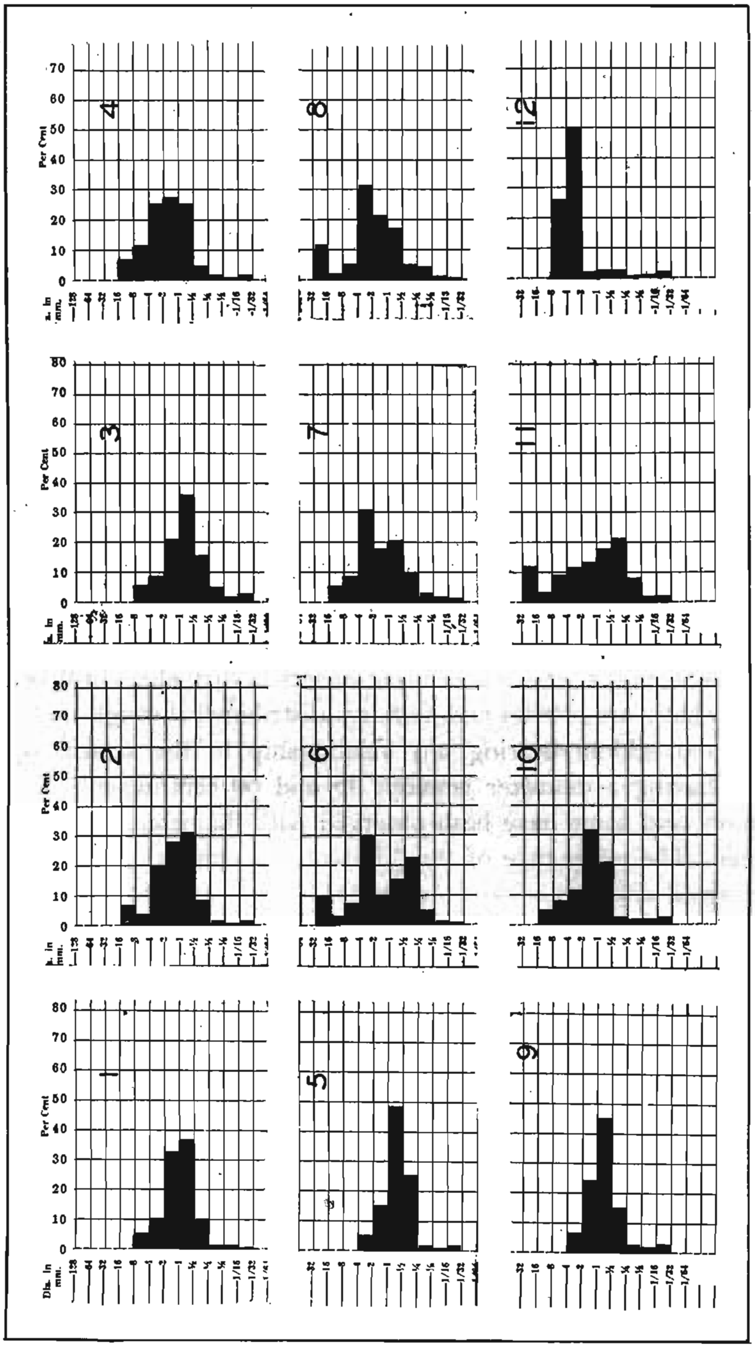


FIG. 18. — Graphs showing mechanical analyses of Kansan gravels. The numbers of this figure correspond with those of figures 19 and 20

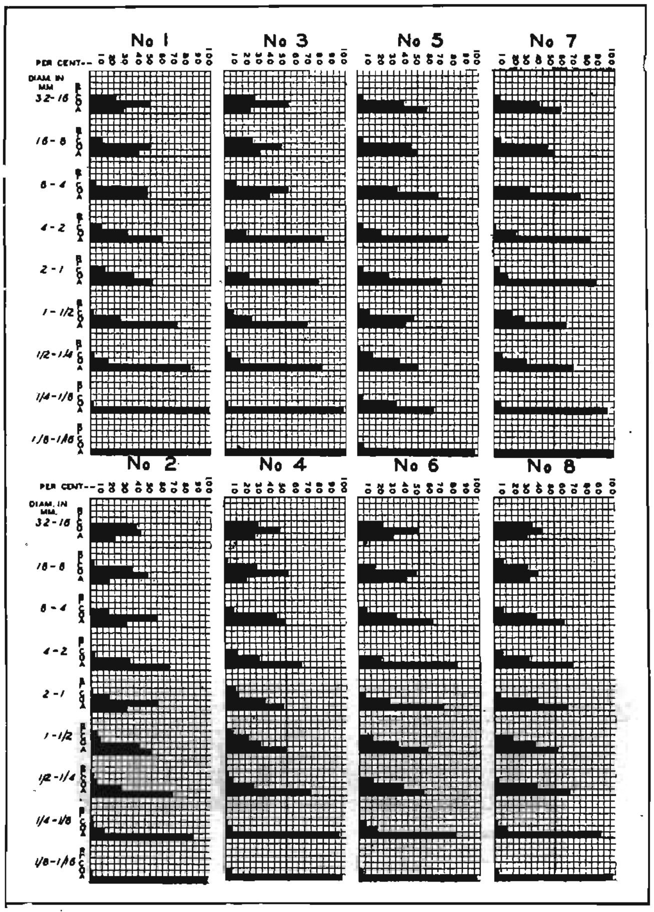


FIG. 19. — Graphs showing shape analyses of each size grade between 1/16 and 32 millimeters in diameter of Kansan gravels. The numbers of these analyses correspond with the numbers of the analyses of figures 18 and 20. R = rounded; r = sub-rounded; C = curvilinear; a = sub-angular; A = angular.

Characteristics of Kansas Gravels in Northeastern Iowa:

The largest pit exposing Kansan gravel is in the southeast quarter of section 21, Burr Oak township (T. 98 N., R. 16 W.), Mitchell county, about 3 miles east of Osage. Here at the top of a low gently sloping rise, at an elevation of 1170 feet above sea level, in a region of gently rolling Iowan drift topography, is the large pit shown in figure 21, which is more than 35 feet deep. The total thickness of the gravel here is 55 feet, as was determined by boring to its base from the deepest part of the pit.

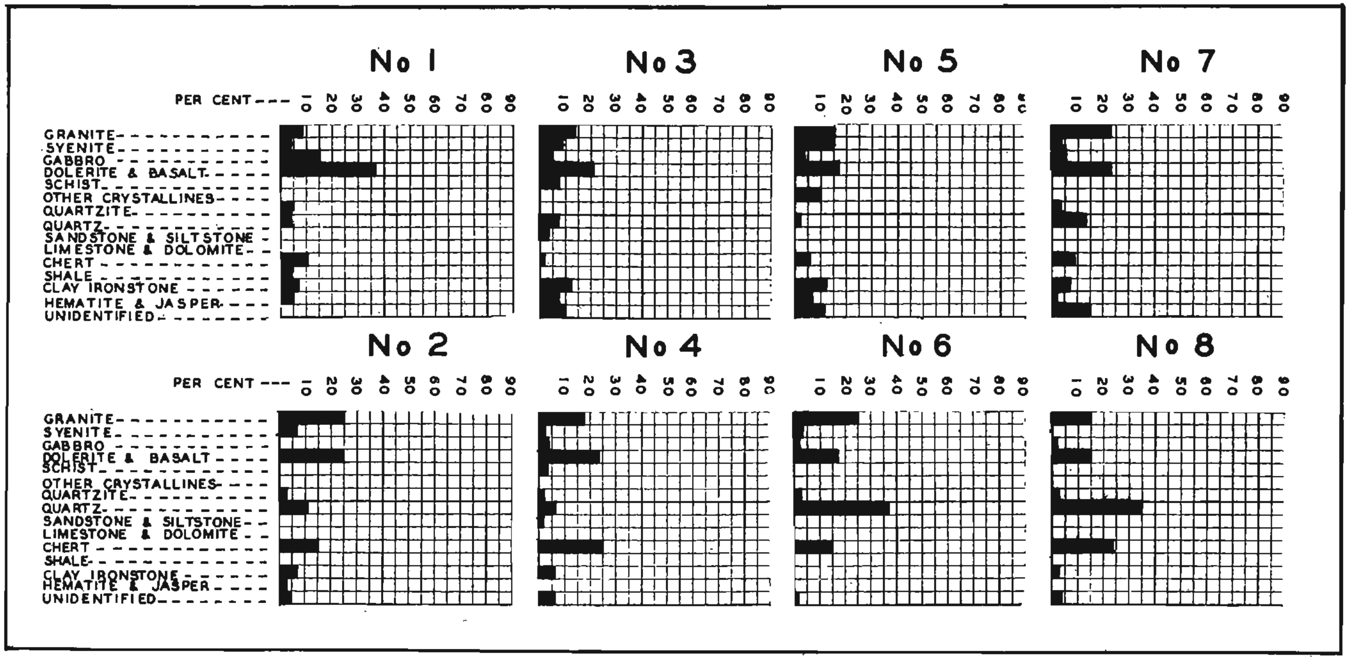


FIG. 20. — Graphs showing lithology of pebbles of Kansan gravel between 16 and 32 millimeters in diameter. The numbers of these analyses correspond with those of figures 18 and 19.

FIG. 21. — Kansan gravel pit about 3 miles east of Osage, Mitchell county.

The gravel is colored by iron oxide to a uniform medium brown (15'i, Ochraceous-Tawny to 15"i, Sayal-Brown) throughout the pit, except in one bed 8 inches thick near the base, which is more highly oxidized to a reddish-brown (12'm, Chestnut) and cemented into a firm mass which can be broken into fragments. Leaching has removed the calcium carbonate from the entire 55 feet of gravel in the section. Many of the igneous rocks are disintegrated and there are some secondary iron concretions. Almost all of the gravel is smaller than one centimeter in diameter. There are several boulders in the bottom of the pit which were uncovered while removing the gravel, most of them smaller than 30 centimeters in diameter. This pit will not average one stone larger than 13 centimeters in diameter to each 2000 yards of gravel. The percentage of each size grade, determined by a mechanical analysis is shown in No. 1 of figure 18. The percentage of rounding of each size grade between 1/16 and 32 millimeters in diameter is shown in No. 1 of figure 19. The lithology of pebbles between 16 and 32 millimeters in diameter is given in No. 1 of figure 20. The gravel shows good stratification in beds which are almost horizontal. Within these beds there is cross-bedding which dips at an angle of about 15 degrees in almost any direction, with the predominating direction southeast. The extreme weathering of the deposit renders the structure indistinct, making it appear almost massive in some parts. The gravel is overlain by a 4-foot layer of weathered Iowan till, leached and colored by iron oxide to a light buff-brown (19"i, Isabella Color) at the base and by the addition of humus to a chocolate-brown (17" ', Wood-Brown) at the surface.

Another deposit of Kansan gravel is in the southeast quarter of the northwest quarter of the same section as the exposure just described. It is at the same elevation (1170 feet above sea level) and there is only a slight sag between them. Here the gravel has been removed to a depth of about 12 feet. The exposed gravel differs from that of the deep pit, which is about one-half mile to the southwest, in that it contains many cobbles and boulders. The stratification is horizontal as in the preceding pit and the greater percentage of the cross-bedding dips toward the southeast.

Another exposure of Kansan gravel in Mitchell county is in the southwest quarter of section 10, Newberg township (T.99 N., R. 18 W.), about 2 miles northwest of St. Ansgar. Here in a gravel pit, near the top of the hill in a region of gently rolling Iowan drift topography, the Kansan gravel is exposed at an elevation of 1178 feet above sea level.

The 20 feet of gravel exposed is leached of its carbonates, colored by oxidation to a medium-brown (15'i, Ochraceous-Tawny to 15"i, Sayal Brown), and cemented into a firm mass. Within the major strata of the gravel there are some thin beds colored black by grain coatings of manganese dioxide, and other much thicker beds, colored a much deeper reddish-brown than the rest of the gravel mass. These beds are cemented into a firm conglomerate. The pebbles show the usual amount of disintegration by weathering and some may be broken easily by slight pressure. Most of the material is sand and fine gravel. The percentage of each size grade is shown in No. 2 of figure 18. The percentage of rounding is shown in No. 2 of figure 19. The lithology is given in No. 2 of figure 20. The gravel is well stratified in almost horizontal beds, and cross-bedding within the major beds dips toward the west. The base of the gravel is exposed in two places. In the north side of the pit the gravel overlies dark-gray till, leached of its carbonates only in the upper 6 inches. In the south side of the pit the gravel overlies limestone bedrock. The over burden is leached Iowan till, 2 feet thick and colored to the usual chocolate-brown by oxidation and humus.

In Mitchell county, about 3/4 mile east of McIntire, in the northeast quarter of section 35, Wayne township (T. 100 N., R. 15 W.), Kansan gravel is exposed along the hillside about 25 feet below the upland, at an elevation of 1300 feet above sea level, in a region of gently rolling Iowan drift topography. The 12 feet of gravel exposed is leached of its carbonates, and exhibits the usual oxidation and weathering. The material consists almost entirely of sand and fine gravel which is well stratified, generally in horizontal beds with some cross-bedding within the thicker beds. The percentage of the different size grades of a representative sample is shown in No. 3 of figure 18. The percentage of rounding is shown in No. 3 of figure 20. There is no visible contact at the base of the gravel with the underlying material, but the top of the gravel is overlain by both Loveland silt and Iowan gravel. The 6-inch bed of Loveland silt lies between the Kansan and Iowan gravels in the south half of the exposure, while along the northern border the silt has been plowed up and incorporated in the base of the overlying Iowan gravel. In the north part of the exposure the Kansan gravel is directly overlain by the Iowan gravel, each having distinctly different characteristics. The Iowan gravel and overlying Iowan till have a combined thickness of about 7 feet and only the upper 5 feet have been leached of their carbonates. The coloring and cementation by oxidation, and the amount of weathering. is much less in the Iowan than in the underlying Kansan gravel. Likewise, the Iowan gravel appears to be poorly stratified, because of the poor sorting of the material, which has an average diameter more than twice that of the Kansan gravel.

About 2 miles north of Osage, in the southwest quarter of section 12, Mitchell township (T. 98 N., R. 17 W.), Mitchell county, Kansan gravel is exposed in a gravel pit at an elevation of 1152 feet above sea level, on a wide flat divide covered with Iowan drift.

The gravel of this pit shows the same general characteristics as the gravel of the pits previously described. They are colored to a medium-brown (15'i, Ochraceous-Tawny to 15"i, Sayal-Brown), and leached to the base of the 20-foot exposure. The material is mostly sand and fine gravel smaller than 2 centimeters in diameter, although there are a few boulders, the largest 60 centimeters in diameter. Size, shape, and rock analyses are given in No. 4 of figures 18, 19 and 20. Along the north side of the pit, below a 2-foot layer of weathered Iowan till, is an exposure of Kansan gumbotil. It is not an inclusion of till but represents the lateral contact of the gravel with the Kansan till which has been altered to gumbotil. This relationship shows that the gravel was deposited as an irregular mass within the till at the surface of the Kansan drift plain.

Another interesting pit in Mitchell county in which Kansan gravel is exposed is along the county road about 3 miles north of Stacyville. in the northeast quarter of section 18, Stacyville township (T. 100 N., R. 16 W.). Here the gravel is exposed along the hillside only a few feet below the upland, in a region of gently rolling Iowan drift topography, 1230 feet above sea level.

The oxidation has colored the gravel to various shades of brown and buff, the color varying with the kinds of material. The carbonates have been leached from the entire 15 feet of gravel, and the usual weathering of the igneous rocks can be observed. The deposit may be roughly divided into two members. The upper 8-foot member consists chiefly of irregularly bedded sand and fine gravel with less oxidation than the average Kansan gravel deposits. It contains three large masses of gumbotil, the largest 15 feet across at the base and 8 feet high as shown in figure 22. The lower bed of gravel is of the usual type in oxidation, leaching, and uniform stratification. Size, shape, and lithologic analyses of average material from the lower 7 feet are given in No. 5 of figures 18, 19 and 20. The gravel

FIG. 22. — Large mass of gumbotil inclosed within the Kansan gravel.

is overlain by a bed of gravelly Iowan till 2 feet thick which is leached and colored to the usual chocolate-brown (17"', Wood-Brown) by oxidation and humus. Kansan gumbotil overlain by Iowan till is exposed in the road cut about 100 feet west of the gravel pit and in another road cut three-fourths of a mile south of the gravel pit, both at the same elevation as the gravel. This relationship of the gravel to the gumbotil plain shows that the gravel was deposited as a pocket at the surface of the Kansan till.

In Minnesota, a short distance north of the Iowa boundary, is a large pit in Kansan gravel. It is in the northwest quarter of section 23, Mower township (T. 10 N., R. 17 W.), Adams county 6 1/2 miles northwest of Stacyville. The gravel is exposed at an elevation of 1260 feet above sea level, a few feet below the upland of gently rolling Iowan drift topography.

The coloring by oxidation varies throughout the exposure; in some parts where the material is almost entirely quartz sand, coloring is seldom darker than light-buff, but in other parts of the exposure where other kinds of rock are present the gravel is colored to various shades of brown. The material consists chiefly of sand and fine gravel, well stratified and with considerable cross-bedding. Nothing observed in the pit was coarser than 12 centimeters in diameter. Size, shape, and lithologic analyses are shown in No. 6 of figures 18, 19, and 20. In the south side of the pit the beds of Kansan gravel have been folded and crumpled by the overriding Iowan glacier. Sand and till were deposited in the troughs and some of it is still unleached. Near the southeast corner of this pit there was in 1927 about 6 feet of calcareous sand, gravel, and till interlayered with leached materials of like kind, which represents the Iowan drift deposited in this area. There were 22 feet of leached sand and gravel exposed below the Iowan calcareous material.

In addition to the pits already described five other Kansan gravel pits having similar characteristics were studied in Mitchell county. In these, no contacts with associated materials were observed other than the thin layers of oxidized and leached Iowan till which usually overlie the gravel within the Iowan area. The most significant feature of these exposures is their comparable elevation, topographic position, and physical characteristics, which enable them to be correlated with the Kansan exposures previously described.

As will be shown in the following descriptions, the characteristics of the Kansan gravels in other parts of northeastern Iowa are similar to those of Mitchell county.

One of the exposures of Kansan gravel in Howard county is in the southwest quarter of section 26, Vernon Springs township (T. 99 N., R. 11 W.), in the south side of Cresco. Here the Kansan gravel is exposed in a gravel pit on the upland at an elevation of 1280 feet above sea level, 25 feet lower than the Kansan gumbotil exposed 2 miles to the northwest.

The 20 feet of gravel exposed in this pit is uniformly colored to a medium-brown (15'i, Ochraceous-Tawny to 15"i, Sayal-Brown) by the iron oxide which cements the gravel into a compact mass that stands as a vertical wall. Leaching has removed all of the carbonates, and weathering has disintegrated many of the granites, greenstones, and other igneous rocks. The deposit is chiefly sand and gravel smaller than 3 centimeters in diameter, deposited in horizontal beds which contain some cross-bedding. Several boulders, the largest having an average diameter of 75 centimeters, are scattered through the gravel mass. A mechanical analysis of the material is shown in No. 7 of figure 18, and the percentage of rounding is shown in No. 7 of figure 19. A rock analysis, is given in No. 7 of figure 20. The gravel lies between limestone bedrock, which is exposed in the base of the pit, and oxidized and leached Iowan till which has a maximum thickness of about 5 feet.

About 1/2 mile north of Fairbanks, in the northwest quarter of section 33, Oran township (T. 91 N., R. 10 W.), Fayette county, Kansan gravel is exposed in a pit located near the upland at an elevation of 1020 feet above sea level, in a region of gently rolling Iowan drift topography.

The gravel of this 15-foot exposure is similar to that of exposures previously described, except that it contains numerous ironstone concretions and several irregular masses of till that have been altered to gumbotil. The size, shape, and lithologic analyses are given in No. 8 of figures 18 to 20. In the underlying material, in a tile ditch at the base of the north side of the pit, the upper 3 inches is leached of its carbonates and resembles gumbotil, but below this the till is dark-gray (15"'', Mouse-Gray) and neither leached nor oxidized. The overburden is weathered Iowan till only 2 feet thick.

Characteristics of Kansan Gravels in Southeastern Iowa:

In part of southeastern Iowa the Kansan deposits are overlain by the thick layer of Illinoian drift and the still younger Peorian loess. Here in a small valley in section 20, Denmark township (T. 69 N., R. 4 W.), Lee county, is a pocket of Kansan gravel with its relations to the surrounding Kansan drift and younger overlying Illinoian drift clearly exposed.

This Kansan sand and gravel deposit is 30 feet thick and shows a distinct difference between the material of the lower 8 feet and that of the upper 22 feet.

The lower 8 feet of the exposure has a distinct blue-black color when moist, with only slight variations throughout its thickness. The material is fine sand except for one 6-inch bed which contains coarser sand but no gravel. The sand is well stratified in very thin beds in which small folds have been developed in many places. In the structure, also, there are minor irregularities such as lenses and cross-bedding. The only coloration by iron oxide is faint concentric bands that have no correlation to the general structure.

The upper 22 feet of the exposure is coarse sand and fine gravel including only a small percentage of pebbles. Nothing larger than 5 centimeters in diameter was observed and pebbles larger than 2 centimeters in diameter are not common. The stratification is good but lens structure and cross-bedding are common within the major beds. In the upper 3 feet an increase in the percentage of clay and of pebbles scattered through the gravel gives it a more massive structure. Oxidation of the iron compounds colors the gravel reddish-brown (15"m, Bister), and cements it into a compact mass in the lower 19 feet, while in the upper 3 feet the oxidation is greater and cements the gravel into a firm, friable conglomerate. The greater oxidation of the upper 3 feet of gravel appears to be the result of its having a higher percentage of clay than the lower 19 feet has, the clay being more readily oxidized, and the clay and iron oxide filling the interstitial space.

Leaching during the Yarmouth interglacial age, before the deposition of the Illinoian drift, has removed the carbonates from the entire 30 feet of gravel. However, the underlying Kansan till is blue-black when moist, and unleached. No distinct line separates this till from the overlying sand, but between them is a sandy till gradation, about 6 inches thick, which is not entirely leached. Descending ground water has carried calcium carbonate from the unleached Illinoian drift above and deposited it as secondary lime concretions in the upper few feet of both the leached Kansan gravel and the till. Marginally, where observed, the gravel grades into the Kansan till, which contains a carbonaceous layer about one foot thick at its surface. This carbonaceous zone represents what was an old soil surface during Yarmouth interglacial time and it likewise shows that the Kansan gravel was at or near the surface of the Kansan till during this interval and thus subjected to the same weathering processes as the till.

Characteristics of Kansan Gravels in Northwestern Iowa:

In northwestern Iowa, the erosion during the interval following the development of the Kansan gumbotil and before the coming of the Iowan glacier removed the gumbotil and leached Kansan drift, leaving at the surface oxidized and unleached drift upon which the Iowan drift and loess deposits were laid down. This erosion removed any gravel deposits which like those described in eastern Iowa were deposited at or near the surface of the Kansan drift. Thus the unleached Kansan drift left at the surface upon which the younger deposits, also unleached, were deposited makes it difficult to differentiate between the Kansan and younger Iowan drifts. Throughout most of the Kansan drift area the overlying deposits of Iowan drift or loess, or both of them, bury the Kansan to such a depth that there are few Kansan exposures either artificial or natural. This likewise limits the number of Kansan gravel exposures, which in their unleached condition as pockets in the Kansan till are difficult to differentiate from the Iowan gravel. This difficulty is overcome in the loess-Kansan area beyond the Iowan drift region.

During the field seasons of 1909 and 1910, and parts of the field seasons of 1911, 1913, 1916, and 1927, Carman [31] made an intensive study of the Pleistocene deposits in northwestern Iowa. In his report on this area he describes several exposures of Kansan gravel, most of which are completely obscured by slump and growth of vegetation at the present time, but even in those studied it seems unnecessary to attempt to improve upon his descriptions. He describes them as follows:

31 Carman, J. E., Further Studies on the Pleistocene Geology of Northwestern Iowa: Iowa Geol. Survey, Vol. XXXV, pp. 111-114, 1931.

"There is in the till of northwestern Iowa a large quantity of gravel and sand in the form of inclosed masses (gravel bowlders). These are known in both the Kansan and Iowan drift regions and are apparently inclosed in both the Kansan and Iowan tills, although it is not possible in most cases to distinguish these tills. These gravel masses were observed in cuts and in the fresher and steeper valley-side exposures. When they are penetrated by bored or drilled wells they are usually reported as gravel layers, but in dug wells their true nature is revealed in most cases. Most wells which stop in gravel masses fail to furnish an adequate supply of water.

"The gravel masses range in size from small pockets a few inches across to huge masses 10 to 20 feet or more in diameter. Common dimensions are three to six feet. A mass exposed in a railway cut in section 6 of Douglas township, Ida county, about 1 1/2 miles south of Washta, is about 35 feet by 20 feet on the face of the cut and another in a Chicago and Northwestern railway cut just east of Sioux Rapids is 20 to 25 feet across.

"Most of the sand and gravel masses are roughly equidimensional or compressed in a vertical direction, but some are irregular in shape. Most of them have a rounded form, but several were seen with corners projecting into the till in such ways as could have been assumed only when the gravel masses were frozen.

"The sand and gravel of the bowlders are, as a rule, stratified. The beds range in position from approximately horizontal to vertical, and locally the layers are contorted. The bedding of a particular bowlder is usually a unit, but a few cases were observed which show faulting and some crushing, and in many cases the bedding is obliterated at the margins of the mass.

"The material of these bowlders is sand, fine gravel, and some silts. Most of it is slightly ferruginous so that an iron-stained dust is released when the gravel is displaced. There are a few masses composed of strongly rusted gravel. In general, the coarse gravel is rusted and partly decomposed, while the finer material is fresh and unaltered. The coarse-grained igneous pebbles are more decomposed than the finer-grained ones and the darker colored varieties (containing mica and hornblende) more than the lighter colored. Most limestone pebbles are altered slightly at the surface and a few are altered to the center or decomposed to clay ironstones.

"Seventeen analyses of gravel associated with till were made, but there is some question concerning the correct interpretation of a number of these gravel bowlders. The analyses of the ten positive cases average 38 per cent igneous and 62 per cent sedimentary rocks, 50 per cent being limestone. The average of the seventeen analyses is 41 per cent igneous rocks and 59 per cent sedimentary. Small rounded balls of till (clay-balls) were seen in a few of the gravel bowlders.

"In most cases the till is fresh up to the edge of the gravel bowlders, but in a few cases a thin shell, concentric with the border, is stained, altered, and partly cemented with ferruginous material. Also in a few cases the gravel is cemented in a shell around the outside of the mass. This alteration and cementation is a contact phenomenon which has been produced since the inclusion of the gravel mass.

"Description of Some Typical Gravel Masses

"Little Sioux river valley across northern Buena Vista and southern Clay counties has been cut deeply into the till, and both natural and artificial exposures along the valley show many gravel bowlders. This is in the Iowan drift region, but an Iowan drift cannot commonly be differentiated from the Kansan, and the till of these bluffs is quite certainly Kansan. A large sand bowlder in a cut of the Chicago and Northwestern railway just east of Sioux Rapids has been noted above (page 105), and gravel masses are numerous in several cuts a little farther east. In the southeast quarter of section 3, Barnes township, Buena Vista county, just east of where the railway crosses the terrace area, is a cut which, although old and slumped, shows a great number of sand bowlders.

"Near the top of the bluff north of the schoolhouse at Peterson, there is a pit excavation 30 to 40 feet across and 15 to 20 feet deep. The material excavated was supplied by several large sand and gravel bowlders packed closely together. Some of the vertical contacts with the inclosing till were exposed. Some of the material is coarse gravel, some is fine sand, and some is silt. The material is stratified, and the beds now stand at various angles. Near the top of the slope leading to the upland southwest of Peterson the road cut exposed a lens of sand 50 feet long and 10 feet thick. The material is slightly iron-stained and around the edges of the mass is somewhat contorted.

"A large sand bowlder was exposed in a road cut on the slope toward the river in the north half of section 26, Waterman township, O'Brien county, and at about the center of section 14 of the same township the east bluff of Waterman creek showed several gravel bowlders, 4 to 10 feet across, inclosed in Kansan till.

"Just east of the center of section 22, Brooks township, Buena Vista county, the west bank of a ravine exposed an old looking ferruginous sand and gravel with some fine silty layers. The exposure had a length of about 50 feet and rose 40 feet above the ravine bed to the top of the slope. In either direction the ravine slope was grassed over and the basal part of the exposure was too badly slumped to show material in place, but Kansan till was exposed in the ravine bed just south of the exposure and rose to eight feet above the ravine bed just north of the exposure. There is little doubt that this is a great gravel mass included in the Kansan till. The bedding of the mass dips slightly to the south and apparently back into the bank to the west. Ferruginous concretionary cementation has affected part of the sand and has formed irregular shaped masses, some of which are more than a foot across. The material composing the mass is much more decomposed and altered than is common for the gravel masses.

"In the north bluff of Storm Lake, near the center of section 4, Hayes township, Buena Vista county, there are several irregular masses of loesslike silt and sand. At several places the layers making up the masses are contored and crumpled and even broken off, so that they abut against other parts of the mass in which the layers have a different angle.

"In the north part of Cherokee, in an alley just east of Second Street and south of Spruce Street, a bank showed a large mass of silt and sand partly inclosed in till. The material is somewhat contorted and the layers are in part steeply inclined. This exposure is probably Iowan drift. A series of road cuts in Kansan till in the northeast quarter of section 28, Cherokee township, showed in 1916 a large number of inclosed gravel masses. The face of one of these cuts near the north line of the section showed almost as much gravel as till.

"Other gravel masses were seen in the south bluffs of Mill Creek between the bridges in the northeast quarter of section 23, Cherokee township; in the bluffs of the creek valley of section 24, Cedar township; along the creek valley through sections 11 and 10, Pilot township, south of Cherokee; and at many other places throughout the area. In fact, most large exposures of till show some of these gravel masses. Most of the gravel masses so far described are in the Iowan drift region, but the Iowan drift is believed to be very thin and the gravel masses are apparently in the Kansan till.

"In the south bank of a ravine in the south part of section 10, Stockholm township, Crawford county, about a quarter of a mile west of the railway, there are several gravel bowlders four to ten feet in diameter and some smaller ones of sandy silt or silt. The material of these gravel bowlders is somewhat iron-stained and in one case the gravel around the border is partly cemented, while in another surrounding clay is iron-stained for two to three inches, concentric with the border of the bowlder. An analysis of pebbles from one of these bowlders gave 30 per cent igneous rocks and 70 per cent sedimentary rocks, 7 per cent of which were clay-balls. The layers of the gravel composing the bowlders are inclined.

"In the south bank of the road cut just east of the railway crossing in the east part of section 15, east of Sioux Falls, South Dakota, there is a mass of gravel completely inclosed in the Kansan till. The gravel is rather fresh and contains shale pebbles and drift pebbles. The analyses showed 49 per cent igneous rocks and 51 per cent sedimentary. The bedding of the mass is inclined."

Another exposure of gravel is in a gravel pit along the hillside in the northwest quarter of section 9, Remsen township, Plymouth county. This exposure is within the Kansan till, near the top of the hill, and is overlain by Peorian loess. Since it is outside the Iowan drift area, the possibility of Iowan age is eliminated.

The pit has not been worked for many years and the slump and vegetation have concealed most of the exposure. The gravel is well stratified in beds which dip primarily toward the southwest. Within the beds of sand and gravel, which are almost all finer than 2 centimeters in diameter, several pebbles, and cobbles having a maximum diameter of about 10 centimeters, are scattered with no definite relation to the stratification. The iron oxide coating the grains colors the mass to a medium-brown (17'' ', Wood-Brown), which is not as dark as those gravels described in eastern Iowa. Cementation by iron oxide is not sufficient to cause the gravel to stand in a vertical section long after exposure; it slumps and soon conceals the structure. None of the gravel is leached, and limestone pebbles are distributed throughout the mass. This mass of gravel is quite large in comparison with the others of this type in this part of the state, and has supplied considerable road material. The dimensions are obscured by slumping, but its apparent diameter is more than 50 feet and its thickness more than 10 feet.

Relations of the Kansan Gravels:

It has been previously stated that the gravels deposited during the invasion of an ice sheet occupy positions at the base, within, and at the surface of the till. A very high percentage of the deposits are exposed at and near the gumbotil horizon.

Most of the Kansan gravels studied in northeastern and southeastern Iowa are near the surface of the Kansan gumbotil plain and have undergone changes comparable to those which altered the till to gumbotil. The gravels deposited deeper within the till sheet are exposed in northwestern Iowa. As a result of a long period of erosion which removed the gumbotil and the leached till, these deeply buried deposits have been brought nearer to the surface and now are exposed as unleached gravel masses.

Mitchell county, Iowa, represents the type area in which to study the relations of the Kansan gravels to the Kansan till and the over-

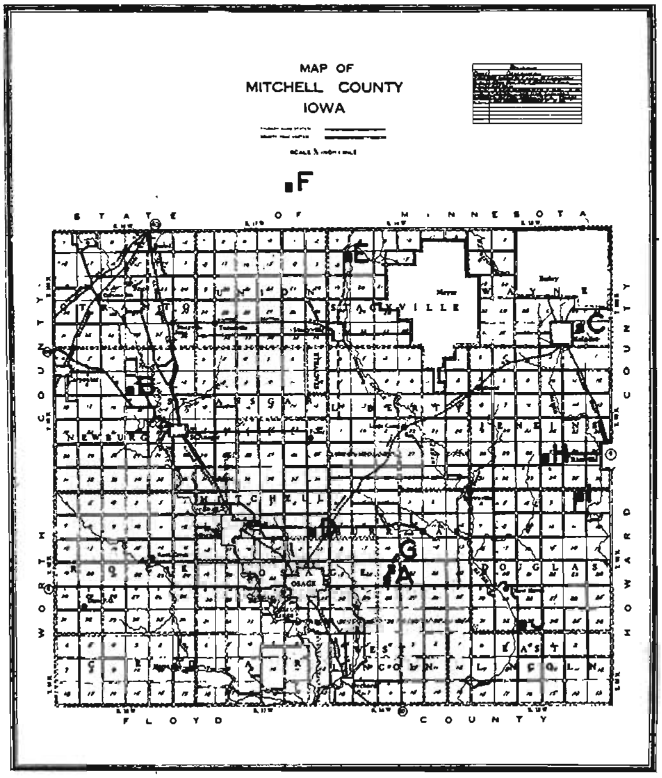


FIG. 23. — Map of Mitchell county, showing the distribution of Kansan gravel exposures studied.

lying Iowan till. Their areal distribution is shown in figure 23, and their elevations and relations to associated materials are given in the following table:

A. T. 98 N., R.16 W., sec. 21	1170	Iowan till Kansan gravel.
B. T. 99 N., R.18 W., sec. 10	1178	Iowan till Kansan gravel Fresh Kansan till and bedrock.
C. T. 100 N., R.15 W., sec. 35	1300	Iowan till Iowan gravel Loveland loess Kansan gravel.
D. T. 98 N., R.17 W., sec. 12	1152	Iowan till Kansan gumbotil Kansan gravel.

E. T. 100 N., R.16 W., sec. 18	1230	Iowan gravelly till Kansan gumbotil Kansan gravel.
F. T. 101 N., R.17 W., sec. 23	1260	Unleached Iowan till Kansan gravel.
G. T. 98 N., R.17 W., sec. 9	1175	Iowan till Kansan gravel.
H. T. 99 N., R.15 W., sec. 27	1240	Iowan till Kansan gravel.
I. T. 98 N., R.15 W., sec. 2	1190	Kansan gravel.
J. T. 97 N., R.15 W., sec. 33	1135	Iowan till Kansan gravel.
K. T. 98 N., R.16 W., sec. 21	1170	Iowan till Kansan gravel.

In two of the exposures (D and E) listed in the preceding table, gumbotil is exposed at the level of the top of the gravel deposit, proving that these deposits occupy a position at the level of the gumbotil plain and consequently have undergone alterations comparable to those of the till. In the north side of exposure D, the gravel is in contact with the gumbotil at the top and with oxidized and leached till lower down, showing that this deposit represents a pocket within the drift. At E, the gravel is exposed along the east hillside and contains some masses of till, altered to gumbotil, near the surface of the gravel (figure 22). In a road cut about 100 feet west of the gravel exposures, Kansan gumbotil is exposed at the same elevation as the top of the gravel and is overlain by a few feet of gravelly Iowan till. There is another exposure of Kansan gumbotil at the same elevation as the Kansan gravel in a road cut ¾ mile southwest. The topographic and geographic relations of the gravel exposures D and E to the Kansan gumbotil, and the characteristics of the gravel, afford conclusive evidence that they are directly related in age and origin to the Kansan drift deposition and were deposited at the surface of the drift.

The exposures A and K in the above table are about 4 miles from D and 18 feet higher, the difference in elevation suggesting that these also were deposited near the surface of the drift, as is further indicated by the leaching of the entire 55-foot section of gravel, which could not have been accomplished had the gravel been covered by a thick layer of Kansan till.

The characteristics and elevations of the other exposures of Kansan gravel listed in the preceding table are in harmony with this relationship to the Kansan drift.

In southeastern Iowa the exposure of Kansan gravel shows both a lateral and vertical gradation into the Kansan till and is related to the associated deposits in the section in the following manner:

2. Loess covering the slopes to an elevation of about 20 feet above the gumbotil on which it lies. The upper surface of the loess is at the upland.
1. Gumbotil, Illinoian, typical in all respects, 3 feet thick.

About 150 yards to the southwest is another exposure lower topographically, and showing the following:

2. Till, Illinoian, oxidized and unleached 7 feet
1. Till Kansan gumbotil-like more strongly oxidized than the till above. Much carbonaceous material in the upper 1 foot; leached, but having some secondary calcium carbonate along joints; grades laterally and vertically into the gravel and silts.

The position within the Kansan till, the gradation both vertically and horizontally into Kansan till, the comparable elevation of the upper gravel surface to that of the Kansan gumbotil and soil zone, and the amount of weathering within the gravel all lead to the same conclusion — namely, that the gravel is a pocket which was deposited at the Kansan drift surface.

The masses of Kansan gravel (gravel boulders) in northwestern Iowa are included within the Kansan till. These Kansan gravel deposits and Kansan till are unleached even to the base of the overlying Iowan till and loess, which indicates that the gumbotil and leached zone formed during the Yarmouth age had been eroded before the Iowan till and loess were deposited. If the weathering within the Kansan deposits in this part of the state before the erosion began was at all comparable to that in other parts of the state, the erosion must have removed almost as much from this surface as the amount of weathered material found in the Kansan drift underlying the next younger drift (the Illinoian) in southeastern Iowa — namely, 8 1/2 feet of gumbotil and 5 feet of leached till. If this assumption is true the gravel masses were deposited in the Kansan till at depths greater than 13 feet.

Age of the Kansan Gravels:

All of the gravel deposited in Iowa during the Ottumwan epoch is closely related to the Kansan till. There are some irregular masses removed from the overridden surface by the advancing Kansan glacier and deposited in the lower part of the till as the ice melted. Some of these masses picked up by the glacier were probably deposited originally by the waters from the advancing ice sheet, while others were deposited at an earlier time. Most of the Kansan gravel is in large irregular masses deposited directly within the Kansan till. Although some of these are buried deeply within the till, most of them are near the upper surface, the gumbotil horizon. All of the Kansan gravel deposits were left in their present position during the deposition of the till which was let down as the glacier melted.

The Gravels of the Centralian Series — The Illinoian and Sangamon Stages

The Centralian gravels were deposited during the Illinoian glacial and Sangamon interglacial ages, both types being directly related to the Illinoian glacier, and its deposition.

The Illinoian glacier crossed the Mississippi from the east and pushed westward a maximum distance of about 30 miles. Over a small area in southeastern Iowa (see figure 2) it deposited a layer of drift which has an average thickness of about 30 feet. The general character of the Illinoian drift is like that of the two older drifts, the Kansan and Nebraskan. The surface was a relatively flat plain upon which 4 to 6 feet of gumbotil was formed by weathering processes during the Sangamon interglacial age. Gravel deposits subjected to the same processes of weathering underwent changes comparable to those within the till.

In some places, erosion has dissected the gumbotil plain, and upon both the Illinoian gumbotil and the eroded surfaces two loesses have been deposited. The older loess is post-Illinoian gumbotil erosion pre-Iowan, and the younger is closely related in age to the retreat of the Iowan ice.

During the Centralian epoch two types of gravel were deposited in Iowa: (1) upland deposits associated with the Illinoian drift, and (2) lacustrine deposits beyond the drift margin. These lacustrine deposits were formed as a result of the glacier damming up several of the streams, making within their valleys a large lake which was not drained until shortly before the Iowan glacier advanced. This lake basin, Lake Calvin, has been described in great detail by Schoewe.[32]

Distribution of the Gravels:

The Illinoian upland gravels have been observed in only one exposure, which is near Muscatine, Iowa. Several small pockets of gravel

32 Schoewe, Walter H., The Origin and History of Extinct Lake Calvin: Iowa Geol. Survey, Vol. XXIX, pp. 49-222, 1924.

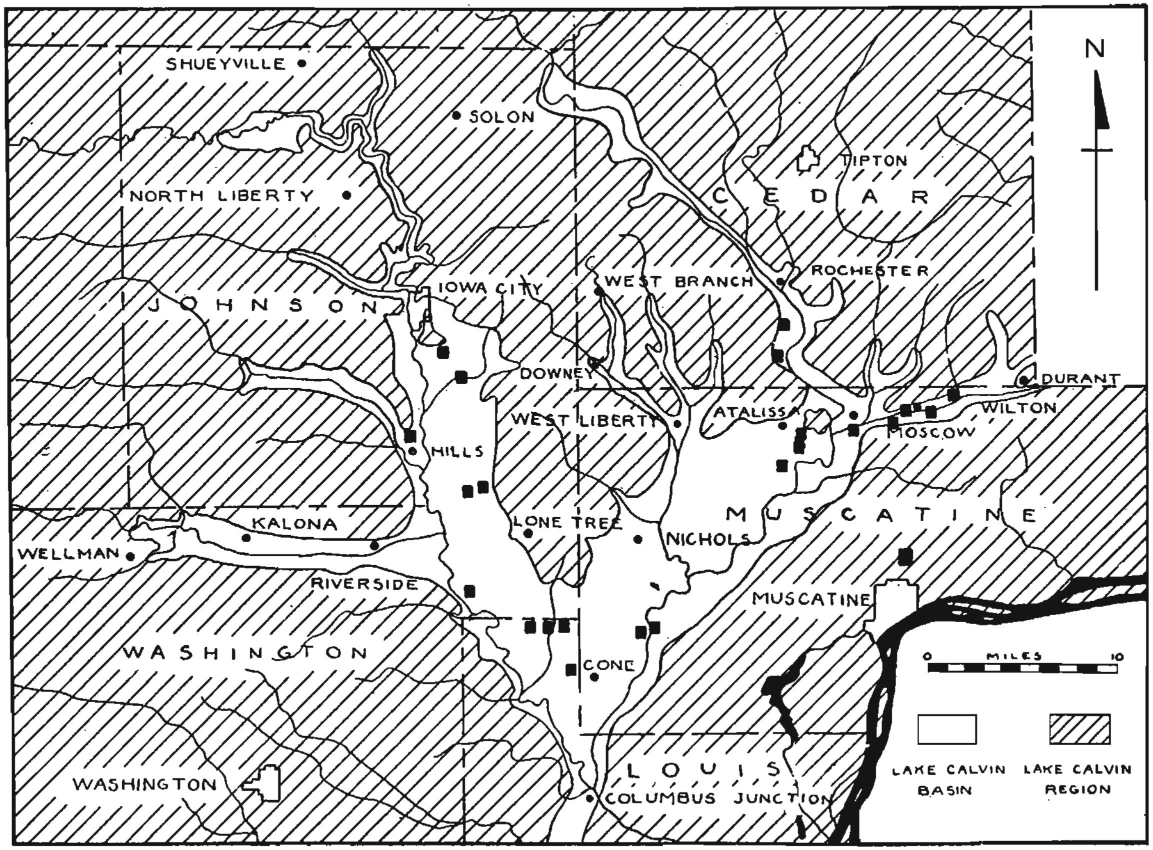


FIG. 24. — Sketch map of the Lake Calvin area showing the location and extent of the lake. The small squares show the locations of exposures described by Schoewe. (Map by Schoewe)

have been removed from the till at other locations, but at present these pits are slumped in and grassed over. Other masses of Illinoian gravel probably occur within the till but are deeply buried below the overlying loesses and possibly some Illinoian till.

The lacustrine silt, sand, and gravel were deposited in extinct Lake Calvin, which had the areal distribution shown in figure 24. In the discussion of the origin and history of this lake, Schoewe described the silt, sand, and gravel exposed at the locations shown in figure 24. A further discussion of the distribution of these deposits will be included with the generalized description of the lake basin.

Characteristics of the Illinoian Upland Gravel:

The only exposure in which the Illinoian upland gravel was studied is in the east half of section 23, Bloomington township (T. 77 N., R. 2 W.), Muscatine county. It is near the upland along the west side of Mad Creek valley.

Within the exposure, which covers more than an acre, the gravel shows a wide range in texture, structure, and degree of alteration. The greatest coloration by iron oxide is in the upper part. In the north end of the exposure the upper 4 feet are colored maroon (11'm, Chestnut-Brown), and cemented into a weakly coherent mass. In another part of the exposure a thin bed is colored maroon and cemented into a firm coherent conglomerate. In still another part of the exposure the same coloration, without cementation, is within fine sand. The other sand and gravel of the exposure ranges in color from maroon (11'm, Chestnut-Brown) to a light-gray (17"b, Cinnamon-Buff) in which iron oxide is unnoticeable. Most of it is colored light grayish-buff (19"i, Isabella Color) by a small amount of iron oxide coloring the light-gray rocks such as limestone and chert. Aside from the coloration by iron oxide mentioned above there are also some lenses generally of coarser material which are colored to various shades by iron oxide. There are also thin seams along some bedding planes and some lenses and thin beds which are colored black. Part of this black coloration is manganese dioxide, but some of it is small fragments of coal and other carbonaceous material. The observed depth of leaching is variable throughout the exposure, which may be due to surface erosion, difference in composition of the gravel, a layer of non-calcareous sand overlying the gravel, or any combination of these. Being located along the valley, some of the surface gravel would be removed as the valley was developed, bringing the unleached material closer to the surface at that point. This can be observed in certain places. Within this exposure there are variations in lithology, certain parts containing a high percentage of carbonates and others having only a small amount. The gravel is overlain by a layer of non-calcareous sand throughout most of the exposure. It is absent in some places but in some it attains a maximum thickness of 8 feet. In other exposures similar to this, sand of this type has been observed which contained practically no carbonates at the time of deposition and thus would be readily leached or appear leached. With all of these variables present the observed depth of leaching cannot represent the true depth to which the carbonates would be removed from normal gravel of this age. In that part of the exposure where conditions seem most nearly normal the carbonates occur within 7 feet of the surface. Weathering has disintegrated many of the crystalline rocks so that they crumble easily and the gray shale falls to pieces soon after exposure to the atmosphere. Only a small amount of the gravel is in horizontal beds, most of it being in beds which dip in any direction at angles below 50 degrees. Lenses and pockets of coarser or finer material are quite common, and the general structure of the entire exposure is irregular and complex. No boulders larger than 30 centimeters in diameter were observed. Except for the few boulders, most

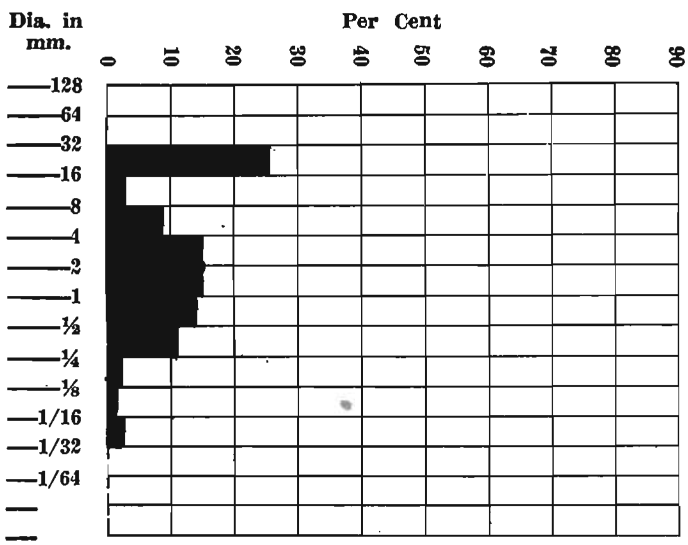


FIG. 25. — Graph showing mechanical analysis of Illinoian gravel.

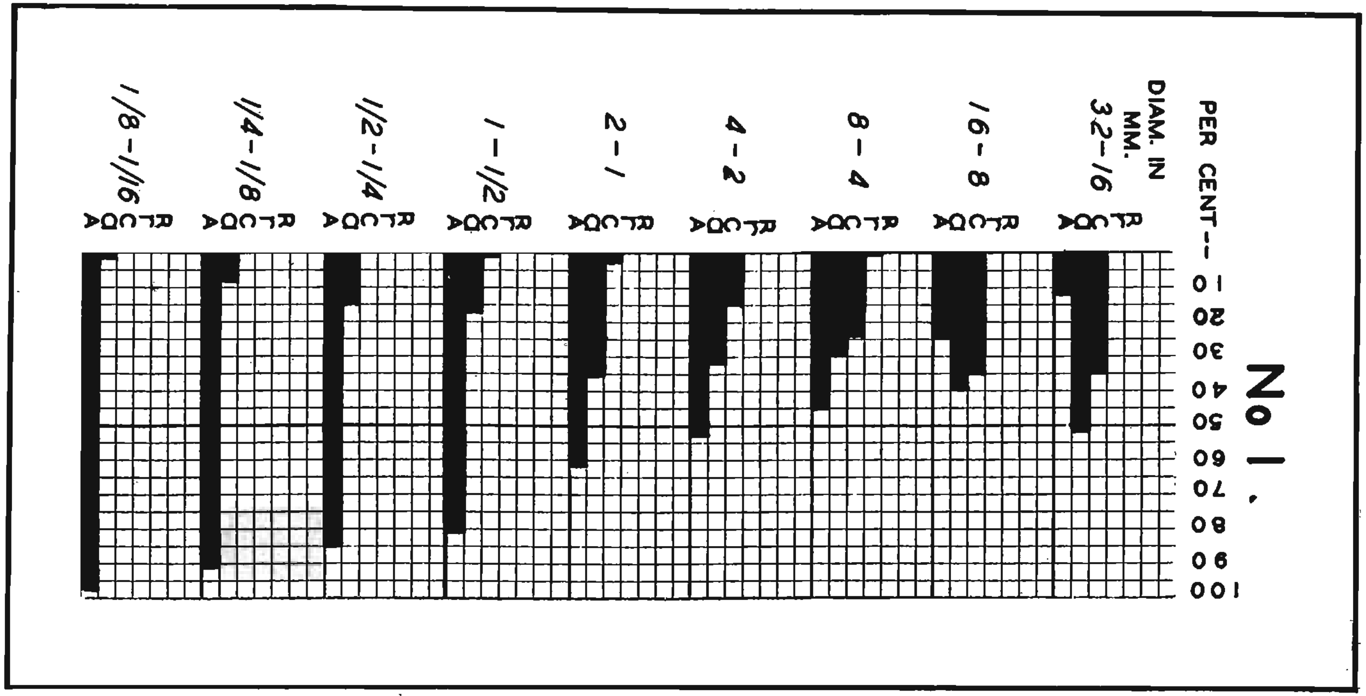


FIG. 26. — Graphs showing shape analyses of each size grade of gravel between 1/16 and 32 millimeters in diameter of Illinoian gravel. R = rounded; r = sub-rounded; C = curvilinear; a = sub-angular; A = angular.

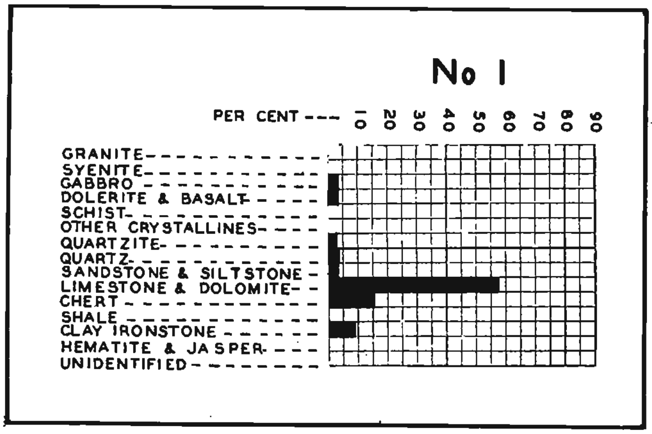


FIG. 27. — Graph showing lithology of pebbles between 16 and 32 millimeters in diameter taken from the Illinoian gravel.

of the gravel is smaller than 5 centimeters in diameter. Lenses, pockets, and irregular masses of sand, silt, or coarser gravel are abundant throughout the exposure. A mechanical separation of a sample of average material is shown in No. 1 of figure 25. The shape of each of the different size grades between 1/16 and 32 millimeters in diameter is shown in No. 1 of figure 26. An analysis of the lithology of the pebbles between 16 and 32 millimeters in diameter is shown in No. 1 of figure 27.

Relations of the Illinoian Upland Gravel:

The top of the gravel is at the same elevation as the surface of the Illinoian gumbotil in this area, 640 feet above sea level.

The gravel has a maximum exposed thickness of 35 feet. It overlies the irregular depositional surface of the unaltered till which in several places extends into the gravel as mound-like masses. The relief of this till surface within the gravel is more than 15 feet.

The top of the gravel, like the base, is very irregular. Throughout most of the exposure the gravel is covered by a layer of laminated sand which has a maximum thickness of 8 feet. In most places it is sharply set off from the underlying gravel, but at one location the two are interstratified and closely related. The sand in turn is overlain by dark-buff, non-calcareous loess which becomes more sandy in the lower few inches where it grades into the underlying sand. It has a maximum thickness of 8 feet in the exposure but must thicken toward the west to form the 15 feet of relief between the top of the gravel and the upland. In one part of the exposure gumboized till is more or less interbedded with the upper 2 feet of gravel.

Age of the Illinoian Upland Gravel:

This irregular mass of gravel within the Illinoian till must have been deposited during the melting of the glacier. The fresh unaltered till below shows that some of the till was deposited before the gravel deposition began. The till that is slightly interbedded with the gravel just below the overburden represents till deposition during the last stages of gravel deposition. All of the evidence suggests that the gravel was deposited simultaneously with the melting of the glacier and deposition of the Illinoian till.

Lake Calvin Basin:

The Illinoian glacier entered Iowa from the east, crossing the present site of the Mississippi river and forcing the river to take a channel along the west margin of the ice. The invasion of the ice not only affected the major stream but also blocked the lower parts of several of the tributaries, such as the Iowa and Cedar rivers, forming lakes in their valleys. These lakes found outlets by flowing over the lowest points in the interstream divides. Probably several lakes were formed at this time, but all except one apparently were short-lived. That one, its areal extent shown in figure 24, has been called Lake Calvin.

Lake Calvin was formed in the valleys of the Iowa and Cedar rivers. These two streams flow from the area of the Iowan drift south and eastward across the Kansan drift. They unite at the edge of the Illinoian drift plain, and from there flow southeastward across the Illinoian drift plain to the Mississippi river.

Three stages in the history of the Iowa and Cedar valleys are significant in the present discussion. The first stage is that during which the Iowa and Cedar valleys were developed. The second stage is that during which the waters of the valleys were ponded by the Illinoian glacier to form Lake Calvin. The third stage records the Iowan glaciation and its influence on the lake basin and the river valleys.

The first stage in this history has been worked out by Leighton for the Iowa river valley,[33] and by Norton for the Cedar river valley.[34] Leighton dates the cutting of the Iowa river valley and its major tributaries of this region as post-Kansan, while Norton states that the wide (bedrock) valleys of the Cedar are at least pre-Kansan in age and may, perhaps, be even pre-glacial.

Lake Calvin, which existed during the second stage of the history, covered the area shown in figure 24. The streams and water from the melting glacier carried sediments that formed typical lacustrine deposits in the lake. Bluffs were formed by the waves sapping the shore; deltas were built by detrital material brought in by the streams; and the finer material from all sources settled in the more quiet waters of the lake to build up its bed. After the lake was drained, these features persisted as marks of the former occupation of this area by lake waters.

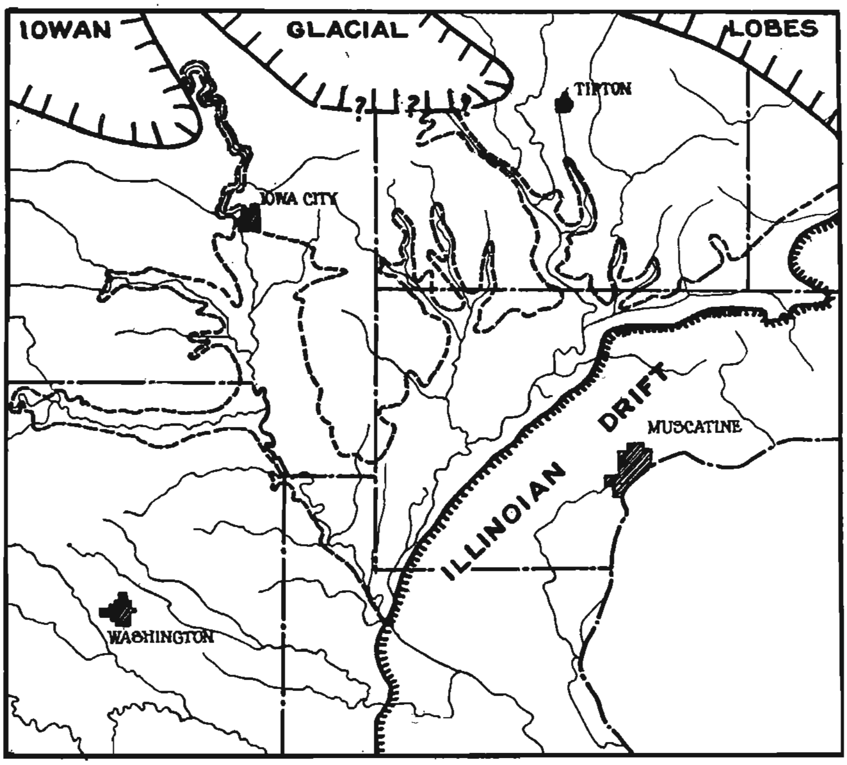


FIG. 28. — Sketch map of the Lake Calvin area showing the drainage during the time of the Iowan glaciation.

33 Leighton, M. M., The Pleistocene History of Iowa River Valley, North and West of Iowa City, in Johnson County: Iowa Geol. Survey, Vol. XXV, pp. 103-181, 1916.
34 Norton, W. H., Geology of Cedar County: Iowa Geol. Survey, Vol. XI, p. 291, 1901.

The third and last stage in the history of this lake area began shortly after Lake Calvin was drained. New conditions created by the advent of the Iowan ice sheet brought about the last stage in the history of the lake area. Figure 28 shows drainage relationships which existed during the third stage.

The drainage lines which crossed the lake floor after is was drained cut their valleys into the lacustrine deposits that then formed terraces along the sides of the streams. The waters from the melting Iowan ice that flowed down the valleys of the Iowa and Cedar rivers were loaded with glacial debris. Much of this material was deposited in the valleys along with reworked material from the eroded lake beds. After the Iowan glacier had retreated and the volume of water decreased to normal, the streams intrenched themselves in these valley deposits which now stand as terraces of sand and gravel above the present floodplains.

The western or Iowa-river arm of the lake basin is about 28 miles long and over this distance has an average width of 4.4 miles. The eastern or Cedar-river arm of the lake basin is about 24 miles long and has an average width of 5.5 miles. Tributary valleys which show that they were in existence and became a part of Lake Calvin during Centralian time are: English River, which shows lake influence for a distance of 15 miles up its valley, and half a mile wide; Old Mans Creek, which has lake deposits for 10 miles along a valley somewhat over a mile wide; and Wilton valley, which shows lake influence for 8.5 miles above Moscow over a floor which is a mile to two miles wide.[35]

The present surface of the bottom of the lake basin is an extensive lowland having a more or less monotonous plain topography with but little relief. It slopes at the rate of about 2 1/2 to 3 feet per mile from the northern to the southern extremities. It includes the terraces shown

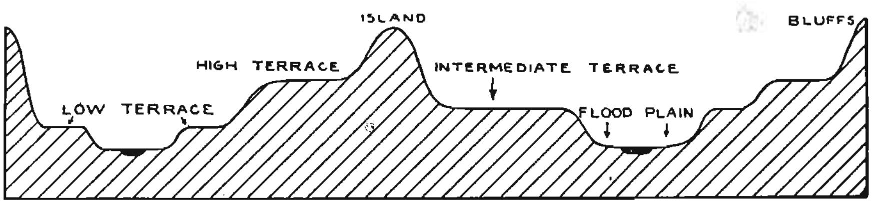


FIG. 29 — Generalized profile of the Lake Calvin basin. (Section by Schoewe.)

35 Schoewe, Walter H., The Origin and History of Extinct Lake Calvin: Iowa Geol. Survey, Vol. XXIX, p. 109, 1924.

diagrammatically in figure 29, which have been described in general by Schoewe [36] in the following manner:

"At least three sets of terraces, a high set, an intermediate set, and a lower one, occur in the Lake Calvin basin. Of these, the intermediate terrace, designated by Udden in his Muscatine county report as the West Liberty plain, is the most extensive and continuous. It comprises practically the entire higher lowland areas in Muscatine county and extends southward as far as Columbus Junction, Louisa county, occupying the higher land area in the triangle made by the junction of Iowa and Cedar rivers.

"The uppermost or highest terrace is confined principally to the Iowa river arm of the lake basin. It forms the higher of the two terraces following the river southward from Iowa City to a point about one and one-quarter miles north of Gladwin in Louisa county. Except for several small remnants on the west side of the river, the terrace is continuous and is limited to the east side of the stream. Terraces presumably corresponding to this upper one are present in Mud Creek valley opposite Wilton Junction and on the higher land bordering the various branches of Wapsinonoc creek north and northwest of West Liberty.

"The lower terrace is restricted to the narrow river-like extensions and to the western branch of the 'V' of the lake basin. This terrace, with one exception, is not continuous but occurs in narrow linear remnants south of Iowa City and as 'mere remnants at the bends of the stream' north of Iowa City and possibly north of Moscow along Cedar river."

He further states, on page 147:

"The higher terrace rises distinctly above the lower one to the west, forming a very sharp and straight escarpment, which on the average is thirty feet high. Near Iowa City it lies sixty feet above Iowa river, while it is fifty feet high in the vicinity of Hills and thirty-two feet high in section 16, Oakland township, Louisa county. It has an elevation of 680 feet above sea level in the vicinity of Iowa City but to the south it is lower, reaching a height of 670 feet near Hills, six to seven miles below Iowa City, and 660 feet two miles south of River Junction. In the lower two tiers of sections in Fremont township, Johnson county, the plain is again somewhat higher, approximating an elevation of 680 feet above sea level. From the elevations mentioned, it is apparent that the surface of the terrace has a much gentler slope — one and four-tenths feet per mile — than the intermediate terrace in Muscatine county."

He describes the intermediate terrace as forming most of the low-

36 *Ibid.*, p. 133.

land of Muscatine and Louisa counties, designated by Udden as the West Liberty plain, but concludes that part of this plain includes some of the higher terrace. The intermediate terrace stands from 20 to 40 feet above the Cedar river, along which it forms an extensive plain.

The lower terrace, confined to the Iowa river valley and its tributaries, occurs as discontinuous remnants about 20 feet above the stream and 40 feet below the high terrace.

Schoewe describes the high and intermediate terraces as lacustrine deposits of the same age and origin, which are higher in the Iowa-river arm because of the greater amount of sediment introduced in relation to the size of the valley, which fills it to a higher level than the Cedar-river arm. The lower terrace is fluvial gravel deposited by the streams flowing from the melting Iowan glacier.

The materials of the high and intermediate terraces are distinctly different from those of the lower terrace. Whereas the two upper terraces are lacustrine in origin, the lower one is glacio-fluvial. In the following discussion Schoewe gives a general description of the materials of the high and intermediate terraces.[37]

"The finding of horizontally laminated clays or silts is positive evidence of quiet water sedimentation and may be taken in most cases as indicating deep water deposits and lacustrine sediments. In general, it may be stated that the materials of the high and intermediate terraces are of low textural range and are finely stratified. Laminated silts or clays, however, are practically limited to the valley of Mud creek . . . As was mentioned in Chapter V under the discussion of the materials and structure of the Wilton Valley terrace, the eastern half of the valley shows a predominance of laminated silts and clays whereas in the west end fine stratified sands are more common. There can be no doubt that the deposits such as are represented by the typical section of terrace materials as given on page 159 (see figure 30) were laid down under quiet water conditions. Practically thirty-four feet of laminated silt or clay is exposed in the type outcrop. Pebbles are entirely lacking and the stratification is horizontal and undisturbed except for a few minor wavy undulations. Other laminated deposits may be seen in the high terrace two and one-half miles east of Hills. . . . Similar sediments are exposed in the intermediate terrace in section 8, Goshen township, Muscatine county. The exposed thickness of these deposits range from seven to twenty feet."

Schoewe describes the material of the lower terrace as follows:[38]

[37] *Ibid.*, pp. 181-182.
[38] *Ibid.*, pp. 162-163

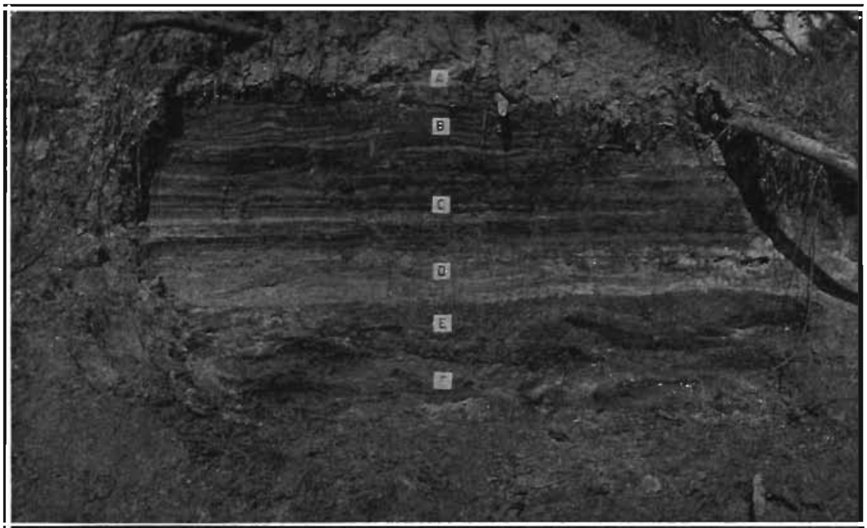


FIG. 30. — View showing typical deposits in the western half of the Wilton Valley terrace, section 11, Moscow township, Muscatine county. (Photo by Schoewe)

"In contrast with the deposits seen in the high and intermediate terraces, the materials of the low terrace are coarser, contain more gravel layers, have a higher textural range and consist predominantly of sands with extremely little silt or clay. In structure there is also a difference. Whereas the high and intermediate terraces contain thinly and horizontally bedded deposits with minor cross-bedding, the prevailing type of structure of the low terrace is well developed cross-bedding and pocket-and-lens stratification."

Detailed descriptions of the materials of each exposure studied are given in his report.[39]

The long duration of Lake Calvin, from the time the streams were dammed by the Illinoian glacier until almost the time of the Iowan ice invasion, has been determined on the basis of the Illinoian gumbotil, the straight line of contact between the high and low terraces along the Iowa river, and the great amount of sediment in the lake basin. Each of these has been discussed by Schoewe.[40]

"It is obvious, if the present view concerning the origin of the gumbotil is correct, that Lake Calvin could not have been drained by way of the Iowa-Cedar river valley shortly after the ice had retreated, since outcrops of Illinoian gumbotil appear on both valley walls of the Iowa-Cedar and Mis-

39 *Ibid.*, pp. 133-168.
40 *Ibid.*, pp. 209-210.

sissippi river valleys. Hence, to say the least, drainage of the lake by this route is post-Illinoian-gumbotil in age. A long-lived Lake Calvin is in accord with the theory of the formation of the Illinoian gumbotil as the levels of the lake and of the gumbotil as they are shown at Columbus Junction were not separated by more than ten to twenty feet, a difference in height which would not give rise to pronounced erosion. Another factor supporting a long existence for Lake Calvin with an outlet south of Columbus Junction and a sudden draining of the lake by way of the Iowa-Cedar valley is the straight line of contact between the high and low terraces in the Iowa river arm of the lake basin. At places where the low terrace is missing, the escarpment of the high terrace is sinuous due to the meandering of Iowa river. At other places, however, where the low terrace lies between the high terrace and the flood plain of the river, the line of contact between the two terraces is unusually straight. This suggests to the writer that the stream which eroded into the high terrace was not meandering and that the formation of the terrace was suddenly halted by the building up of another flood plain which was subsequently cut away to form the low terrace. Therefore, the writer believes that Lake Calvin existed almost to the coming of the Iowan glacier, that the lake was drained in a comparatively short time, and that the down cutting of the lake bed to form the high terrace was shortly interrupted by the aggrading of the valley. The change from an eroding to an aggrading stream was the result of overloading of the stream with sediment received from the melting Iowan ice sheet to the north. As soon as the glacier had retreated from the region, the stream, no longer receiving an unusual amount of sediment, found itself above grade and consequently began to remove the deposited material, producing thus the low terrace, the destruction of which is still in progress."

The Loveland Formation

The Loveland formation includes loess, silt, sand, and gravel which were deposited during the Loveland interval. This formation rests upon the eroded surface of the Kansan gumbotil plain and is overlain by Wisconsin (Iowan, Peorian, and Mankato) deposits. The Loveland interval therefore began not earlier than late Yarmouth time and ended not later than the earliest deposition of the Eldoran epoch, the Iowan.

The type section of this formation is at Loveland, Harrison county. Here Shimek[41] gave the name to a deposit which is a "heavy, compact, reddish (especially on exposure to the air) or sometimes yellowish

41 Shimek, B., Aftonian Sands and Gravels in Western Iowa: Bull. Geol. Soc. of America, Vol. 20, footnote, p. 405, 1909.

silt which when dry is hard with a tendency to break into blocks like a joint clay and when wet becomes very tough and sticky, and hence is sometimes called a gumbo." Although the formation originally included only loess and silt, later studies within the type area and over the rest of the state reveal that the Loveland deposits also include sand and gravel.

The Distribution of the Loveland Gravel:

The Loveland formation has been traced throughout all of the state except that covered by the Mankato drift. No doubt it was also deposited there as in other parts of the state but is concealed by the thick, undissected drift sheet.

Regardless of the wide distribution of the Loveland formation, the differentiated exposures of sand and gravel are confined largely to several valleys in the western and southern parts of the state as shown in figure 31. Since these valleys lie wholly within the loess mantled Kansan drift area, the only possible source of the sand and gravel is the erosion of the Kansan drift, Nebraskan drift, or bedrock. Other valleys within this same area the heads of which extend into the Mankato and Iowan drift areas contain extensive terraces of sand and gravel deposited by the waters from the melting Mankato and Iowan ice fronts. Loveland sand and gravel were probably deposited in all of these valleys which were formed at the same time and under the same erosional conditions. However, those valleys the heads of which extended into the Iowan and Mankato drift areas received later deposition from the melting glaciers. In some places Loveland deposits were probably deeply buried, in others removed, and in still others reworked and incorporated in the younger deposits. During the Loveland interval the amount and rate of erosion was greater in northwestern Iowa than in other parts of the state. Consequently, it is not surprising to find within this area most of the Loveland sand and gravel, which is directly related to this erosion.

The Characteristics of the Loveland Gravel

General Characteristics:

The Loveland sand and gravel can be studied best in northwestern Iowa, where they were deposited in the valleys developed during the Loveland interval. The subsequent stream erosion has cut through

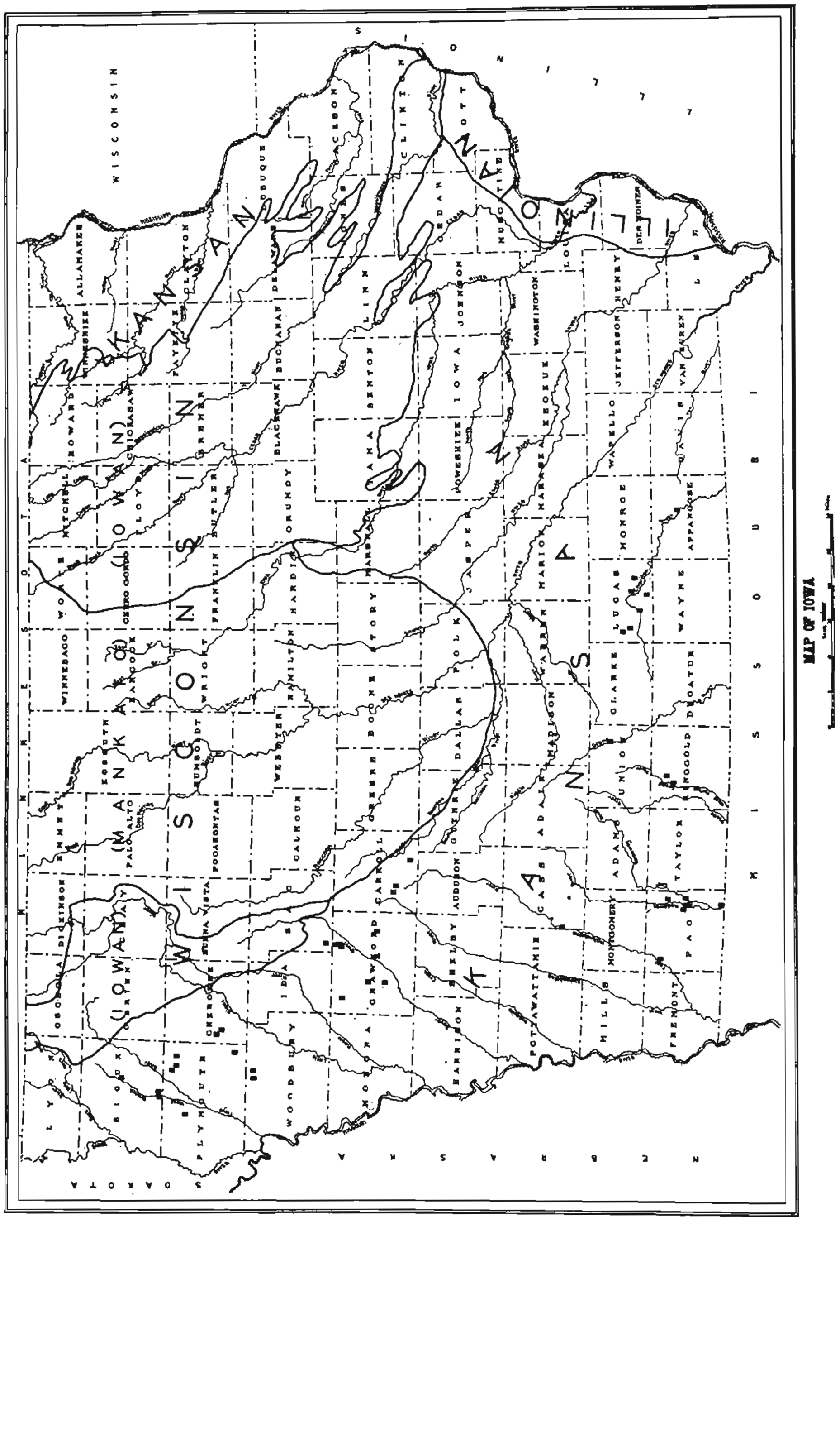


FIG. 31. — The squares show the locations of the Loveland gravel exposures in Iowa.

them, leaving the remaining parts as terraces which vary in height above the level of the present stream. The sand and gravel deposits are well exposed and sometimes show their relations to the overlying and underlying materials.

In southern Iowa, Loveland sand and fine gravel are exposed along several valleys. Most of these exposures are at approximately the present stream level, some are a few feet higher, and others can be studied only by use of an auger. Likewise, along a single stream they may be exposed at one location while a short distance in either direction the stream will be flowing on the alluvium or silt which overlies them.

Since the characteristics of the Loveland gravel of northwestern Iowa are so different from those of the Loveland gravel of southern Iowa, it will be necessary to give a general description of each. The basis for the physical differences between these materials from the separated areas will be given in the discussion of their origin.

The Loveland gravel deposits are exposed within the eroded Kansan drift region which is mantled by loess. They are underlain by yellowish oxidized and unleached Kansan till, or possibly some older formation, and overlain by loess which is closely related in age to the Iowan member of the Eldoran epoch. There is no distinct weathered zone, representing a long time interval, either between the erosion of the Kansan valleys and the deposition of the gravel or between the deposition of the gravel and that of the overlying loess. In some of the exposures all of the above-stated relations are visible, but in most of them only the gravel and overlying loess are exposed.

After an extensive study of the Loveland deposits of northwestern Iowa, Carman makes the following statement with regard to the gravels: [42]

"Most of the valley gravels appear to have originated within the Iowan drift region apparently as outwash from the Iowan ice sheet. This material was gathered into the valleys of the Iowan area and some of it was deposited there. Some of it was carried on southwest down the valleys into the Kansan region and deposited. This will account for most of the valley gravels of the Kansan region, but not for all of them. The gravels of certain valleys of the Kansan region could not possibly have come from the Iowan ice sheet as here interpreted and mapped. In fact, it would prob-

[42] Carman, J. Ernest, Further Studies of the Pleistocene Geology of Northwestern Iowa: Iowa Geol. Survey, Vol. XXXV, p. 137, 1929.

ably be necessary to extend the Iowan over all of northwestern Iowa, at least as far south as Crawford and Carroll counties, to make such an origin possible for all the gravels. These gravels must, therefore, have originated in the Kansan region. It is not possible to distinguish the gravels of Iowan age from those that originated in the Kansan region so alike are they in their general characteristics. Further, in both regions they rest on unleached till and are overlain by loess."

The Loveland gravel deposits in northwestern Iowa generally appear fresh with very little, if any, oxidation of the iron compounds. In some of the exposures the gravel is gray and only slightly oxidized but in some others it is colored buff (17'' 'd, Vinaceous-Buff) like that of the Peorian loess. No exposure was observed in which the iron oxide colored the gravel darker than buff or cemented either the mass or separate beds into a conglomerate. The only sections showing leaching within the gravel are those in which the overlying loess is thin and the post loess leaching has removed the carbonates from the loess and the upper few inches of the underlying gravel. In accordance with the lack of oxidation and leaching very few of the igneous rocks, commonly in a weathered condition in the older gravel deposits, are disintegrated.

Most of the material is stratified in horizontal beds between 6 and 12 inches thick. Within these beds cross-bedding and lens structures are common, most of which dip in the general direction in which the present stream flows. The sorting is good. In some of the exposures the material is well sorted except for a few pebbles, cobbles, or boulders scattered through the beds of finer material and unrelated to the general stratification. In other exposures the gravel is poorly sorted and there is a wide size range, from sand to cobbles, all within single beds. The deposits show a wide size range both within separate exposures and in the group as a whole. Some exposures are almost entirely sand, while in others there is considerable gravel as coarse as 3 to 5 centimeters in diameter. Within separate exposures there is sometimes fine sand, silt, or loesslike material interstratified with the coarser gravel, or the opposite extreme, an abundance of cobbles and occasionally boulders as large as 60 centimeters in diameter scattered through the finer material. In general the sizes of this material are comparable to those of Iowan terrace gravel deposits within this area. The percentage of each of the different size grades as determined by mechanical analyses is given graphically in figure 32, each graph representing a

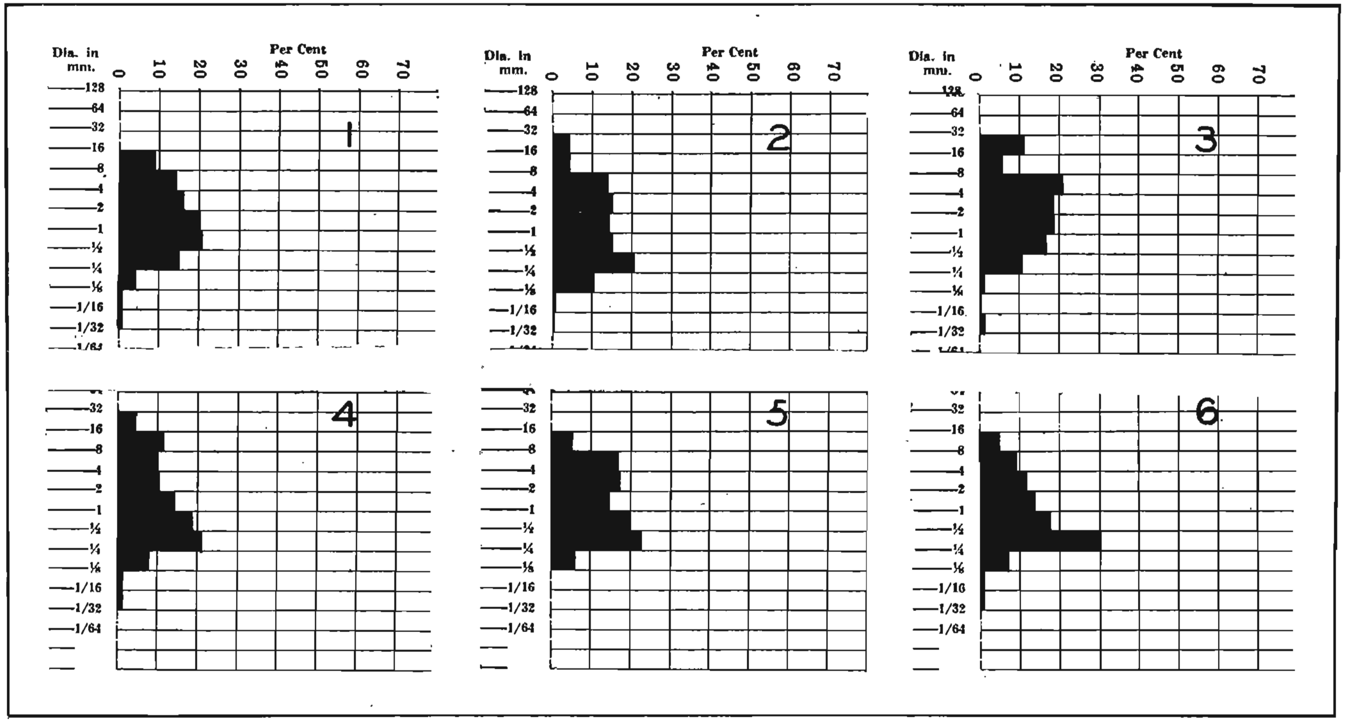


FIG. 32. — Graphs showing mechanical analyses of Loveland gravel. The numbers of this figure correspond with those of figures 33 and 34.

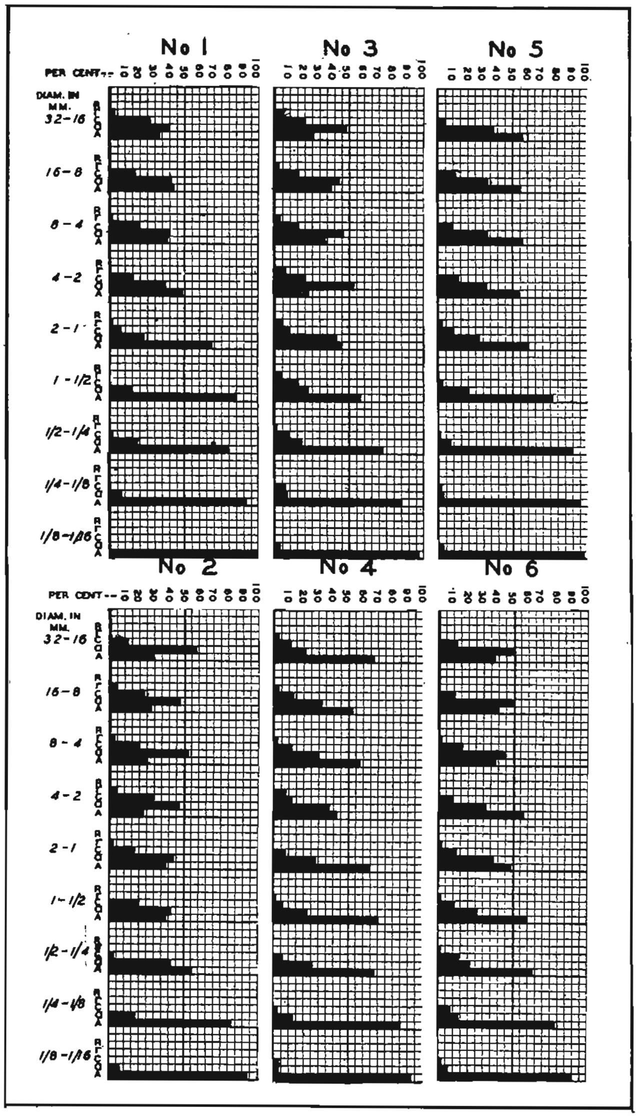


FIG. 33. — Graphs showing shape analyses of each size grade between 1/16 and 32 millimeters in diameter of the Loveland gravel. The numbers of these analyses correspond to the numbers of figures 32 and 34. R = rounded; r = sub-rounded; C = curvilinear; a = sub-angular; A = angular.

sample which is an average of the exposure from which it was taken. These analyses are from type exposures, some of which will be described separately later in this report; the others are included only for comparison. The shape analyses of the size grades between 1/16 and

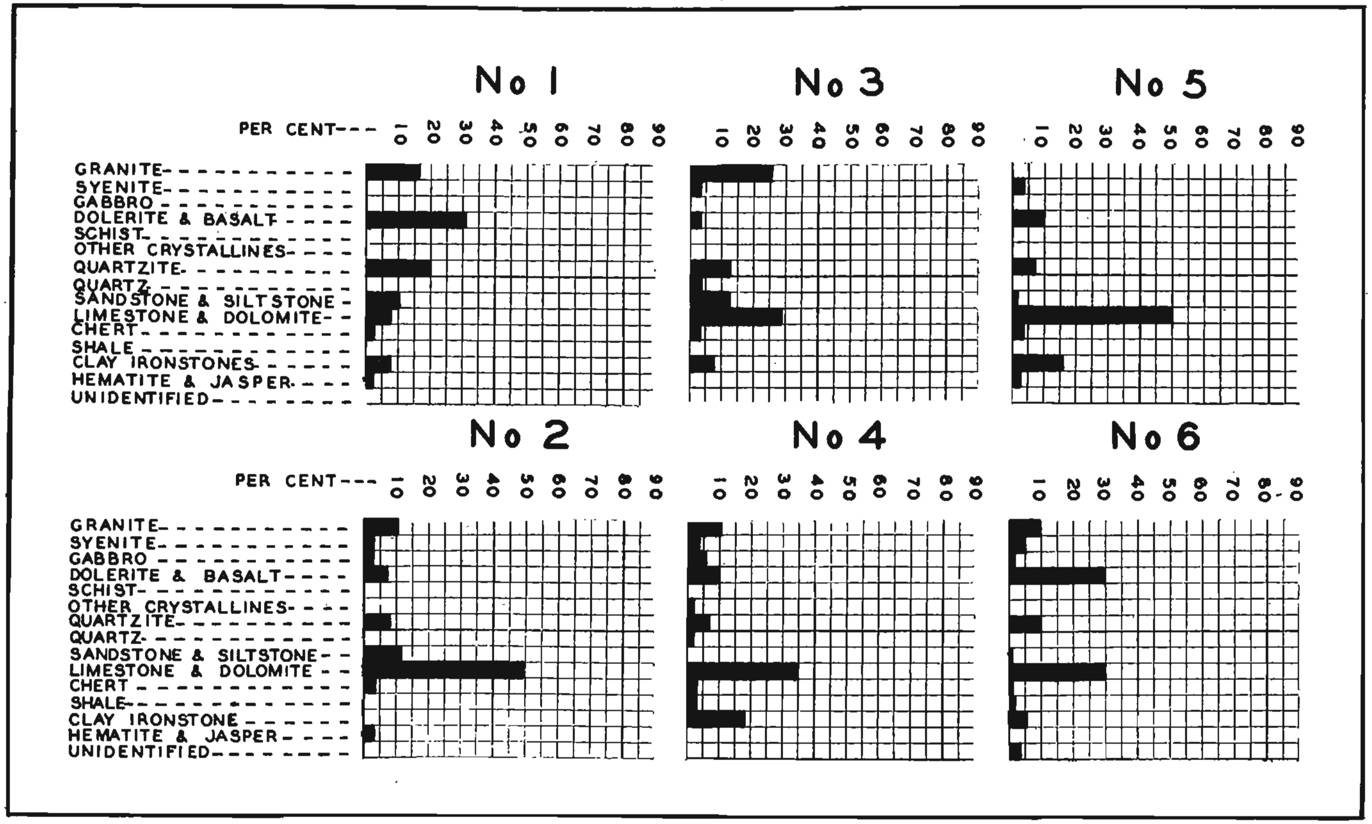


FIG. 34. — Graphs showing lithology of pebbles between 16 and 32 millimeters in diameter. The numbers of these analyses correspond to those of figures 32 and 33.

32 millimeters in diameter are shown in figure 33. The rock content, determined by analyses of the pebbles between 16 and 32 millimeters in diameter, is shown in figure 34.

The Loveland gravel in southern Iowa is generally gray and uncolored by oxidation of iron compounds. However, in a few exposures the iron oxide colors all of the gravel medium-brown (15"i, Sayal-Brown), and in other exposures it colors only thin beds. Carbonates, either primary or secondary, were found in very few exposures. Most of the material is siliceous or fine-grained igneous rock, so there is no distinct evidence of weathering and disintegration. Where studied in place, the material showed good stratification and sorting. Most of the beds were almost horizontal but some dipped downstream. There is no wide size range in any exposure studied nor within the group. In some exposures the material is fine sand with very little coarser than 1 centimeter in diameter; in others it is gravel ranging between 0.5 centimeters and 2 centimeters, but some is as coarse as 4 centimeters in diameter. No cobbles or boulders were found in material definitely recognized as Loveland. In some of the exposures there is silty loess-like material which is closely related and in places interbedded with the sand and gravel deposits.

The Loveland materials observed are only along streams, and their relations to other deposits are difficult to determine, for seldom is their upper surface more than 1 foot above the stream level and generally it is in the bed of the stream. In some valleys in which they are not exposed they have been observed at greater depths during bridge construction.

Characteristics of the Exposures of Loveland Gravel:

Loveland gravel is exposed along streams in many places in northwestern and southern Iowa, as shown in figure 31, but from the general descriptions it is evident that there is a striking difference between the deposits of these two parts of the state. They differ not only in general characteristics and relations but also in distribution and abundance. In northwestern Iowa they are especially abundant in several valleys along which they form extensive terrace deposits, now well exposed.

One of the best streams along which to study Loveland gravel is Otter Creek, a tributary to the Boyer river. It heads up in and flows across Kansan drift, emptying into the Boyer river near Deloit. Along this stream Loveland gravel is exposed in several places.

A good exposure of this gravel along Otter creek is in the southwest part of Sac county. It is near the center of the west half of section 26, Wheeler township (T. 86 N., R. 38 W.), about 5 miles south of the southeast corner of Odebolt. Along the east side of the valley a vast amount of gravel has been removed from several pits which extend intermittently for about 1/4 of a mile along the terrace. Only one gravel pit is now in use and available for study. In the other pits most of the gravel and the overlying and underlying material is concealed by slumping. Although these exposures represent a terrace deposit, the thick overlying loess projects the slope of the hillside over them so that no terrace is visible. The top of the gravel is 40 feet above the stream and extends through all of the exposures at the same level. The exposure is 42 feet thick, the upper 20 feet loess and lower 22 feet gravel. Although no till was exposed in the bottom of the pit, it is doubtful whether the gravel extends much deeper for all of the other pits end at about this same depth, and there is no other apparent reason for their not going deeper. The gravel exposed may be divided into two members — the upper member, which is sand 2 1/2 feet thick, and the lower member, which is gravel 19 1/2 feet thick.

The oxidation of the iron compounds has colored all of the gravel light-buff (17'' 'b, Avellaneous), only slightly darker than the overlying loess (17'' 'd, Vinaceous-Buff). The carbonates have been leached from the upper 9 feet of the overlying loess, and in the unleached loess below fossil snails are found. The 2 1/2 feet of sand at the top of the gravel is also non-calcareous, however, being sand, it probably contained no carbonates when deposited. The coarser gravel below, and even where interstratified with the sand, is all unleached. Some of the large igneous rocks, such as granites and schists, were slightly disintegrated by weathering, but within those smaller than 3 centimeters in diameter very little weathering was observed. No secondary concretions of either iron oxide or lime were found. The upper 2 1/2 feet of sand is all finer than 2 millimeters in diameter and about 85 per cent is between 1/16 and 1/2 millimeter in diameter. It is well stratified in indistinct horizontal beds about 2 inches thick which have no cross-bedding. The lower 19 1/2 feet of gravel is almost all smaller than 6 centimeters in diameter except 13 boulders lying in the bottom of the pit, the largest of which is 35 centimeters in diameter. The average gravel is practically all below 16 millimeters in diameter and 70 per cent is between 1/4 and 4 millimeters in diameter. This gravel is well stratified in beds less than 10 inches thick and generally about 3 inches thick which dip southeast at an angle less than 5 degrees. The small amount of cross-bedding, confined to the thicker beds dips in any direction, principally south. A mechanical analysis of an average of the gravel is shown in No. 1 of figure 32. Shape analyses are given in No. 1 of figure 33. The lithology, as determined by a pebble count, is shown in No. 1 of figure 34.

The 20 feet of Peorian loess which is uniform throughout its entire thickness in both color and texture is sharply divided without gradation from the underlying gravel. No contact with older material at the base of the gravel is visible.

About 3 miles farther south along this same stream there is another good exposure of Loveland gravel. It is in the southeast quarter of section 2, Otter Creek township (T. 85 N., R. 39 W.), Crawford county. The upper surface of the gravel is 20 feet above the level of the stream and is overlain by Peorian loess. Where the loess is exposed overlying the gravel, it is only about 3 feet thick. However it probably thickens toward the hills, whose slope extends down over the gravel terrace. The exposed gravel is 12 feet thick but probably extends several feet deeper.

Oxidation of the iron compounds colors the gravel uniformly throughout the section to light-buff (17" 'b, Avellaneous), about the same color as the overlying loess. Both the gravel and the overlying loess are highly calcareous, the loess containing many lime concretions in its lower part. There is very little disintegration of the rocks by weathering except in some of the less-resistant types. The gravel is well stratified in almost horizontal beds generally less than 6 inches thick. Within the thicker beds is some cross-bedding which dips principally toward the southeast. The entire 12 feet of gravel exposed is quite uniform in texture, although some coarser beds and some finer beds are contained within the average gravel. Size, shape, and rock analyses are shown in No. 2 of figures 32, 33, and 34.

The gravel is overlain by 3 feet of buff (17" 'd, Vinaceous-Buff), calcareous loess which contains a few pebbles and many concretions within its lower part. The absence of leaching within the loess is perhaps the result of recent erosion which has removed the leached material. In this pit the base of the gravel was not exposed.

Another exposure of the Loveland gravel along Otter Creek is about 5 miles farther down stream. It is in the northeast quarter of the northwest quarter of section 36, Otter Creek township (T. 85 N., R. 39 W.), Crawford county. Here within a distance of 3/8 of a mile are 3 pits which contain similar material, 2 on the west side and 1 on the east side of the stream. The terrace in which they occur is 50 feet above the stream.

The gravel is colored buff by oxidation, the coloration varying slightly within the exposure according to the different textures of the beds. At the base of the upper 6-foot bed of gravel there are some thin beds colored black by manganese dioxide. The gravel is all calcareous even up to the base of the leached overlying loess. Weathering has disintegrated very little of the material. Upon the basis of texture the exposure can be divided into three members: the upper 6 feet of coarse gravel, the next 5 feet of slightly finer gravel, and sand at the base. The upper 6-foot bed is well stratified but the coarse material makes the stratification less distinct. Within this bed of coarse gravel there is some interstratification of thinner beds of fine sandy gravel. The largest material observed in this upper member is smaller than 10 centimeters in diameter, and 70 per cent of it is between 1/2 and 8 millimeters in diameter. The oxidation colors this bed to a buffy-brown (17'' 'i, Buffy-Brown), and at its base some of the thin layers are colored black by manganese dioxide. The middle 5-foot member is slightly finer than the upper member but represents about the same type of material, differing chiefly from that above by more oxidation of the iron compounds, which colors it darker, (19''i, Isabella Color). At the base, the lowest member of well-stratified fine sand is all smaller than 8 millimeters in diameter and 60 per cent is between 1/8 and 1/2 millimeter in diameter. It is a darker buff (17''i, Tawny-Olive) than either of the overlying gravel beds. A mechanical analysis of the average material from the 2 upper beds is shown graphically in No.3 of figure 32. The shape of different size grades is shown in No. 3 of figure 33. A rock analysis of pebbles is given in No. 3 of figure 34.

In this and the two exposures near by, the gravel is overlain by Peorian loess which is leached; in neither of the sections, however, is the loess more than 2 feet thick.

At several other locations along Otter Creek besides those described, gravel is exposed in the terraces. One large well-developed exposure is in the southeast quarter of section 12, Goodrich township (T. 84 N., R. 39 W.), Crawford county, near where the stream flows into the Boyer river. This exposure is at an elevation of 50 feet above the stream, and the material is similar to that of the exposures just described except that it is finer. In an average sample of this material, about 73 per cent is between 1/4 and 2 millimeters in diameter.

Along Deep Creek there is a distinct terrace from which Loveland gravel has been removed in several places. This stream heads up in the southwest corner of O'Brien county and flows southwest across Sioux and Plymouth counties, joining Willow Creek about 3 miles northeast of Le Mars. Carman[48] has described several exposures between Remsen and Le Mars, and states that gravel has been seen in every section between the two towns.

The gravel is exposed in a terrace 20 feet above the level of the stream in the south central part of section 31, Meadow township (T. 93 N., R. 43 W.), Plymouth county, about 1 mile north of Remsen. The overburden is loesslike and is probably Peorian loess. It is 3 to 4 feet thick and colored to chocolate-brown in the upper 18 inches by oxidation and humus, while in the lower part it is light buff like normal loess. Leaching has removed the carbonates from all of the overburden, but from none of the underlying gravel.

The gravel is colored by oxidation to a light buff (19"i, Isabella Color), throughout all of the 10-foot exposure. None of the gravel is leached and only a few of the rocks show weathering. The material is well stratified, the beds dipping southwest at an angle of about 3 degrees. The strata are thin and never more than 10 inches thick. There are some lens structures and cross-bedding but only within thicker beds. Within this exposure there are several boulders and cobbles which range in size up to 25 centimeters in diameter, although most of them are smaller than 15 centimeters in diameter. A mechanical analysis of an average of the gravel from this pit is shown in No. 4 of figure 32. It shows a relatively even distribution of about 85 per cent of the material between 1/4 and 16 millimeters in diameter. The percentage of rounding is shown in

[48] Carman, J. E., Further Studies on Pleistocene Geology of Northwestern Iowa: Iowa Geol. Survey, Vol. XXXV, pp. 147-149, 1929.

No. 4 of figure 33. The rock content, determined from an analysis of pebbles is shown in No. 4 of figure 34. Although only 10 feet of gravel is exposed in this pit, test holes show the gravel to be more than 45 feet thick.

Another exposure of gravel along Deep Creek is about 4 miles farther downstream. It is in the northwest quarter of section 4, Marion township, (T. 92 N., R. 44 W.), Plymouth county, about 1 mile east of Oyens. Here the gravel is exposed in a terrace 25 feet above the level of the stream. It has been removed over a wide area to a maximum depth of 30 feet, although only about 10 feet of the gravel is exposed above the water in the bottom of the pit. The gravel is covered by about 6 feet of loesslike overburden.

The characteristics of the gravel of this exposure are similar to those of the exposure just described and analyses of the size, shape, and lithology of average material are shown in No. 5 of figures 32, 33, and 34.

Three good exposures of Loveland gravel occur along Brushy fork which heads up in west central Carroll county and flows southeast to where it joins the South Raccoon river near Guthrie Center. The entire length of this stream course is within the Kansas drift area, eliminating the possibility of the gravel being outwash from the Mankato or Iowan ice fronts.

The two best exposures are about 8 miles below the head of the stream. They are only a few hundred feet apart and occur in the same terrace. They are in the southeast quarter of section 28 and the northwest quarter of section 34, Roselle township (T. 83 N., R. 35 W.), Carroll county. These exposures are very much alike and will be described together. The terrace in which they occur stands about 15 feet above the level of the stream and is covered by Peorian loess, the surface of which slopes back into the hills.

This Loveland gravel looks fresh, and slight oxidation colors it to a light grayish-buff (17'' 'b, Avellaneous) throughout the entire exposure. It contains limestone pebbles from top to bottom and shows practically no weathering or disintegration of the material. All of the gravel is well stratified, but within the major beds there is considerable cross-bedding and many lenses. None of the gravel observed is larger than 2 centimeters in diameter and very little (about 4 per cent) larger than 1 centimeter in diameter. A mechanical analysis of the average material shows about 70 per cent between 1/2 and 4 millimeters in diameter.

The loess overlying the gravel is leached to a depth of 3 1/2 feet in one exposure while in the other it is unleached to the surface. However, it is possible that there has been erosion on the unleached loess surface. The contact of the base of the gravel was not exposed.

About 6 miles farther down the stream there is another exposure of Loveland gravel similar to the one just described. It is in the central part of section 20, Newton township (T. 82 N., R. 34 W.), Carroll county, in the southwest corner of Dedham.

The gravel of this exposure is colored to a slightly darker-buff (19"i, Isabella Color) than the one just described farther upstream. Leaching has removed the carbonates from the overlying 4 feet of loess and from the upper 6 inches of gravel. Only a few of the rocks show disintegration by weathering. The gravel is well stratified and cross-bedding is common within the major beds. The material of this exposure is coarser and not so uniform in texture as that of the other exposures observed along this stream. Other than a few large boulders in the base of the pit which have a maximum average diameter of about 30 centimeters, nothing observed was larger than 5 centimeters. A mechanical analysis of average gravel shows 50 per cent between 1/4 and 1 millimeter in diameter and only 5 per cent between 8 and 16 millimeters in diameter. A mechanical analysis of the average gravel is given in No. 6 of figure 32. The percentage of rounding is shown in No. 6 of figure 33. A lithologic analysis of pebbles is shown in No. 6 of figure 34.

Loveland silt, sand, and gravel is exposed along several streams in southern Iowa. However, it is deeply buried below younger loess and alluvium, and only in a few places do the present stream valleys cut deep enough to expose this material. Along some of the streams the Loveland materials have been encountered only in excavations below the level of the stream bed.

In the report on the geology of Page county, Calvin[44] described some old loess, silt, and sand deposits but had difficulty in explaining their origin. In the light of present knowledge it is evident that they are of Loveland age. In this report he gave the following descriptions:

"In some instances there are indications of two distinct beds of loess.

44 Calvin, Samuel, Geology of Page County: Iowa Geol. Survey, Vol. XI, pp. 444-447, 1901.

For example, on top of the hill east of the Grabill brickyard, the fresh cut surface showed:

		Feet
4.	Light colored loess, not very ferruginous	6
3.	Yellowish sand, the upper 10 inches clay colored, the lower part showing cross-bedding. The laminae in the cross-bedded portion are inclined toward the east, away from the river valley	2½
2.	Dark colored, ferruginous, weather-stained loess, quite different in appearance from No. 4	5
1.	Very much weathered drift, ferruginous, leached, the cobbles and pebbles much decayed, the whole stained with organic matter; exposed	7

"The two beds of loess are very distinct in color, No. 2 showing signs of much greater age than No. 4. The obliquely bedded sand, No. 3, may probably be of eolian origin. The altitude is 160 feet above the present flood plain of the river, and it is scarcely conceivable that this material could have been deposited by currents of water flowing toward the east."

In this section the old loess is no doubt Loveland loess containing a pocket of gravel. The younger loess is Peorian which overlies the Loveland and other older deposits that were exposed at the time it was deposited.

Calvin also described deposits within the valleys which he was unable to interpret in harmony with conditions of the Pleistocene as then known. They are as follows:

"In nearly all the valleys of Page county there is a formation which in some of its phases resembles loess; but in other of its aspects it is clearly an aqueous deposit. It has evidently been laid down since the valleys reached approximately their present depth. North branch near Clarinda has its channel cut in this material. It is yellowish in color, tough, jointed and obscurely stratified. Unlike loess, it contains occasional pebbles and pockets of sand . . . Above the section described at Braddyville, west of the railway track, there is a body of this clay, 20 feet thick and forming a distinct terrace 50 yards yards or more in width at the top. The hard, enameled scales of the gar pike, Lepidosteus, were found in this bed at Braddyville, the scales retaining their proper relations to each other as if the fish had been buried at the time the silt was forming. Between the point where the scales were found and the railway station, some recent cuttings show beds of stratified sand below the level of the clay. The same yellow silt is found beneath sandy alluvium in the valley of Buchanan creek, east of Braddyville. It is well shown in the bank of the Nishnabotna river west of Essex, where it is overlain by 6 feet of a fine, loess-like silt and 2 or 3 feet of black loam. At the Rankin Brothers' brickyard at Shenandoah, the section of the clay pit shows:

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

"Nos. 1 and 3 resemble loess, but No. 2 records a distinct episode between the more recent and a more ancient period of loess formation during which the valley was temporarily flooded.

"The distribution of this deposit is practically universal in all the valleys below a certain level. There has been some valley cutting since it was laid down, but little as compared with what took place beforehand."

At present we recognize an old loess, the Loveland, which contains lenses and pockets of sand and gravel as those Calvin described within this area. Also, recent studies reveal similar deposits at other locations both within this county and in other counties in southern Iowa. Even though Calvin did not recognize the origin and age now accepted for these deposits, he must be credited with accurate descriptions and interpretations of his observations.

In the dredged ditch along the East Nodaway river, in the southwest quarter of section 34, Nebraska township (T. 69 N., R. 36 W.), Page county, about 3 miles east of Clarinda, there is a good section which shows Loveland silt, sand, and gravel. It is:

	Feet
4. Alluvium, black, silty clay, unstratified, tough and heavy, unleached	10
3. Loess, gray-brown mottled, unstratified, leached	4
2. Silt, gray stratified, grades into No. 3, beds thin, laminations at the top, but toward the base the beds become thicker and the material coarser, including sand and some gravel, all leached	3
1. Gravel, gray, sandy, leached, poorly stratified in relatively horizontal beds; exposed	⅓

In the above section, Nos. 1, 2, and 3 are interpreted as Loveland, and the overlying material, No. 4, as younger alluvium.

In an excavaton in the valley of the West Nodaway in the northwest quarter of section 32, Nodaway township (T. 69 N., R. 36 W.), Page county, a thick bed of gray silt is exposed under the dark-colored alluvium. This section appears to be comparable to the one previously described, the silts representing Loveland valley deposition.

Another exposure similar to the one along the East Nodaway river is along the dredge channel of the West One Hundred and Two river. This is in the northwest quarter of section 10, Mason township (T. 68 N., R. 35 W.), Taylor county. The section is as follows:

	Feet
4. Alluvium, black, heavy, unstratified, leached	12
3. Loess, gray with mottling of iron oxide, leached, tough and heavy; slight gradation into No. 4	9
2. Silt, gray, indistinctly stratified; one bed near the base is fine, almost clay; leached	2½
1. Sand, buff, leached, contains some black claylike material. Below the level of the surface of the stream it is colored grayish-green by the water	1

Numbers 1, 2, and 3 of this section are interpreted as Loveland and No. 4 as recent alluvium. Although no gravel is exposed in this section, the stream flows on gravel less than 1/4 mile away, which suggests that it has cut across a lens of gravel included in the silt and sand.

In Ringgold county, the Loveland is exposed along the dredged channel of Platte River near the center of the south side of section 3, Benton township (T. 68 N., R. 31 W.), about 2 1/2 miles west of Benton. Here the section is as follows:

	Feet
4. Black, silty loam, soil layer	1½
3. Loess, light brownish-buff, and leached; grades into No. 4 through a 6-inch transition zone	8
2. Loess, gray, leached; tough and plastic; looks like an old loess	6
1. Sand, fine-white, leached, contains a few small pebbles; exposed	2

In the above section the numbers 1 and 2 are believed to represent Loveland valley deposits, No. 3 Peorian loess, and No. 4 Peorian loess modified by a soil zone. This section is near the edge of the valley and does not contain alluvium but rather loess like that on adjoining slopes.

Exposures of Loveland deposits, including sand and silt have been observed in several places along stream valleys in Lucas county. One of the best of these exposures is along a branch of White Breast Creek, near the center of section 21, Benton township (T. 71 N., R. 21 W.), about 1/2 mile west of Russell. The section here is as follows:

	Feet
10. Soil filled with roots	2
9. Gray sand and gravel oxidized, brownish and reddish, strongly cemented	3
8. Sandy clay band	½
7. Gravel oxidized, brownish yellow	1¼
6. Clay seam, distinct	⅙
5. White sand	1
4. Yellow sand, pebbly below	1
3. Clay seam	⅙
2. White sand with yellow streaks, oxidized at base	1
1. Yellowish, grayish clay, drift	8

All of the above section is leached of its carbonates and represents

Loveland deposition along the valley. If there is any Peorian loess here it is very thin.

Aside from those described above, there are many other deposits of Loveland silt, sand, and gravel throughout this area, as shown by the locations on figure 34. Although they are not described, they are similar to those described within the same area.

Relations of the Loveland Gravel:

The Loveland formation — consisting of loess, silt, sand, and gravel deposited during the Loveland interval — is widely distributed, having been found in most parts of the state. The loess and silt are the most widely distributed, but sand and gravel occupy some valleys in western and southern Iowa.

The term Loveland was introduced by Shimek [45] in 1909, but has been further defined during more recent years by Kay,[46] who has recognized and described it throughout most of the state. Further descriptions of the formation and its relations have been given by Carman [47] in his most recent report on the Pleistocene geology of northwestern Iowa. The Loveland formation rests upon the eroded surface of the Kansan gumbotil plain. Therefore, the Loveland interval began not earlier than late Yarmouth time, as the gumbotil had been formed and the mature dissection of the drift plain had occurred before the Loveland was laid down. This formation is in many places leached, and some of the materials show alteration beyond the mere removal of the more soluble constituents. A young loess, commonly unleached, overlies the Loveland in most places, indicating that the alteration of the Loveland loess and silt occurred before the deposition of this overlying material. Iowan till overlies the Loveland in other sections. The Peorian loess and Iowan till, closely related in age and resting on the Loveland deposits, show that the Loveland interval preceded their deposition.

The type section of the Loveland was described from Loveland, Iowa, in northwestern Pottawattamie county, where the loess rests upon 11 feet of oxidized and unleached till over bluish-gray un-

45 Shimek, B., Aftonian Sands and Gravels in Western Iowa: Bull. Geol. Soc. of Amreica, Vol. 20, footnote, p. 405, 1909.

46 Kay, G. F., Recent Studies of the Pleistocene in Western Iowa: Bull. Geol. Soc. of America, Vol. 35, pp. 71-73, 1924. Loveland Loess, Post-Illinoian, Pre-Iowan in Age: Science, N. S., Vol. LXVIII, pp. 482-483, 1928. Significance of Post-Illinoian, Pre-Iowan Loess: Science, N. S., Vol. LXX, pp. 259-260, 1929. With Apfel, E. T., The Pre-Illinoian Pleistocene Geology of Iowa: Iowa Geol. Survey, Vol. XXXIV, pp. 277-281, 1929.

47 Carman, J. Ernest, Further Studies on the Pleistocene Geology of Northwestern Iowa: Iowa Geol. Survey, Vol. XXXV, pp. 49-52, 1931.

weathered till. Here the Loveland loess is covered with thick buff loess, most of which is Peorian in age. Both loesses are fossiliferous, fossils being more abundant in the Peorian loess than in the Loveland.

Another exposure of Loveland loess is in a railroad cut just east of McPherson station on the Chicago, Burlington and Quincy railroad, in Montgomery county. Here leached Loveland loess more than 20 feet thick is exposed under 25 feet of buff calcareous loess.

From these two sections alone, it is evident that the Loveland loess varies greatly in the amount of alteration, and thus must have been deposited at different times during the interval. Other exposures show differences similar to those just described.

The gravel and sand deposited in the valleys, like the loess and silt deposited on the uplands, show differences in alteration within the different exposures studied.

In the previous descriptions of gravel exposures in northwestern Iowa there is no evidence of a period of weathering between the time of gravel deposition and that of loess deposition. Only where the overlying Peorian loess is thin and all leached is there any leaching in the upper part of the Loveland gravel.

An exposure of gravel along the south side of the valley of East Fork, east of Denison, in Crawford county, shows not only buff calcareous loess overlying calcareous gravel but also interbedding of the two. The entire length of this stream is within the Kansan drift area, so it could not contain Iowan gravel. If this loess is Loveland rather than Peorian, the Peorian loess which is thick within this area is either absent here or cannot be differentiated from the Loveland loess. Besides being closely related to the overlying Peorian loess, the Loveland terraces correspond in elevation with the Iowan and Mankato terraces of this area. The gravel of these terraces, the Loveland and Iowan or possibly Mankato, are similar in most respects but differ slightly in general lithologic content, the Loveland containing a greater percentage of the more resistant kinds of rock.

The overlying silt and loesslike clay are not distinctly separated from the sand and gravel but in some places are interbedded. The noncalcareous condition of these deposits would suggest that they were weathered for a long period of time before the deposition of the Peorian loess. This being true, these Loveland deposits must have been deposited long before those of the Peorian loess and also long before Loveland gravel of northwestern Iowa. However, this difference in the deposits need not all be explained on the basis of time of deposition, because the long period of erosion was far more effective in northwestern Iowa, where it removed all of the gumbotil and leached till from the Kansan, than in southern Iowa, where it merely cut valleys in the gumbotil plain. This not only would allow a greater supply of gravel for the streams of northwestern Iowa but there would also be a greater percentage of gravel derived from the unweathered till.

The Age of the Loveland Gravel:

The age of the Loveland gravel has been discussed along with the relations of the deposits. However, in summary, the following statements might be made: Loveland deposits of loess, silt, sand, and gravel lie upon the eroded surface of the Kansan drift or older deposits, the erosion beginning after the formation of the Kansan gumbotil and during the Yarmouth Age. They are overlain by Iowan till and Peorian loess. These two limits bound the Loveland interval during which these materials were deposited. In previous papers by Kay, listed in footnote No. 46 (p. 116), the age of the deposits has been discussed in detail. It suffices here to state that, on the basis of present evidence, the sand and gravel, like the loess and silt, may have been deposited at any time during the interval, some probably during the late Yarmouth age and others as late as the immediately pre-Iowan. In fact, all evidence is in harmony with the conclusion presented by Carman,[48] that part of the gravels of northwestern Iowa were deposited just before the Peorian loess deposition or approximately at the time of the Iowan glacial advance. However, it is probable that those of southern Iowa were deposited during an earlier part of the interval and that the distant Iowan glacier had little effect upon deposition within these valleys. It is possible that deposits similar and of the same age as those of southern Iowa were also deposited in the valleys of northwestern Iowa, but with the climatic changes accompanying the Iowan glacial advance, more material was introduced and the older deposits were reworked and deposited along with the newly introduced material.

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48 Carman, J. Ernest, Further Studies of the Pleistocene Geology of Northwestern Iowa: Iowa Geol. Survey, Vol. XXXV, p. 149, 1931.

The Gravels of the Eldoran Series — the Iowan and Mankato Substages

THE IOWAN GRAVELS

As the Iowan glacier melted, it deposited its load on the eroded surface of the Kansan drift and on other surface deposits over which it had advanced. However, the Iowan drift was thin and did not fill the valleys and thus did not level the surface as had the older glacial deposits, but spread over the eroded Kansan surface as a blanket, forming a drift-mantled erosional topography. The water flowing from the melting glacier deposited gravel of two general types: (1) masses within and on the surface of the Iowan till, forming what will be referred to as Iowan upland gravel; and (2) outwash, referred to as Iowan terrace gravel, deposited along unfilled pre-Iowan valleys both inside and beyond the Iowan drift border. These two types of Iowan gravel will be treated separately, since they are of different origin and have different characteristics.

The Iowan gravel deposits have been studied for many years chiefly within northeastern Iowa, and have been described in many reports. However, in the reports published before 1915 and in some since, they have been described and interpreted as Buchanan gravels deposited during the retreat of the Kansan glacier. The two types of deposits were recognized and given the names Upland phase and Valley phase of the Buchanan. In the report on the geology of Howard county, Calvin described the genesis of these deposits which he thought were of Kansan age.[49] Calvin's Valley phase is Iowan terrace gravel, but his Upland phase includes both Iowan upland gravel and Kansan gravel. He failed to differentiate the Iowan upland gravel from the Kansan upland gravel.

THE IOWAN UPLAND GRAVEL

Distribution of the Gravel

The Iowan upland gravel deposits distinctly related to the Iowan till, are unevenly distributed throughout the area covered by the Iowan glacier. They occur within the Iowan drift areas of both northeastern and northwestern Iowa and are distributed as shown in figure 35. Their abundance, characteristics, and accessibility make them ex-

49 Calvin, Samuel, Geology of Howard County: Iowa Geol. Survey, Vol. XIII, pp. 67-68, 1903.

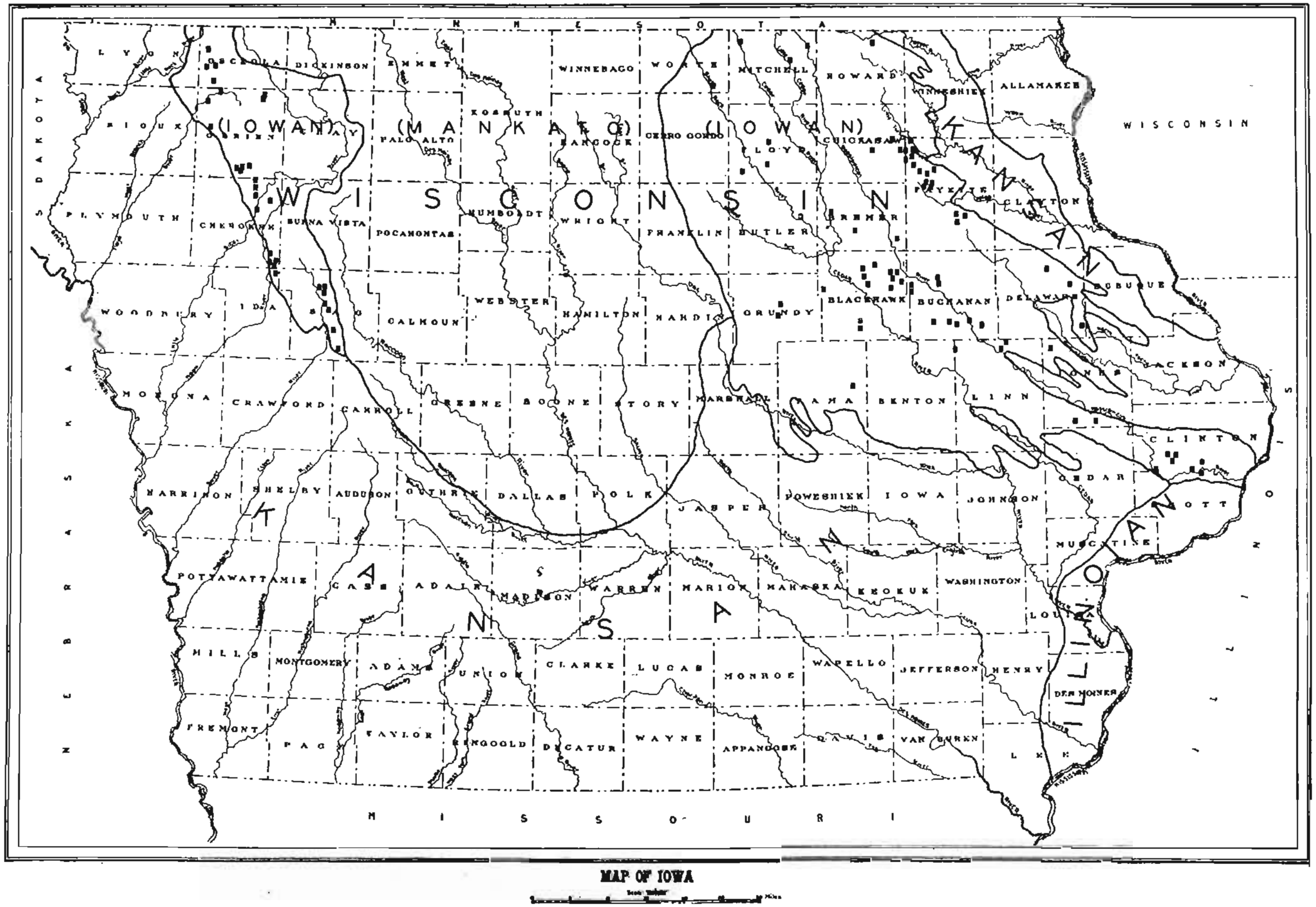


FIG. 35. — The squares show the locations of Iowan upland gravel exposures in Iowa.

tremely valuable as road surfacing material, for which they have been used extensively. Since there has been very little post-Iowan erosion, good natural exposures are rarely found and the gravel pits from which the deposits have been removed afford many good fresh exposures for study. It is probable that some of the Iowan upland deposits are masses so deeply buried within the Iowan till that they are not available for commercial use. However, the Iowan till is so thin in most places that large masses of gravel could not be buried deeper than a few feet except where the till is covered by thick Peorian loess.

Characteristics of the Gravel

General Characteristics:

The deposition of the Iowan upland gravel is closely related to the retreat of the Iowan glacier and deposition of the Iowan till. The known exposures of the gravel occur at any one of four general positions with respect to the Iowan till: (1) Several exposures show Iowan gravel interbedded with Iowan till. (2) A few are pockets buried within the till. (3) Others are small kamelike knobs or hills which stand above the drift surface, and (4) many of them are pockets of gravel located near the tops of the hills, their upper surface almost at the same level as that of the drift.

The Iowan areas in which the gravel deposits were studied have not been buried by more recent post-Iowan deposits other than the Peorian loess, which was deposited almost immediately following the deposition of the Iowan till; but they have been at the surface and subjected to the processes of weathering during subsequent time.

The Iowan till and Peorian loess combined have been leached of their carbonates to an average depth of 4 to 6 feet, and the iron compounds have been oxidized still deeper. This makes these deposits divisible into three zones: the oxidized and leached at the surface, underlain by the oxidized and unleached, which in turn is underlain by the unaltered material. Weathering has not continued long enough for gumbotil to form, as it has on the older drifts.

During the time that the till and loess were being altered to their present condition, the gravel occupying a like position was undergoing comparable changes.

The leaching within the gravel has removed the carbonates to an average depth of 4 to 6 feet, which is approximately the same as within the till. In a few exposures ground water has deposited calcium carbonate at lower depths in the form of concretions and cement. This cementation is quite variable in respect to the general stratification; sometimes it is within one bed or zone, but more frequently it cements irregular masses which vary in size from a few inches to more than 20 feet in diameter. The cemented gravel forms a firm, friable conglomerate which in extreme cases will fracture across the weaker rocks rather than through the cement surrounding them.

The oxidation of the iron compounds generally colors the complete exposure to a uniform color which ranges from light-buff (15'i, Ochraceous-Tawny) to reddish-brown (11'k, Hazel). However, in some exposures the different beds show extreme variation in color and some entire exposures show almost no coloration by iron oxide. The wide range in color makes it impossible to differentiate Iowan gravel from other gravels on the basis of oxidation. When present, the iron oxide coating the grains and partly filling the interstitial spaces cements the gravel into a compact, weakly coherent mass which stands in exposures with a vertical face, but can be broken easily with slight pressure. Occasionally thin beds are more highly oxidized and form a firm conglomerate which breaks more readily across some of the weaker rocks than does the cement. Thin beds, seldom more than 1 inch thick are sometimes colored black by manganese dioxide which coats the grains. The disintegration of the rocks by weathering — so evident in the Kansan, Nebraskan, and Illinoian gravels — is not as commonly observed in the Iowan deposits.

Most of the deposits are well stratified, generally in horizontal beds. However, they may include many irregularities such as lenses, pockets, cross-bedding, steeply dipping beds, clay-balls, boulders, inclusions of Iowan till, and inclusions of older material such as till, gumbotil, and Loveland loess which were removed from the pre-Iowan surface by the advancing Iowan ice. In places leaching, poor sorting of the material, and oxidation of the iron compounds give the deposits an unstratified appearance. There is a wide size range within the separate exposures and throughout most of these deposits. Most of the material is smaller than 6 centimeters in diameter, but there are many cobbles and boulders distributed through the gravel, some of which have an average diameter of more than 80 centimeters.

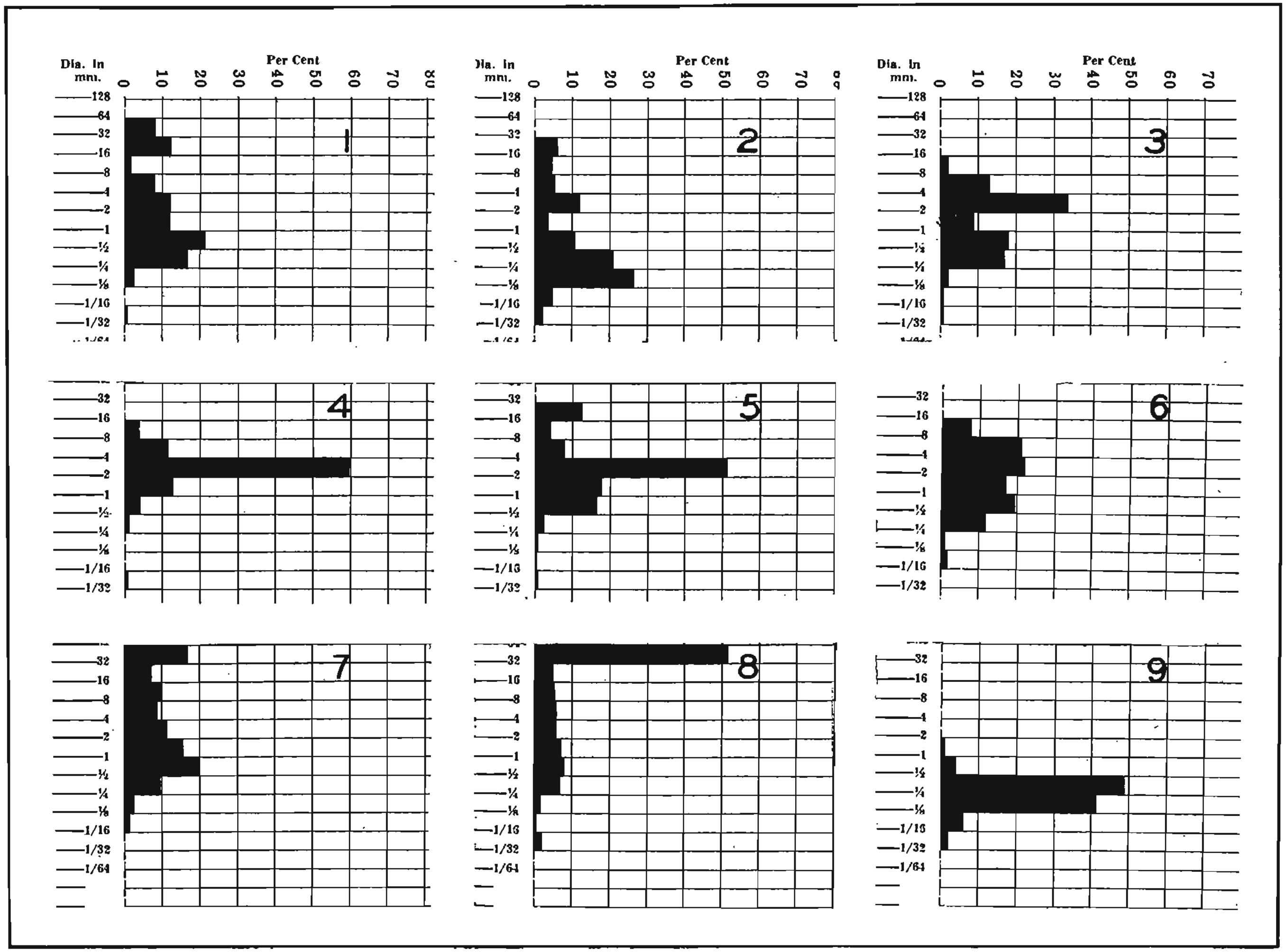


FIG. 36. — Graphs showing mechanical analyses of Iowan upland gravel. The numbers of this figure correspond with those of figures 37 and 38.

The percentage of each different size grade as determined by mechanical analyses of average samples from each exposure is shown in figure 36. The percentage of rounding of each size grade between 1/16 and 32 millimeters in diameter of the above mechanical analyses

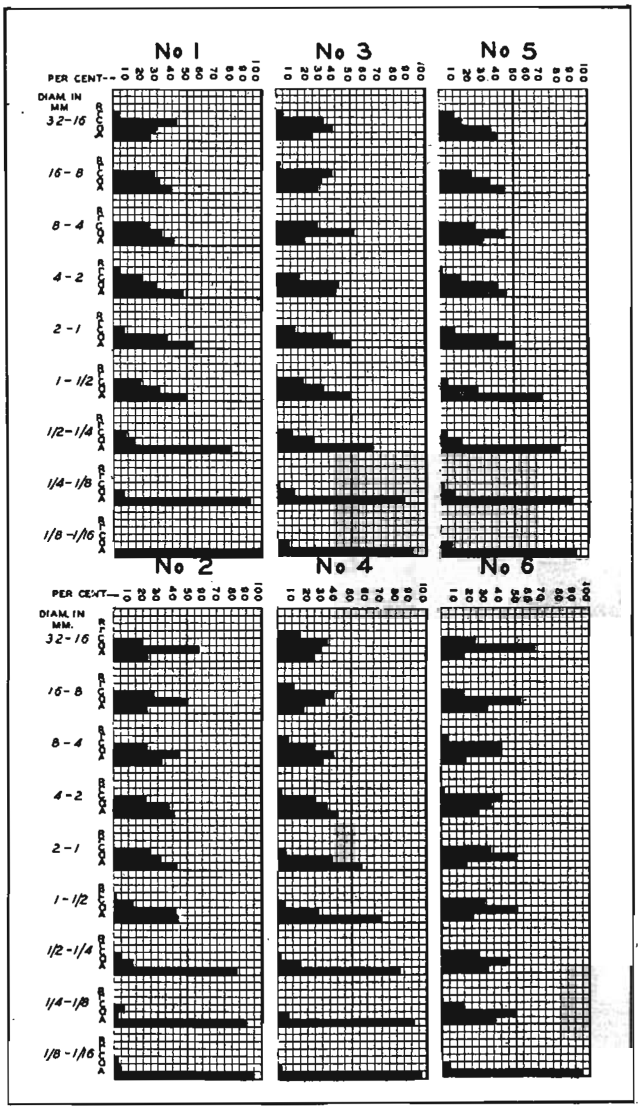


Fig. 37. — Graphs showing shape analyses of each size grade between 1/16 and 32 Millimeters in diameter of the Iowan upland gravel. The numbers of these analyses correspond with those of figures 36 and 38. R = rounded; r = sub-rounded; C = curvilinear; a = sub-angular; A = angular.

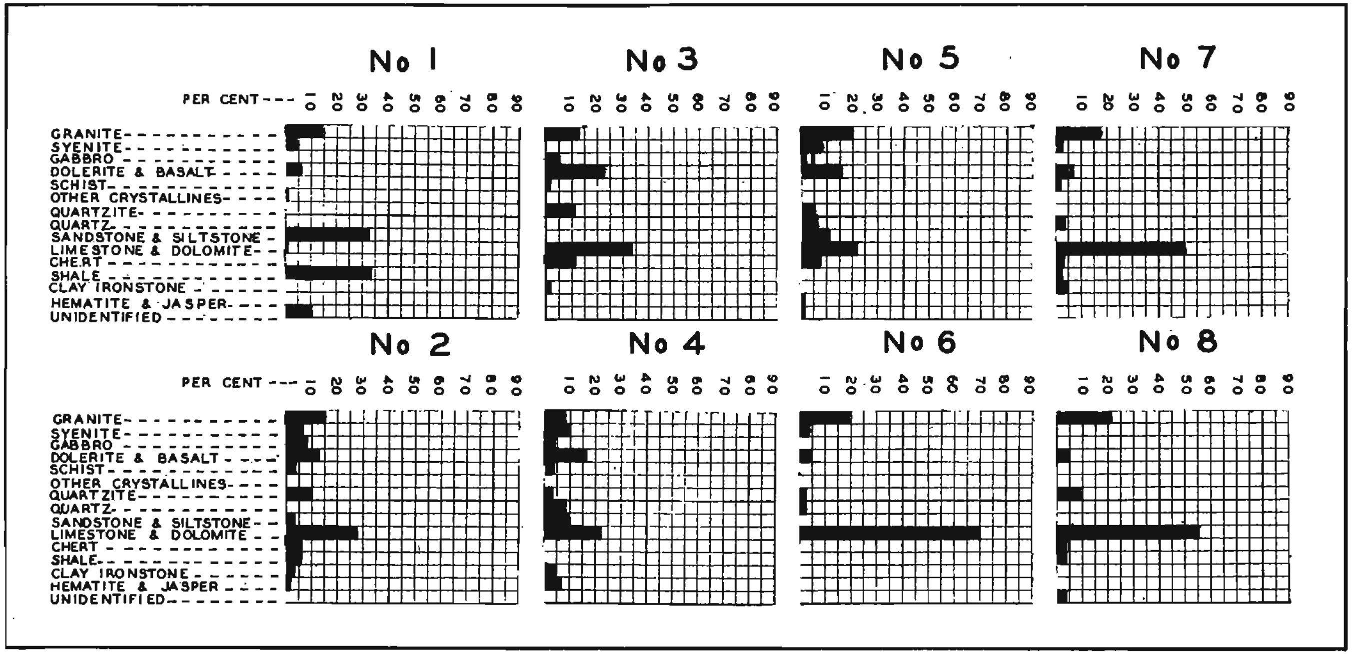


FIG. 38. — Graphs showing lithology of pebbles between 16 and 32 millimeters in diameter. The numbers of these analyses correspond with those of figures 36 and 37.

is shown in figure 37. Rock analyses of pebbles between 16-32 millimeters in diameter are given in figure 38. The analysis numbers in both shape and rock analyses correspond with those of the mechanical analyses.

Iowan till, Peorian loess or both may overlie the gravel. They are generally thin but have been observed to have a thickness of 15 feet. Weathering has removed the carbonates to an average depth of 4 to 6 feet and has oxidized the iron compounds much deeper. Humus has colored the oxidized material of the upper 18 to 24 inches to chocolate-brown (13" "i, Benzo-Brown), this color becoming lighter with increase in depth. The gravel overlies Iowan till in most of the exposures, either oxidized or unoxidized but never leached. However, in a few exposures they have been observed to overlie either Loveland loess, Kansan till, Kansan gumbotil, or Kansan gravel.

Characteristics of the Exposures

One of the most interesting exposures of Iowan gravel is in a pit in the southwest quarter of section 22, Cedar Falls township (T. 89 N., R. 18 W.), Black Hawk county, 2 miles west of Cedar Falls. Here the gravel is exposed along the hillside in an area which has a relief of about 75 feet.

This exposure shows the following section:

	Feet	Inches
6. Loess: leached, oxidized, and filled with humus which colors it to Chocolate-brown (13""i, Benzo-Brown). (Peorian)	2	
5. Pebble band on the surface of the Iowan till. (Iowan)		1
4. Till: oxidized to the usual buff color (19"i, Isabella Color) of the Iowan, leached to a depth of about three feet; several large boulders, the largest having an average diameter of eight feet. (Iowan)	12	
3. Silt and fine sand: unoxidized, leached and well stratified in thin horizontal beds, grading into gravel at the base. (Iowan)	1	
2. Gravel: well stratified, unleached, oxidized to a medium-brown; pebbles show some striations and some stream wear. (Iowan)	10	
1. Till; gray (15""', Mouse-Gray) on the surface when dry, and blue-black when wet; unleached and unoxidized, and contains boulders. (Iowan)	4	

The iron oxide which coats the grains colors the deposit to a rusty-brown (17', Raw Sienna) and cements the gravel so that it will stand in vertical exposure. After the gravel has been exposed in the section for a short time the iron oxide in the outer few inches becomes much harder and cements the gravel more firmly. Leaching has removed the carbonates from the overburden to a depth of 5 1/2 feet, below which both the till and gravel are unleached. Most of the crystalline rocks appear fresh but a few are slightly disintegrated. The material consists chiefly of sand and gravel finer than 3 centimeters in diameter; it is well stratified and interbedded in horizontal beds. The percentage of each size grade is shown in No. 1 of figure 36. The percentage of rounding is shown in No. 1 of figure 37. The rock content of the pebbles between 16 and 32 millimeters in diameter is shown in No. 1 of figure 38.

This exposure represents an irregular mass of Iowan gravel inclosed within Iowan till and is significant from the standpoint of its relationship to the Iowan till. The leaching extends to a depth of about 5 feet in both the till and the gravel, while the oxidation extends to greater depths.

About 1/2 mile south of this exposure there is another exposure of Iowan gravel in a cut along the highway. In this cut the gravel is a small pocket near the surface of the till. It is within leached and oxidized till and likewise is leached and oxidized. The overburden is Peorian loess 2 feet thick.

In the top of an elongated hill near the margin of the Iowan drift area, in the southwest quarter of section 12, Smithfield township (T. 92 N., R. 7 W.), Fayette county, between Fayette and Arlington, 12 feet of Iowan upland gravel is exposed in a group of three pits which are only a few hundred feet apart. In this region there is 120 feet of relief between the pits and the bottom of the valley which is less than 1/2 mile away. About 40 feet of this relief is above the Kansan gumbotil plain. This exposure shows many irregularities. It contains well-stratified beds of gravel in some parts, stratified sand and silt in others, and masses of unstratified or slightly stratified material in still others. Accompanying the variations within the clastic texture of the gravel, there are similar variations in the amount of oxidation and leaching. The coloring by iron oxide varies throughout the exposure from a reddish-brown (11'k, Hazel) in one bed of silt 8 inches thick, through various shades of brown and buff, to gray (21'' 'f, Pale Olive-Buff) unoxidized sand which is highly siliceous and occurs in both beds and irregular masses. The uniform beds of gravel are leached to the usual depth of about 5 1/2 feet, which includes the overburden. However, most of the beds and masses of gray unoxidized siliceous sand and silt contain no calcium carbonate even where they are below this depth and below unleached gravel. There is a wide range in size from large boulders 60 centimeters in diameter distributed through the exposure to beds of fine sand and silt. Most of the gravel is finer than 5 centimeters in diameter, and more than 30 per cent of the material exposed is silt and fine sand which is in irregular masses and interbedded with the gravel. The percentage of each size grade, is shown graphically in No. 2 of figure 36. The percentage of rounding is shown in No. 2 of figure 37. The rock content is shown in No. 2 of figure 38.

The overburden is leached Iowan till and Peorian loess that has a maximum thickness of about 6 feet. Within the upper 16 to 24 inches it is colored to a dark-brown (13" "i, Benzo-Brown), but below this it gradually grades into a lighter shade of brown (17" 'i, Buff-Brown) with the increase in depth.

Another interesting exposure of Iowan upland gravel is in the northeast quarter of section 35, Wayne township (T. 100 N., R. 15 W.), Mitchell county, about 1/2 mile east of McIntire. Here in a pit along the hillside the gravel overlies both Kansan gravel and Loveland loess.

The iron oxide which coats the grains colors the deposit a light-brown (15'i, Ochraceous-Tawny) but cements the mass so slightly that it slumps soon after exposure. The gravel reaches its maximum thickness of 5 feet in the middle of the exposure, from which point it becomes thinner toward the edges, where it has a thickness of about 2 feet. The combined thickness of the gravel and overlying till is 7 feet. The gravel is fairly well stratified in a general horizontal position but is poorly sorted; it shows some cross-bedding, and some steeply dipping beds. Most of the material is smaller than 5 centimeters in diameter, although there are some cobbles as large as 15 centimeters in diameter scattered through the finer material with no relation to the stratification. A few of the pebbles and cobbles show glacially planed surfaces and striations. The percentage of each size grade is shown graphically in No. 3 of figure 36. The percentage of rounding is given in No. 3 of figure 37. The rock analysis is shown in No. 3 of figure 38.

The overburden is Iowan till, colored in the upper 18 to 24 inches to the usual dark brown by oxidation and humus, below which it grades into the usual lighter shades of normal oxidized Iowan till. Only where thickest (5 feet) is there unleached Iowan till above the gravel. Underlying the Iowan gravel is Kansan gravel and Loveland silt. The former shows a marked difference in characteristics from the Iowan gravel and the latter has been partly plowed up and incorporated into the base of the Iowan gravel.

In the northwest part of Mitchell county the Iowan upland gravel is exposed in the northwest quarter of section 14, Otranto township (T. 100 N., R. 18 W.), less than 1/4 mile southwest of Mona. Here on the relatively flat Iowan upland is a pocket of gravel which lies on the Kansan gumbotil and extends through the Iowan drift which at this location is only 5 feet thick. Practically all of the gravel has been removed, but it seems from all available evidence that the gravel was about the same thickness as the Iowan till. Although the exposure is only 5 feet thick there are a few inches of unleached material immediately above the Kansan gumbotil. The complete removal of the gravel and slumping since the pit was last used makes a detailed study of the gravel impossible.

In Howard county in the northwest quarter of the southwest quarter of section 10, Albion township (T. 100 N., R. 11 W.), overlooking the Upper Iowa river, a pit exposes 28 feet of gravel. It is located at the extreme end of a narrow tongue of Iowan drift which extends out into the rugged loess-mantled Kansan drift topography. The top of the exposure is 80 feet above the valley below.

The iron oxide colors the complete section of gravel to a light buffy-brown (17" 'i, Buffy-Brown). It does not cement the gravel but merely helps to compact the mass so that it does not slump readily. In no part of the exposed gravel is there any variation from the usual color. Leaching has removed the carbonates to a depth of 3 to 5 feet, and most of the igneous pebbles appear fresh. The exposure may be roughly divided into an upper 3-foot member and a lower 25-foot member on the basis of size of material and stratification. The upper 3 feet contains some boulders ranging up to 25 centimeters in diameter and a large amount of coarse gravel, all poorly stratified. The lower 25 feet of the exposure consists of well-stratified and cross-bedded gravel ranging between 0.5 centimeters and 2 centimeters in diameter, except for a small amount of sand which is mixed but not interbedded with the gravel. The percentage of each size grade of an average sample of the lower member is shown graphically in No. 4 of figure 36. The percentage of rounding is shown in No. 4 of figure 37. The rock content determined by an analysis of pebbles is shown in No. 4 of figure 38.

The overburden is loesslike silt, colored dark-brown (13" "i, Benzo-

Brown) by oxidation and humus. It is about 1 foot thick; is leached, and grades into the top of the coarse leached gravel which in the upper 10 inches is colored to about the same shade as the overburden.

One-half mile north of Paris in the northeast quarter of section 19, Jackson township (T. 86 N., R. 6 W.), Linn county, 30 feet of Iowan upland gravel is exposed at the top of the hill in a region of rolling Iowan drift topography. This exposure is at the margin of the Iowan drift but at the extreme end of a long narrow recess between two lobes of the Iowan drift.

There is very little oxidation within this gravel, which is light grayish-buff (19"i, Isabella Color) and leached to a depth of 4 to 6 feet, including the overburden, which varies from 2 to 4 feet in thickness. Except for a few disintegrated granites and schists the igneous rocks are unweathered. The gravel is well sorted, and stratified in beds which are essentially horizontal in some parts of the exposure and in other parts dip steeply toward the east. Cross-bedding which is common within the thicker beds, also dips toward the east. At two locations within the pit the gravel is cemented by secondary calcium carbonate, forming a firm conglomerate. A large mass of this conglomerate has a width of more than 40 feet and includes half of the gravel exposed along the west side of the pit. No relationship exists between the type of material and the cementation and stratification. The percentage of each size grade determined by a mechanical analysis is shown in No. 5 of figure 36. The shape is shown in No. 5 of figure 37. Likewise the rock content, determined by an analysis of pebbles between 16 and 32 millimeters in diameter, is shown in No. 5 of figure 38.

The overburden is sandy Iowan till which has been leached of its carbonates and colored by oxidation and humus to a medium dark-brown (13" "i, Benzo-Brown) in the upper part but becomes lighter in color with increase in depth.

An exposure of Iowan upland gravel within a region of rolling Iowan drift topography is at the top of an elongated hill in the southeast quarter of section 13, New Oregon township (T. 98 N., R. 11 W.), Howard county. This gravel section is in a region where the pre-Iowan erosion exposed the limestone bedrock in many places. As a result the Iowan glacier found the limestone more readily available and likewise the gravel deposited by it contains a high percentage of limestone.

The gravel in this exposure is overlain by thin Iowan till except along the margin, where it has a maximum thickness of 4 feet. This variation in the thickness of the overburden makes a marked difference in the depth of leaching and the character of the uppermost gravel, as will be shown in the following description. Along the margin where the gravel is overlain by 4 feet of normal Iowan till leaching is to a depth of about 5 feet — 4 feet in the till and 1 foot or less in the gravel. However, in the main part of the pit, where the sandy overburden is only about 1 foot thick, leaching is to a depth of from 2 to 2 1/2 feet. This wide variation in the depth of leaching could be due to either the removal of material by erosion or the contraction of beds by removal of the soluble carbonates. Although possible, there is little basis for the conclusion that the leached material has been removed by erosion. Since the gravel contains about 50 per cent limestone, its removal would reduce the volume of the gravel by one-half. If 4 feet of gravel were leached, the remaining gravel would be only about 2 feet thick. At the upper surface of the gravel of this exposure there is a concentrate of coarser non-calcareous material which is almost entirely unstratified and contains overburden within the interstices. It is a zone which seems to represent a gradation from gravel into overburden. This zone can be easily explained on the basis that the overburden sifted down into the space left as the limestone was dissolved away. In this exposure the zone of concentration is thicker and more distinct where the overburden is thin than where it is thick. Furthermore this relationship is more evident in those deposits containing a high percentage of limestone. Hence, it seems probable that the 16 inches to 2 feet of the leached gravel where the overburden is thin is a concentration from about twice that thickness of original gravel. The thin overburden may have undergone some erosion but not necessarily any great amount. Oxidation colors the mass of gravel uniformly to a light buffy-brown (19"i, Isabella Color) with very little variation in color except in the narrow band of gravel immediately below the overburden, which is colored dark dirty-brown (13" "i, Benzo-Brown) by the addition of humus. In the leached gravel there is no stratification, but below this and towards the base of the section the stratification becomes good. In general the stratified beds are almost horizontal, dipping at a low angle toward the southeast. A large number of small boulders which are almost all platy limestone are scattered through the gravel. These limestones generally lie with their greatest diameters parallel to the stratification. An analysis of the rocks larger than 3 centimeters in diameter shows about 85 per cent to be limestone, of which 45 per cent are angular, 45 per cent sub-angular, and 10 per cent curvilinear in shape. The general characteristics of the gravel are shown in figure 39.

FIG. 39. — Type of gravel of an Iowan upland deposit.

A group of kamelike hills is in section 17, 18, 19, and 20, Center township, (T. 93 N., R. 9 W.), Fayette county, about 2 miles west of Randalia. These knobs which stand out above the surface of the gently rolling Iowan drift are about 5 miles from its margin. Gravel pits expose gravel in the tops of many of these knobs, which are not generally more than 20 feet above the surrounding drift surfaces.

Within these exposures are many irregularities in both gravel and overburden. The overburden is Iowan till which in some places is covered by loess. It ranges in thickness from 2 to 8 feet and shows the usual amount of leaching and oxidation characteristic of these materials. The gravel is in irregularly shaped masses. It is uniform neither in texture, in oxidation, nor in depth of leaching. Practically all of the gravel is smaller than 7 centimeters in diameter, and a large percentage is sand and silt. Some of the material is well stratified in practically horizontal beds, and some of the thicker beds contain cross-bedding. In some places well-stratified sand and silt are as much as 3 feet thick, and in other places they occur as irregular masses enclosed within the gravel. In the latter case many of the beds of sand and silt are folded, crumpled, or otherwise distorted. Oxidation varies from medium-brown (17 i, Raw-Sienna) in the coarser gravel to light-buff (17"b, Cinnamon-Buff) in the sand and silt. There is no definite depth of leaching within the deposits, but under normal conditions where gravel underlies the overburden, leaching is to depths like those of other Iowan gravel deposits. However, the sand and silt are generally non-calcareous wherever exposed. Within the exposures there are inclusions of irregular masses of till only a few feet in diameter. Some appear to be Iowan while others are probably Kansan, although this differentiation is based upon leaching alone. There are also irregular masses of fine silt which are possibly Loveland in age, and near the base of one exposure there are some small masses that look like gumbotil. Clay-balls are common.

The characteristics of these deposits are not out of harmony with their position. They are within a few miles of the margin of the Iowan drift and the stratified sand and gravel is much like that of other similarly located deposits. In an exposure about 6 miles northeast of here both Kansan gumbotil and Loveland loess are exposed below a layer of Iowan till and loess, and in another exposure in the same vicinity Nebraskan gumbotil is exposed. It seems logical to assume that these older materials were transported by the ice and incorporated in the Iowan gravel deposits.

Many other deposits occupying topographic positions similar to these just described are found throughout the northwestern part of this county and the eastern part of Chickasaw county. However, the gravel exposed in them is generally more uniform in every respect. In the other deposits inclusions of Iowan till and older deposits are uncommon and the general character of the gravel is more like that of the Iowan upland gravel previously described.

From studies of the Pleistocene deposits in northwestern Iowa, Carman recognized and described Iowan drift and Iowan gravel. The detail in which this work was done and the long period of time devoted to the study enabled him to observe many exposures, some of which are now covered by slumped material. He described one very significant exposure of interbedded Iowan till and gravel as follows:[50]

"By far the greatest example of interbedding of gravel and till observed was found in the east bluff of Mill creek in the west half of section 14, Cherokee township, three miles north of Cherokee. Mill creek at this place flows against the base of the east slope of its valley, and this slope rises very steeply 100 to 120 feet to the crest of a narrow ridge which overlooks the valley of Mill creek on the west and the Little Sioux valley on the east. The good exposures just south and north of the line through the center of section 14, were distributed through a distance of about 80 rods, and were found in little gullies and slides that gave exposures of the underlying material. The lower 30 to 40 feet of the valley slope is gentle but showed a few exposures of typical Kansan till. Above this is a steep slope of 75 to 100 feet, consisting of about equal parts of interbedded Iowan till and gravel which alternate several times in the vertical section. The gravel horizons range in thickness from mere seams to 20 feet, but a common thickness is 10 to 15 feet.

"Most of the gravel is fresh and has a light color owing to the predominance of gray limestone pebbles. It contains many clay-ball pebbles from the associated Iowan till and some of Kansan and Nebraskan tills. The interbedding of gravel and till and the presence of the clay-balls of the associated till in the gravel show that the gravel belongs to the same stage as the till.

"These exposures in the Mill creek bluff of section 14, were such good ones that the following sections are given, recording in detail the succession found in several of the better exposures. The exposures were all mere gully washes and were partly obscured by slumping and surface accumulation. The sections are given in order from south to north.

Section A. — The most southern exposure, that covered approximately all of the height of the slope, was 30 to 40 rods south of the quarter-section line. This exposure is shown diagrammatically in A of figure 40.

	Feet
11. Grass-covered, gravelly, clay slope rising to the top of the ridge, which is here 106 feet above the creek. Probably Iowan till, but it may contain some gravel layers	12
10. Till, light brownish gray, with pebbles and cobbles. Iowan. The exposure is not entirely continuous and the division may contain some gravel. Numbers 11 and 10 combined would make a till zone 30 feet thick, which is greater than for any single zone of till known along this bluff. There is also the unexposed zone (9) below, which may be largely till. It is not probable that numbers 11, 10 and 9 form a single continuous till zone, or even that numbers 10 and 11 are without a single gravel layer.	18
9. Unexposed slope	10
8. Gravel, light-colored	4

50 Carman, J. Ernest, Further Studies on the Pleistocene Geology of Northwestern Iowa: Iowa Geol. Survey, Vol. XXXV, pp. 84-88, 1931.

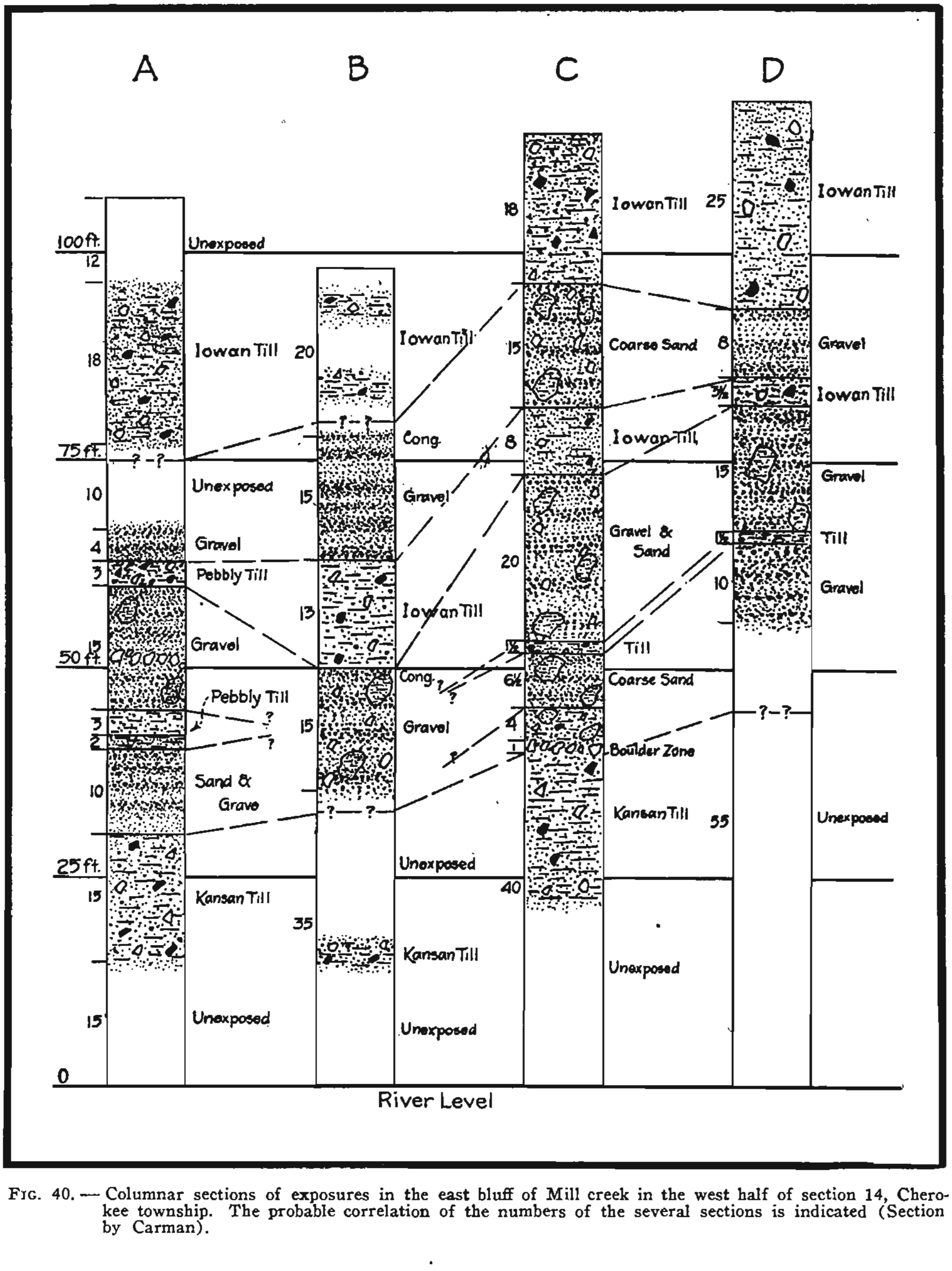


FIG. 40. — Columnar sections of exposures in the east bluff of Mill creek in the west half of section 14, Cherokee township. The probable correlation of the numbers of the several sections is indicated (Section by Carman).

7.	Till, light brownish gray, with pebbles, cobbles and small ocherous masses. In some places the pebbles and cobbles make up fully half of the whole. The basal contact on the gravel is very sharp, without any alteration or deformation of the gravel	3
6.	Gravel with large pebbles and boulders scattered through it and a layer of boulders about 5 feet above the base. Many included clay-balls and masses of Iowan till are present. The gravel has a light color and limestone is the dominant material. Shale pebbles are quite abundant. This is the typical gravel associated with the fresh Iowan till	15
5.	Till, brownish yellow, which breaks into elongated chunks	3
4.	Till, brownish blue-gray, sandy	2
3.	Sand and gravel; at top a fine-grained yellow sand; only partly exposed	10
2.	Slope with several exposures of oxidized brownish yellow Kansan till	15
1.	Unexposed slope to creek level	15

Numbers 1 and 2 of this section are Kansan till. Above these the Iowan section gives at least three gravel zones, and a better exposed section probably would increase the number.

Section B. — The gully just north of the quarter-section line fence exposed the following, beginning 98 feet above the creek and passing downward. The columnar section is shown in B. of figure 12. (figure 40 of this report.)

		Feet
5.	A pebbly clay slope with a few exposures of brownish gray till	20
4.	Gravel horizon; cemented to a conglomerate near the top	15
3.	Till, brownish yellow-gray; harder and more compact than number 5. Where it is fresh it breaks into irregular chunks and crumbles to a sandy clay. The lower 3 feet includes much gravel	13
2.	Gravel, light colored, with pebbles, cobbles, clay-balls, and some larger masses	15
	In the gully the upper 2 feet of this horizon is cemented, forming a calcareous conglomerate, but this does not continue horizontally beyond the gully. The lower part of the slope is so badly slumped that the lower contact of the gravel could not be exposed.	
1.	Unexposed to creek level, except for one small outcrop of oxidized, brown Kansan till at 15 feet above the creek	35

This section shows two distinct layers of fresh gravel, each at least 15 feet thick, and each overlain by Iowan till. A cemented horizon is found at the top of each gravel zone. The cementing material is calcareous and the cementation is sufficient to make firm conglomerate, large blocks of which lie on the slope below the outcrop. The cemented parts differ in thickness and seem to be irregular cemented masses rather than continuous beds. This cementation is due to the evaporation which takes place when ground water percolating downward passes from the compact till to the porous gravel. If the water has become saturated with calcareous material this evaporation will cause deposition.

Section C. — This exposure was in a gully about 40 rods north of the quarter-section line fence. It is shown in C of figure 12. (figure 40 of this report.)

		Feet
9.	Gravelly clay slope	18
8.	Sand, ferruginous, coarse, with pebbles, cobbles and clay masses	15

7. Till, sandy, brownish gray, breaks out in irregular chunks and pulverizes to a sandy clay	8
6. Gravel, ferruginous, or coarse sand with pebbles, cobbles and numerous large clay masses, some of which are 2 to 4 feet across	20
5. Till, bluish gray, with brown streaking along joints	1½
4. Sand, coarse, with pebbles, a few cobbles and clay-balls. The lower 18 inches is about half clay in the form of clay-balls	6½
3. Till, yellowish brown, with many pebbles and pockets and seams of sand	4
2. Gravel, coarse, with cobbles and boulders	1
1. Brown Kansan till was exposed for 18 inches below the top of the zone and at one point 10 feet lower. Remainder of division to creek level, unexposed	40

Section D. — At the place where the bluff begins to bend to the west there is a gully which branches about 50 feet above the creek. The following exposure was seen in the north branch of this gully. It is represented in D of figure 12. (figure 40 of this report.)

	Feet
7. Pebbly clay slope rising to the crest at 118 feet above the creek	25
6. Gravel with clay-balls	8
5. Till, brownish gray	3½
4. Gravel with cobbles and clay masses	15
3. Till, brownish yellow, plastic, sandy	1½
2. Gravel with clay masses	10
1. Unexposed to water level	55

"Several other exposures to the north show a part of the section and in every case where more than a few feet is exposed an alternation of gravel and till is to be seen.

"The beds of all these gullies are filled with boulders. Pink and gray granite of the fine-grained type predominate, but basalts are numerous and limestones are more prominent than is common among boulders.

"The sections given above show two, three and four gravel horizons, and few of the exposures were continuous enough to demonstrate that other thin gravel layers are not present. Some similarities of sections which are very close together were noted but on the whole it appears that the individual horizons are not continuous through the length of the bluff. Figure 12 shows such correlations as can be made between the various members of the several sections.

"The fresher till interbedded with gravel in the upper parts of the exposures just described is interpreted as Iowan. The till exposed in the lower 30 to 40 feet of the bluff is darker and firmer than that which is associated with the gravel beds and is interpreted as Kansan. In the lower ends of several of the gullies toward the north end of this bluff the Nebraskan drift is exposed.

"At several places in the exposures described above the interbedded gravel contains such a great number of clay-balls that they constitute a very important part of the whole. These clay-balls indicate that the material had not been carried far before deposition, for clay material could not have withstood the wear incident to long transportation, even though it was firmly frozen. As the clay-balls were formed probably on or near the edge of the ice sheet, their presence indicates the nearness of the ice front at the time of gravel deposition."

An exposure of upland Iowan gravel, near the southern extension of the Iowan drift of northwestern Iowa, is in the northeast quarter of the southwest quarter of section 10, Boyer Valley township (T. 88 N., R. 37 W.), Sac county. This is in a region of gently rolling Iowan drift topography. The gravel is exposed in four separate gravel pits which are only a few yards apart and cover much of the highest part of a hill. These deposits represent irregular masses of gravel within the Iowan till and do not extend above the general level of the Iowan drift. The overburden is loess ranging in thickness from 1 to 4 feet. It is leached of its carbonates and colored by oxidation to the usual buff color (17'' ', Wood-Brown) below the soil zone which is colored brown (13'' ''i, Benzo-Brown) by oxidation and the addition of humus. The lower 6 inches of the loess contains some sand and pebbles from the surface of the underlying gravel. In the bottoms of the exposures the gravel overlies typical Iowan till, unleached and colored buff (17'' 'd, Vinaceous-Buff) by oxidation in the upper 6 inches, below which it is gray (15'' '' ', Mouse-Gray). In some places this till is immediately overlain by fine sand.

Oxidation has colored most of the gravel of the section to a rusty-brown (17i, Raw-Sienna), but within a few of the beds the color is either a slightly lighter or darker shade. The depth of leaching in the gravel varies inversely with the thickness of the overlying loess; the combined depth within the two is about 3 1/2 feet. Weathering has disintegrated some of the coarse crystalline rocks along their margins. The gravel is well stratified in thin, nearly horizontal beds. Rarely and only within a few of the thickest beds is there any cross-bedding. The sand at the base of the gravel is in thin beds like that of the gravel. A few boulders, the largest having an average diameter of about 35 centimeters, are scattered through the gravel. There are also clay-balls; some are as large as 10 centimeters in diameter but most are smaller than 1 centimeter. A mechanical analysis of the average gravel is shown in No. 6 of figure 36. Within this average material 58 per cent is soluble in hydrochloric acid. The percentage of rounding is shown in No. 6 of figure 37. The lithology, determined by an analysis of pebbles is shown in No. 6 of figure 38.

In the southwest part of Cherokee county, in the northwest quarter of section 35, Diamond township (T. 90 N., R. 20 W.), there is a group of three kamelike knobs on the Iowan upland. Gravel has been removed from each of the knobs; in two of them the gravel face is concealed by slumping, while in the other it is well exposed. The overburden has an average thickness of 3 feet. It is leached of its carbonates and colored light-brown (17'' 'i, Buffy-Brown) by iron oxide and humus. It consists of sandy silt with pebbles numerous at the base but less numerous toward the top.

The characteristics and structure of the gravel vary widely throughout the exposure. The oxidation colors most of the material to various shades of rusty-brown (17''i, Tawny-Olive), and in some places it cements the gravel into a compact mass which crumbles under slight pressure. The remaining sand is unoxidized and light-gray in color. Leaching has removed the carbonates from the 3 feet of overburden and to a depth of about 1 foot from the underlying gravel. Below this there is a small amount of limestone in all of the gravel, but some of the sand is non-calcareous. Some of the gravel is cemented by secondary lime. The entire mass of gravel has a very irregular structure; only the lowest bed, which is cross-bedded sand and containing some pebbles, is continuous throughout the exposure. The other material, both gravel and sand, is very irregular in thickness and thins out within short distances. Some of the gravel is stratified, but most of it is in poorly sorted, unstratified beds. The sand is well stratified and contains much cross-bedding, which dips at an angle of about 35 degrees in every direction, although generally either north or south. The material of this section ranges from sand to boulders which are about 25 centimeters in diameter. Pebbles are scattered through the finer beds of sand. The per cent of rounding is high for gravel of this type, as is especially noticeable in the coarser material. Even the dark pink quartzites, which here occur in unusually large numbers, show considerable wear. Almost all of the many clay-balls are smaller than 3 centimeters in diameter, but some are as large as 10 centimeters.

Upland Iowan gravel is especially well exposed in kamelike hills in the south central part of O'Brien county. One of the best exposures is in the northwest quarter of section 22, Liberty township (T. 93 N., R. 41 W.), within an area of rolling Iowan drift topography. Here the gravel exposed in a gravel pit near the top of the hill represents a mass partly enclosed within Iowan till. This exposure has been described in extreme detail by Carman,[51] in his report on the Pleistocene Geology of northwestern Iowa.

Another exposure of Iowan upland gravel is in the southeast quarter of the northwest quarter of section 24, Lincoln township (T. 97 N., R. 40 W.), O'Brien county. The gravel is exposed at this location in two pits only a few yards apart near the upland in a region of gently rolling Iowan drift topography in which there is not to exceed 50 feet of relief. This deposit does not occur in a kame but is below the gently sloping Iowan drift surface. The gravel is overlain by 2 to 3 feet of leached loess, which is colored chocolate-brown (17'' ', Wood-Brown) by oxidation and humus. This overburden has an irregular contact with the underlying gravel and in places appears to grade into it.

The small amount of oxidation colors the gravel light-buff (17'' 'b, Avellaneous) throughout most of the exposure, but the color varies slightly with different textures. The 11-foot section of gravel is unleached and almost all of the lime present is in the form of limestone pebbles. There is a distinct difference in the structure and clastic texture of the two pits. In the north pit there is a wide size range from clay to beds of coarse gravel which contains cobbles and occasionally a large boulder. About 20 of these boulders lie in the bottom of the pit. However, the average gravel of this exposure is similar to that of the other pit. The structure is very irregular and much of the material is stratified in beds of variable thickness which dip at a low angle toward the southeast. There are many lenses and some cross-bedding, both dipping primarily in the same direction as the stratification. In the south pit the structure and texture are uniform throughout the exposure. All of the gravel is finer than 3 centimeters in diameter and the average is like that of the mechanical analysis shown in No. 7 of figure 36. The gravel is uniformly stratified in beds which dip toward the southwest at an angle of about 45 degrees. Clay-balls are common in both of these pits. Dark-pink quartzite boulders, as described in the exposure in the southeast part of Cherokee county, are rare. A rock analysis of the pebbles is shown in No. 7 of figure 37. The shape of the different size grades is shown in No. 7 of figure 38.

As shown in figure 34, there are many exposures of Iowan upland gravel within the Iowan drift areas of Iowa. However, all of these

51 Carman, J. Ernest, Further Studies on the Pleistocene Geology of Northwestern Iowa: Iowa Geol. Survey, Vol. XXXV, pp. 93-95, 1931.

are similar in most aspects to the few representatives which have been described.

Relations of the Gravel

The upland Iowan gravel deposits show their relations to associated materials in many exposures, some of which have been previously described.

In the southwest quarter of section 22, Cedar Falls township (T. 89 N., R. 14 W.), Black Hawk county, an irregular pocket of gravel overlies unleached and unoxidized Iowan till. It is enclosed along the sides by Iowan till which is unleached and is in part oxidized, and in part unoxidized. It is covered by 15 feet of Iowan till and loess which is oxidized and leached in the upper part. The gravel is oxidized but unleached except in a bed of sand at the top. As previously stated, the non-calcareous character of this sand need not represent leaching, for similar non-calcareous sands have been seen entirely enclosed within calcareous gravel. Therefore, there is no reason to believe from the character of the gravel that this is not a pocket of Iowan gravel buried deeply within the Iowan till, as all other evidence indicates.

Carman has described Iowan gravel interbedded with Iowan till in the west half of section 14, Cherokee township (T. 92 N., R. 40 W.), Cherokee county. In his descriptions of the gravel he indicates the unquestionable relationship to the Iowan till within which it occurs. He states:

"The sections given above show two, three and four gravel horizons, and a few of the exposures were continuous enough to demonstrate that other thin gravel layers are not present. Some similarities of sections which are very close together were noted but on the whole it appears that the individual horizons are not continuous through the length of the bluff.

"The fresher till interbedded with gravel in the upper parts of the exposures just described is interpreted as Iowan. The till exposed in the lower 30 to 40 feet of the bluff is darker and firmer than that associated with the gravel beds and is interpreted as Kansan."

In the exposure described near Mona, Iowa, in the northwest quarter of section 14, Otranto township (T. 100 N., R. 18 W.), Mitchell county, the calcareous gravel lies directly upon Kansan gumbotil and extends through the entire thickness of the thin Iowan till. Oxidized and leached Iowan till is exposed along the sides of the pit in several places.

Another exposure of this gravel which is closely related to the underlying Kansan deposits is about 9 miles southeast of Mona, near Stacyville, in the central part of section 18, Stacyville township (T. 100 N., R. 16 W.), Mitchell county. Here, in a shallow road cut, about 2 1/2 feet of Iowan gravel is exposed overlying Kansan gumbotil. The gumbotil is closely related to a large exposure of Kansan gravel less than 100 yards to the east. This Iowan gravel is closely related to the thin Iowan till which overlies the Kansan drift within this area.

Still another exposure in Mitchell county in which the relationship of the Iowan gravel to older deposits is shown is in the northeast quarter of section 35, Wayne township (T. 100 N., R. 15 W.), about 1/2 mile east of McIntire. Here unleached Iowan gravel overlies leached Kansan gravel. In the south part of the pit the Iowan and Kansan gravels are separated by a 6-inch bed of gray, leached Loveland silt which along its northern margin is broken up and incorporated in the base of the overlying Iowan gravel. The Iowan gravel here is overlain by Iowan till which, where it is thin at the center of the exposure, is leached, but which, where it thickens toward the margins of the exposure, is in some places unleached.

Kansan gumbotil has been plowed up and incorporated in large masses in the base of the Iowan gravel in an exposure in the northeast quarter of the northwest quarter of section 27, Perry township (T. 89 N., R. 10 W.), Buchanan county. This is within the Iowan drift area, and a thin layer of Iowan till and Peorian loess overlies the gravel.

Oxidized and unleached till is exposed at the base of many of the Iowan gravel exposures distributed throughout the Iowan areas of both northeastern and northwestern Iowa. In many places it is not possible to state definitely whether the till is of Iowan or Kansan age, because where the leached zone of the Kansan has been removed by erosion before the deposition of the thin Iowan till which now is also oxidized, these two tills might both be exposed and not differentiated. This is especially true in northwestern Iowa, where the gumbotil and leached Kansan till have been eroded away. However, in most exposures a comparison of the till underlying the gravel with that of the till exposed along the sides of the gravel affords strong evidence as to whether the tills are of the same age. Almost every exposure of gravel studied shows till either at its base, along its sides, or in both positions.

The overburden is Iowan till, Peorian loess, or sandy silt. Iowan till which is sometimes from 2 to 4 feet thick is the overburden in many exposures and many of these are also overlain by Peorian loess. However, in a few exposures the gravel is overlain by sandy silt; the deposition of which probably continued during loess deposition and thus the gravel was not covered by loess. In some exposures loess is the only material overlying the gravel. Weathering processes have oxidized these overburdens and leached them of their carbonates to a depth of about 5 feet.

The relations of the gravel deposits to the including till sheet and to the general topography are important in the interpretation of their origin. Four types have been recognized and described. Of these the most common type is small kamelike hills on the surface of the drift plain. Some of these hills are almost entirely gravel, covered by a thin veneer of till, loess, or possibly both; and others are essentially till in which one or more pockets of gravel occur. There is a wide range in the sizes of these gravel deposits, some being small and shallow and others large and extending deep down into the till, perhaps in some cases to its base. Almost as common as the small hills above are irregular pockets of gravel which are entirely enclosed within Iowan till and loess. Their upper surfaces are at practically the same level as the general drift surface and they are seldom covered by more than 6 feet of overburden. In a few places the gravel is in irregular masses deeply buried within Iowan till. Carman has described deposits in northwestern Iowa as interbedded with Iowan till, apparently as large lenses. Although these are well exposed where described, they have not been observed elsewhere. The rarity of the last two types of gravel deposits is not at all strange, because each represents an unusual type that could not be included within the normal thin Iowan till.

The Age of the Gravel

The position of the gravel deposits in relation to the Iowan drift surface and the amount of alteration which they have undergone show that they were deposited in their present positions during the melting of the Iowan ice. All of the deposits are closely associated with the Iowan till; some occur as masses within the till and others as outwash on its surface. Some of the masses now included within the till were frozen masses of gravel picked up by the glacier from the surface over which it passed and redeposited within the till. These masses had been formerly deposited either in front of the advancing Iowan ice or during pre-Iowan time.

THE IOWAN TERRACE GRAVEL

The Distribution of the Gravel:

The Iowan ice advanced over the eroded surface of the Kansan drift and deposited a thin layer of till which was spread over this surface like a blanket. These older valleys were not filled by this Iowan till but served as drainage courses for the streams flowing from the melting ice that carried sand and gravel which was deposited along these valleys within and beyond the Iowan drift area. However, in northwestern Iowa, some of the valleys that were eroded in the Kansan drift did not extend into the area covered by the Wisconsin glacier and thus did not receive drainage from either the Iowan or Mankato ice sheets. However, these valleys contain extensive gravel terraces, the gravel having been derived from the eroded material of the drift during the Loveland interval. Valleys of the same origin and age extended into the Iowan drift area carrying drainage from the melting ice and receiving the glaciofluvial outwash carried by the streams. It is evident that in northwestern Iowa at least some Loveland gravel was in the valleys before the advance of the Iowan glacier and constitutes part of the gravel fillings. The Loveland and Iowan terraces are so similar that they cannot be differentiated except on the basis of relations to surrounding materials and location in relation to source material. It is probable that the valleys whose heads lie within the Iowan drift area contain gravel of both Iowan and Loveland ages which cannot be differentiated, and in these valleys there is no doubt but that they contain Iowan gravel beyond the Iowan drift margin. Since it is certain that the Iowan gravel forms most of the terrace material within the Iowan area and since the presence of Loveland gravel has not been proven, these terraces will be mapped as Iowan. However, beyond the Iowan drift margin, all of the evidence is in favor of the Loveland gravel forming part of the deposit, even though it may be partly reworked by the streams which deposited gravel as they flowed from the Iowan glacier. These will be mapped as unidentified, except where the relations are such that their age can be definitely determined. Even though no Loveland gravel has been found in northeastern Iowa, the same system of mapping will be used.

Streams flowing from the melting Mankato glacier sometimes cross the Iowan drift area, involving a problem of differentiation similar to that of the Iowan and the Loveland, and where they continue beyond the Iowan margin, it makes gravel of three ages possible. These also, unless definitely differentiated, are included as undifferentiated gravel.

The distribution of the exposures of terrace gravel in the valleys within the Iowan area which did not receive Mankato glacial drainage is shown in figure 41. However, this does not mean that all of the Iowan outwash gravel was deposited as terraces within the Iowan area since a large percentage of the undifferentiated gravel was deposited by streams flowing from the melting Iowan ice.

The exposures of Iowan terrace gravel represented in figure 41 are almost all gravel pits from which the gravel has been removed for road surfacing. However, some are artificial constructional cuts, natural cuts along streams, or prospects by the Iowa State Highway Commission. These gravel terraces are almost continuous along the valleys. The number of exposures mapped is no criterion of the abundance of the gravel but rather an indication that the clastic character as well as the topographic and geographic location is such that they have been naturally exposed or that there has been a greater demand for them at these locations for commercial purposes.

The Characteristics of the Gravel

General Characteristics:

The Iowan terrace gravel is present in the valleys of the Iowan drift region. Most of the present streams have intrenched themselves in these broad gravel fillings, and the remaining parts have formed terraces which differ greatly in height, some being as much as 100 feet above the streams.

In some exposures the gravel was observed to overlie oxidized till which could be either Iowan or older. It is impossible to determine the age of the till in most places, for none of the exposures show a contact of the till along their sides with the till underlying the gravel. In none of the exposures was the gravel underlain by gumbotil or any other good horizon marker. The overburden is of two types: coarse, unstratified, sandy silt, which contains pebbles in decreasing amounts with increase in height above the gravel, and typical Peorian loess which is usually entirely free from pebbles. In some places the

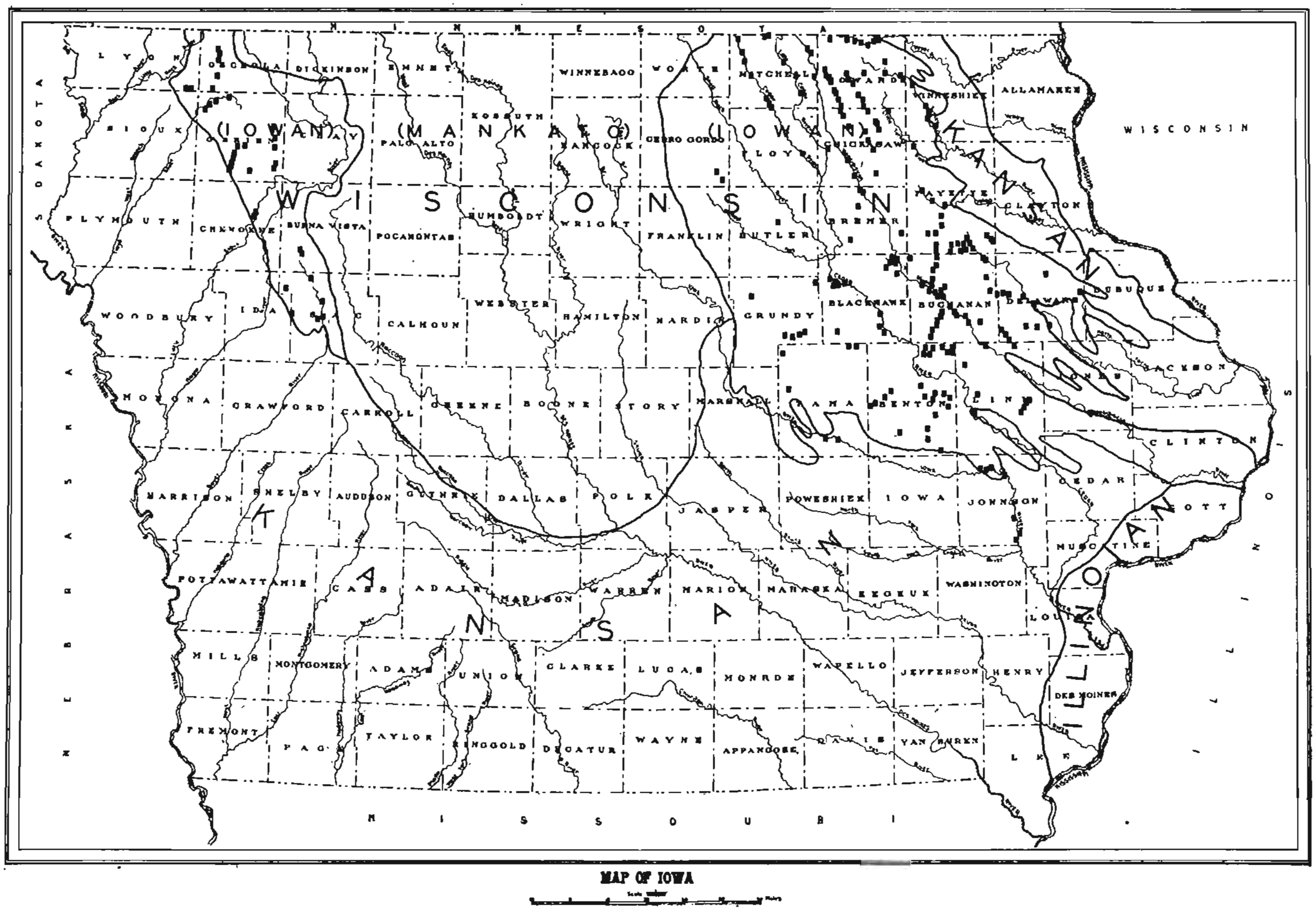


FIG. 41. — The squares show the locations of Iowan terrace gravel exposures within the Iowan drift area of Iowa.

sandy silt grades upward into the loess. In no exposure was there any suggestion of a time interval between the deposition of the gravel and overburden.

Since deposition, weathering has developed some changes within the gravel and overburden but they are not as uniform as those changes within the Iowan upland gravel. The depth at which the carbonates occur within the overburden and gravel varies from a few inches to as much as 20 feet. This variation is not due primarily to differences in the depth of leaching but to lithology, topographic position, and subsequent erosion. In an exposure containing average lithology and texture, unaffected by subsequent erosion or deposition, leaching has been effective to about the same depths as in normal sections of Iowan upland deposits, from 4 to 6 feet. If there is any marked difference, leaching is to slightly greater depths within the valley deposits, which is probably due to the greater freedom of the ground water circulation. Most of the finer material appears fresh and only rarely is there any disintegration within the cobbles and boulders. The coloration varies from gray, unoxidized gravel (17"b, Cinnamon-Buff) in certain exposures in northwestern Iowa to dark-buff (17"i, Tawny-Olive) in some exposures in northeastern Iowa. The more common color is medium-buff (17" 'b, Avellaneous to 19"i, Isabella Color). In a few exposures, certain beds are colored dark-brown (11'm, Chestnut-Brown) by oxidation of the iron or black by manganese dioxide. There is no cementation by either iron oxide or calcium carbonate in any of the exposures.

In northeastern Iowa most of the exposures within the Iowan drift area may be roughly divided into three members. In descending order they are: overburden, coarse and average gravel, and sand and fine gravel. The thickness of each of these members varies widely throughout the different exposures. In northwestern Iowa the exposures show only two divisions, overburden and average gravel. The fine gravel and sand of the lower member of northeastern Iowa is either missing or unexposed.

The overburden has an average thickness of about 3 feet but ranges from a few inches to more than 6 feet. In no place is there any indication of a time interval between it and the underlying gravel with which it is interbedded in certain exposures. Where the overburden is loess it is colored by oxidation to the usual color of loess — chocolate-brown (13" "i, Benzo-Brown) in the upper 2 to 3 feet by oxidation and humus and deeper down by oxidation alone to medium-buff (19"i, Isabella Color). It is unstratified and only rarely contains pebbles except in the lower few inches. The sandy silt which commonly overlies the gravel is colored to light chocolate-brown (17"', Wood-

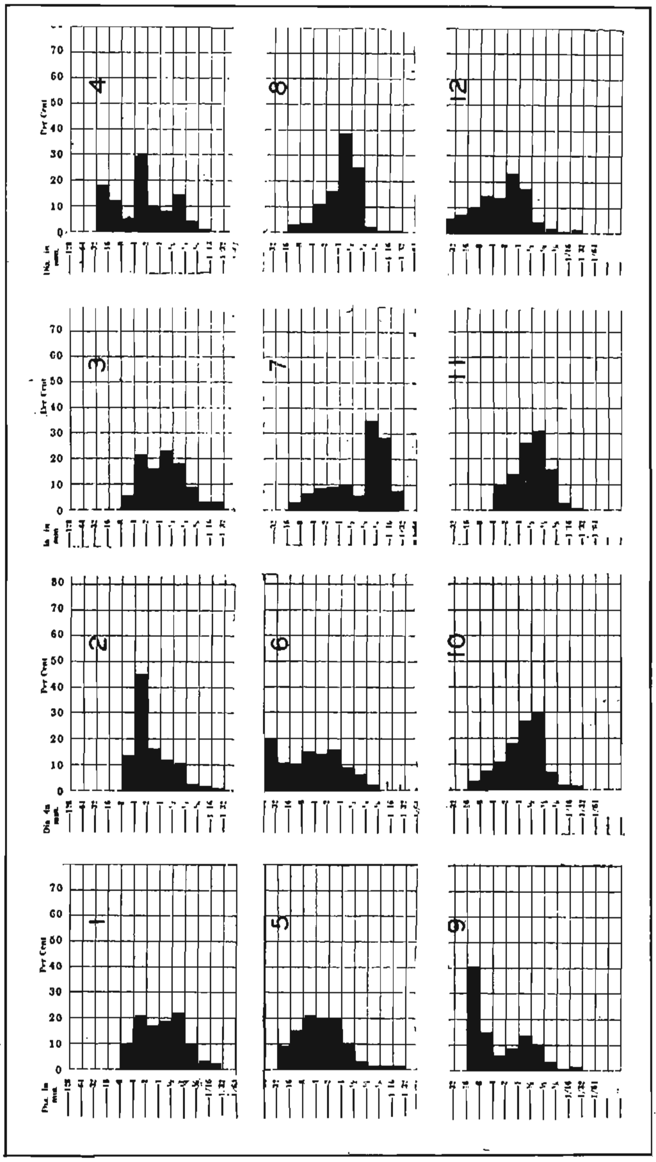


FIG. 42.—Graphs showing mechanical analyses of Iowan terrace gravel. The numbers of this figure correspond with those of figures 43 and 44.

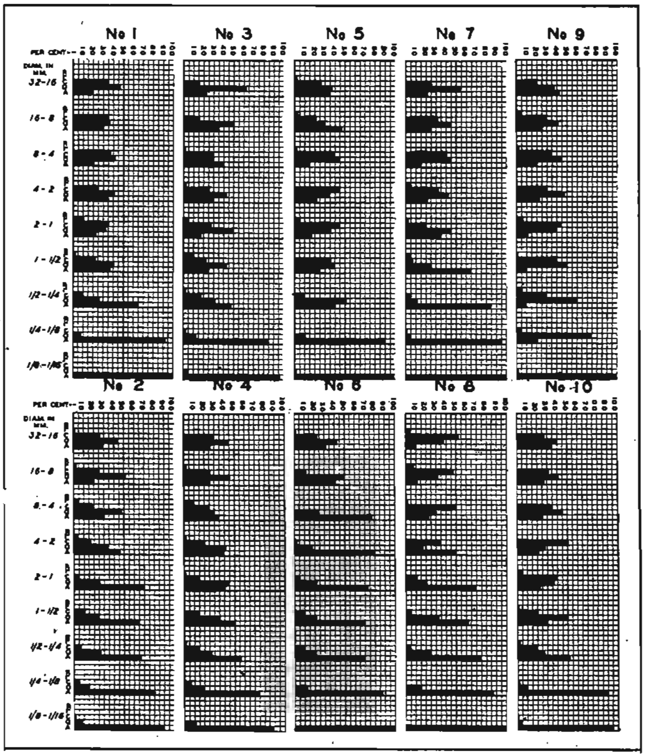


FIG. 43. — Graphs showing shape analyses of each size grade between 1/16 and 32 millimeters in diameter, of the Iowan terrace gravel. The numbers of these analyses correspond to those of figures 42 and 44. R = rounded; r = sub-rounded; C = curvilinear; a = sub-angular; A = angular.

Brown) in its upper part but is slightly lighter toward the base, where it exceeds 2 to 3 feet in thickness. Within it stratification is rare, but pebbles occur in the basal portion and are sometimes scattered sparsely throughout its entire thickness.

The second member, which is coarse and average material, is not present in all places, but where it is absent the overburden lies in contact with the finer material which has practically no commercial value and thus is seldom exposed. Where the coarse and average material is present it may be only a few feet thick or extend to the base of the exposure as found in many places in northwestern Iowa. Although there is a wide textural range from fine sand to boulders, most of the gravel is sandy, as is shown in the mechanical analyses of figure 42. The material shows little wear as is shown in figure 43, but more wear than within the Iowan upland deposits. The general lithology shown in figure 44 is similar to that of the Iowan upland deposits except for the absence of clay-balls and the occurrence in some deposits of a higher percentage of siliceous material and of the harder, more resistant igneous rocks. As previously stated, the color varies from gray unoxidized gravel to that which is colored by iron oxide to a dark-brown. Thin beds are colored black by manganese dioxide. Except in the upper layer of coarse heterogeneous material at the base of the overburden the gravel is well sorted and stratified in approximately horizontal beds within which cross-bedding, and lens-and-pocket structures are common.

The lower member consisting of fine gravel and sand is seldom well exposed because of its low commercial value. It varies in thickness as do the other members and in some places constitutes practically all of the section. It consists of various-size grades of sand and fine gravel within which may be included an occasional cobble or boulder. It consists essentially of siliceous and hard crystalline rocks. Carbonates either as limestone pebbles or secondary deposition may or may not be present. It shows various degrees of oxidation of the iron compounds which do not cement the gravel but merely color it to various shades from gray (21"f, Pale Olive-Buff) to dark-buff (17"i, Tawny-Olive). Stratification and cross-bedding are good, although interrupted in places by lenses and pockets of gravel and sparsely scattered boulders and cobbles.

Characteristics of the Exposures

The characteristics of the Iowan terrace gravel vary so widely that no one description would be adequate for an entire area. Regardless of the differences there are certain features which they have in common that can be used in discussing their characteristics. The gravel exposures can be divided into the following groups: (1) those which are highly siliceous and contain little if any carbonates, (2) those which contain a high percentage of carbonates, and (3) those in which the percentage of carbonates is intermediate between types one and two. In describing the Iowan terrace gravel the exposures will be grouped under these divisions, although there is a complete gradation from the non-calcareous to those consisting almost entirely of carbonates. The greatest percentage of the exposures are of the intermediate group.

Non-calcareous gravel:— Although observed along several valleys

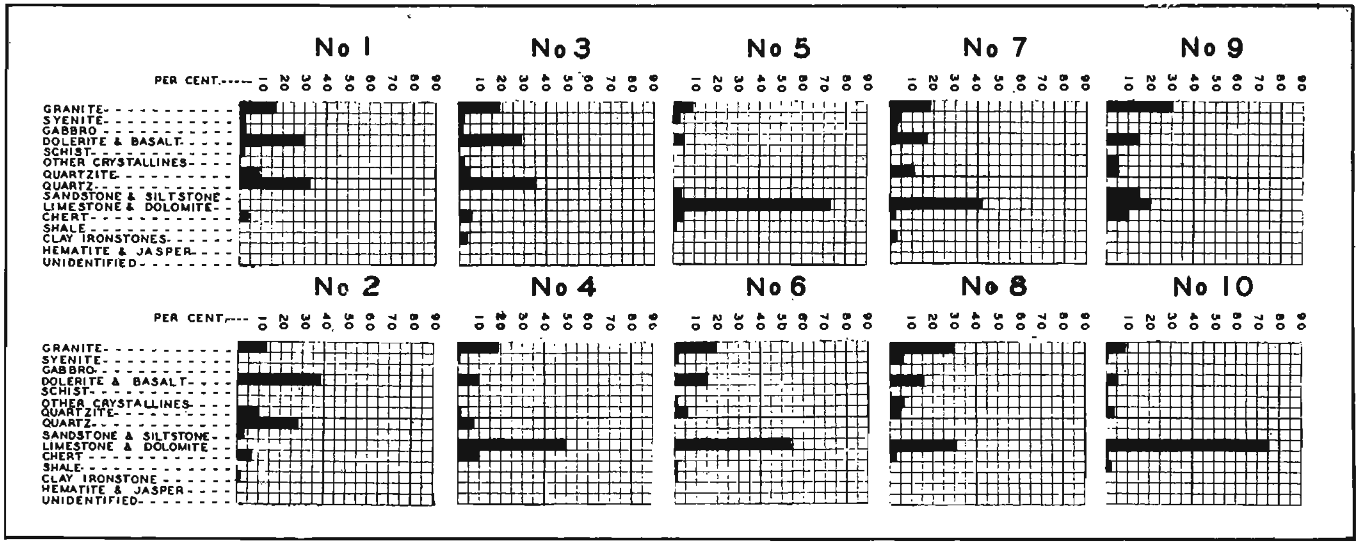


Fig. 44. — Graphs showing lithology of pebbles between 16 and 32 millimeters in diameter. The numbers of these analyses correspond with those of figures 42 and 43.

in northeastern Iowa this group of exposures represents only a small percentage of the exposures of Iowan valley gravel.

One of the best exposures of this type of gravel is located in the northwest quarter of section 2, Jenkins township (T. 99 N., R. 15 W.), Mitchell county. Here along a tributary to the Wapsipinicon river, 1/2 mile south of McIntire, the gravel is exposed in a terrace which is about 30 feet above the level of the stream and only a few feet below the flat Iowan upland. The gravel is exposed to a depth of 15 feet in a fresh unslumped road cut.

The oxidation colors the different beds of highly siliceous gravel to shades varying from light-buff (19"i, Isabella Color) to reddish-buff (17"i, Tawny-Olive), but in no place is it sufficient to cement any of the material. No carbonates, either primary or secondary, are exposed in the entire section. All of the gravel appears fresh. The upper 5 feet of the gravel is almost entirely sand, deposited in thin, horizontal beds within which cross-bedding is not common. About the only irregularities are pebbles smaller than 2 centimeters in diameter scattered sparsely throughout this finer material. The lower 8 feet differs from the upper 5 feet in that there are more pebbles scattered through the finer material and thin beds, small lenses, and pockets of coarser material are included within the stratification. Nothing within the exposure exceeds 3 centimeters in diameter and less than 4 per cent is larger than 8 millimeters in diameter. The percentage of each size grade of a sample of average material is shown in No. 1 of figure 42. The percentage of rounding of each size grade between 1/16 and 32 millimeters in diameter is shown in No. 1 of figure 43. The rock analysis given in No. 1 of figure 44 shows that the pebbles between 16 and 32 millimeters in diameter are chiefly siliceous. The overburden is sandy loess-like silt ranging from 1 to 2 feet in thickness. It is colored dark-brown (13" "i, Benzo-Brown) by humus and oxidation. Scattered through it are a few pebbles which increase in number toward the base. No contact with material underlying the gravel was exposed.

Another exposure similar to the one just described is in the southwest quarter of section 27, Wayne township, about 1 1/2 miles to the northwest. This exposure also occurs in a terrace which is about 30 feet above the level of the stream and at about the same level as the surrounding Iowan upland drift surface. The material and structure are very much like that of the exposure just described except that a few limestone pebbles were found within the non-calcareous gravel in one part of the exposure at a depth of 6 feet.

In the southwest quarter of section 3, Sumner township (T. 88 N., R. 9 W.), Buchanan county, is an exposure of Iowan terrace gravel a few hundred feet east of the bridge on primary 11 over the Wapsipinicon river, south of Independence. Here in a terrace which stands 25 feet above the river a gravel pit has exposed 15 feet of material, 6 feet of overburden, and 9 feet of gravel.

The gravel exposed in this section resembles a recent deposit. It is gray and shows no oxidation of iron compounds. Although there is no evidence of leaching, the gravel contains no carbonates, either primary or secondary. None of the rocks show signs of weathering or disintegration. Within the 9 feet of gravel exposed, nothing exceeds 3 centimeters in diameter, and less than 1 percent is larger than 8 millimeters in diameter. However, by digging 2 feet deeper in the bottom of the pit, a bed of pebbles was encountered which had a maximum average diameter of 4 centimeters. The percentage of each size grade, determined by a mechanical analysis, is shown in No. 2 of figure 42. All of the coarser material has been slightly rounded by stream action, but the finer grades still retain most of their angularity, as is shown in No. 2 of figure 43. The rock content determined by a pebble count is shown in No. 2 of figure 44. Although the gravel is well sorted, it displays a very complex structure consisting almost entirely of cross-bedding, lenses, and pockets as shown in figure 45.

FIG. 45. — Stratification within an exposure of Iowan terrace gravel.

The overburden is 6 feet thick. The upper 4 feet consists of light-chocolate (17" 'i, Buff-Brown) colored silt, containing small pebbles, and it becomes slightly coarser with increasing depth. The lower 2 feet contains no pebbles and is a dark-brown fine sandy silt.

In Linn county, along Otter creek about 5 miles northwest of Cedar Rapids, in the northwest quarter of section 25, Monroe township (T. 84 N., R. 8 W.), Iowan terrace gravel is exposed in a railway cut. This cut is 25 feet deep, but the lower 10 feet is concealed by slumped material from above. The gravel becomes finer toward the surface and grades into the overburden of loess.

Iron oxide colors the different beds of gravel to various shades of buff, but in no part of the exposure does it cement the gravel. The 15 feet of highly siliceous, slightly weathered gravel that is exposed contains no carbonates. This exposure consists chiefly of sand finer than 4 millimeters in diameter within which there are only a few pebbles coarser than 2 centimeters in diameter. Analyses of size, shape, and lithology are given in No. 3 of figures 42, 43, and 44. This exposure is located within a Kansan inlier in the Iowan drift area and is covered only by Peorian loess. The loess becomes coarser with increase in depth, grading into, and in some places interstratified with the underlying sand and gravel, which shows that the two were being deposited at the same time.

Highly calcareous gravel:— In contrast to the deposits described above are those which contain a high percentage of limestone and dolomite, especially within the coarser material. These have been observed in many places within both northeastern and northwestern Iowa. In northeastern Iowa they are exposed in several places along the Upper Iowa, Turkey, Little Turkey, and Volga rivers. In these exposures the limestone and dolomite generally occur as angular platy fragments sometimes as large as 30 centimeters in average diameter and 10 centimeters in thickness. In northwestern Iowa almost all of the exposures are of this highly calcareous type, but the rocks have been rounded during transportation and seldom occur as platy fragments. The locations of the streams along which these exposures occur render it impossible for most of them to contain gravel from the Mankato ice sheet, but where Mankato gravel is in the same valley, the age must be determined on the basis of stratigraphic relationships.

An exposure of highly calcareous Iowan terrace gravel is in the southeast quarter of the northeast quarter of section 14, Westfield township (T. 93 N., R. 8 W.), Fayette county, along the north side of the Volga river at the west side of Lima. Here the gravel is exposed in a gravel pit in a terrace which is 23 feet above the stream.

The 13 feet of gravel exposed consists of a 2 1/2-foot leached zone overlying a 10 1/2-foot highly calcareous zone, the two zones having distinctly different characteristics. The limestone and dolomite which constitute about 65 per cent of the material of the lower zone give the predominating color to the mass. This is darkened to a light-gray (17"b, Cinnamon-Buff) by the additional igneous material present. The gravel is unoxidized and the only disintegration by weathering is in a few of the weaker crystalline rocks. The gravel is well stratified in horizontal beds parallel with which lie the long axes of the limestone and dolomite plates. Few of the beds are more than 6 inches thick and the only cross-bedding is of the sand and finer gravel in certain parts of these thicker beds. A mechanical analysis of average material, excluding the 10 per cent which is larger than 4 centimeters in diameter, is shown in No. 4 of figure 42. A shape analysis is shown in No. 4 of figure 43. The material larger than that represented in this analysis is almost all angular and sub-angular fragments of limestone and dolomite; the remaining rocks are igneous, generally sub-angular to curvilinear in shape. The lithology determined from an analysis of pebbles between 16 and 32 millimeters in diameter is shown in No. 4 of figure 44. The upper 2 1/2-foot zone of gravel appears to have been similar to that of the lower calcareous zone at the time of deposition, but during subsequent time, leaching processes have removed the carbonates, leaving only the non-calcareous gravel. The contraction of the beds by removal of the high percentage of carbonates destroyed the good stratification and left an unstratified mass of sand and gravel. The color of this material is darker than that of the calcareous material below because of the loss of the light-colored carbonates and a slight oxidation of the iron compounds. The gravel is overlain by 18 inches of loesslike silt, leached of its carbonates and colored by humus and iron oxide to a chocolate-brown (13'' "i, Benzo-Brown) color.

Another exposure of this type of gravel is in the northwest quarter of section 2, New Oregon township (T. 98 N., R. 11 W.), Howard county, along the Turkey river at New Oregon. Here the gravel is exposed in a terrace which stands 25 feet above the river.

This deposit is similar to that in the preceding description except that there is a lower percentage of coarse limestone.

Highly calcareous Iowan terrace gravel deposits are exposed at many places in northwestern Iowa. One of the best exposures is in a gravel pit in the east side of Sibley in the northwest quarter of section 18, East Holman township (T. 99 N., R. 41 W.), Osceola county, near the valley of Otter Creek. Here there is a wide flat area, approximately at the upland, underlain by gravel which has been exposed in several places both east and south of town. Carman[52] has described several exposures of this gravel and discussed in great detail its relations to the associated deposits. A new gravel pit, only a few yards west of the large pits which he described, exposes 20 feet of gravel.

Within this exposure the iron oxide that coats the grains colors almost all of the mass to a dark-buff (15'i, Ochraceous-Tawny) and binds the gravel together so that it will stand in a vertical section without slumping. Although the oxidation is uniform in this pit, in one nearby which was described by Carman there is considerable variation from top to bottom. In another pit about 1 1/2 miles to the southeast there is extreme variation in the amount of oxidation as well as some coloration by manganese dioxide. Disintegration of the rocks by weathering is chiefly within the gray shale which shatters readily when exposed to the atmosphere, but there is some within the less resistant igneous rocks. Leaching has not extended below the overburden and some limestone pebbles are included in its base. The gravel shows good horizontal stratification in beds varying in thickness, some reaching a maximum of almost 2 feet. Within some of these beds there is cross-bedding and lens-and-pocket structures. The cross-bedding dips at various angles within different beds, reaching a maximum of about 40 degrees. The lens-and-pocket structures generally consist of coarser or finer material and locally almost entirely of gray shale. The structure is not as distinct in this pit as in those which do not contain as much clay and iron oxide. No boulders occur within the gravel and very little gravel is larger than 10 centimeters in diameter. A mechanical analysis of the material from the coarser part of the exposure is shown in No. 5 of figure 42. The shape of the different size grades is shown in No. 5 of figure 43. The lithology of the pebbles is given in No. 5 of figure 44. This analysis shows that the pebbles

[52] Carman, J. Ernest, Further Studies on the Pleistocene Geology of Northwestern Iowa: Iowa Geol. Survey, Vol. XXXV, pp. 141-144, 1931.

are more than 75 per cent limestone and dolomite. The gravel is overlain by 3 feet of typical Peorian loess which is leached of its carbonates. It is colored chocolate-brown (13" "i, Benzo-Brown) at the top by oxidation and humus but grades into a light-buff (17" 'd, Vinaceous-Buff) with increase in depth. There is a 1-foot gradational zone between the overburden and gravel. The gravel overlies an irregular surface of oxidized and unleached till which is probably Iowan. In certain places within this wide terrace deposit Carman has observed sections in which the gravel thins out and the loess lies in direct contact with the till.

Iowan terrace gravel is well exposed in several small gravel pits along the Little Sioux river near Cherokee. One large exposure still in operation is in the northwest quarter of section 14, Cherokee township (T. 92 N., R. 40 W.), Cherokee county. Here the gravel has been removed to a depth of about 60 feet from the upper terrace, which stands about 80 feet above the level of the river.

Oxidation has colored the gravel to medium-buff (15'i, Ochraceous-Tawny) throughout most of the section, but within some narrow seams parallel to the bedding planes, within both the coarse and the fine material, the oxidation is to a dark reddish-brown (11'k, Hazel). Leaching has removed the carbonates from the 3 to 5 feet of loess overlying the gravel, but the gravel is unleached throughout its entire thickness. Very few of the rocks have been disintegrated by weathering. Most of the gravel that is exposed in the 25-foot section above the water in the base of the pit is well stratified. Just below the overburden there is a 3-foot layer of coarse poorly sorted and poorly stratified gravel which contains large cobbles and boulders and thin beds of well-stratified fine gravel and sand. Underlying this layer of coarse gravel is a 15-foot layer of finer gravel which represents an average for the exposure. It is almost all finer than 5 centimeters in diameter but very little is finer than 1 millimeter in diameter. The well-stratified beds dip toward the south at an angle of about 8 degrees and include cross-bedding and other minor structures. Below this is another layer of coarse material which is like that at the top. It has an average thickness of 2 feet but becomes thinner at one edge. Just above the water is a 3-foot layer of sand which is well stratified. Its beds dip southward and include a large amount of cross-bedding and other minor structures. Iron oxide colors fine seams to a dark brown along the stratification lines. A mechanical analysis of the average gravel from the 15-foot layer is shown in No. 6 of figure 42. A shape analysis is shown in No. 6 of figure 43. The lithology determined from pebbles is given in No. 6 of figure 44.

Carman [58] describes the relation of these gravel deposits to the surrounding deposits in great detail and states that these gravel deposits are closely related in age to the deposition of the Iowan drift.

Intermediate type of gravel:— This group of deposits includes most of the Iowan terrace gravel. It embraces all of those deposits ranging between the two extremes previously described. In general, these deposits are found distributed throughout the entire area of northeastern Iowa and in several places in northwestern Iowa. They appear fresh with only moderate oxidation which colors the grains to various shades of buff. Leaching has removed the carbonates to a depth of 5 or 6 feet in most exposures, although in some places leaching may be either more or less.

This type of Iowan terrace gravel is exposed in several places along Black Hawk Creek. However, the best exposure is south of Holland in the southeast quarter of section 35, Colfax township (T. 88 N., R. 17 W.), Grundy county. Here it is exposed in a gravel pit within a terrace which stands 18 feet above the stream. In the 10 foot exposure there are 6 feet of gravel overlain by 4 feet of loess.

The thin coating of iron oxide which covers the grains colors the entire exposure of gravel to light-buff (15'i, Ochraceous-Tawny), but affords very little cementation or compaction. Leaching has removed the carbonates from the overlying 4 feet of loess and the upper 1 foot of gravel, below which there are many limestone and dolomite pebbles, as well as concretions of secondary lime which have been leached from the overlying beds and deposited at this lower level. The gravel is poorly sorted but deposited in distinct beds which are almost horizontal. Within these major beds is some cross-bedding, and a few clay-balls. The gravel has a low textural range, the largest pebbles observed having an average diameter of about 3 centimeters. However, most of the gravel is smaller than 1 centimeter in diameter. A mechanical separation of an average sample of the gravel is shown in No. 7 of figure 42. The percentage of rounding is shown in No. 7 of figure 43. A lithologic analysis of pebbles is shown in No. 7 of figure 44. The

58 Carman, J. Ernest, Further Studies on the Pleistocene Geology of Northwestern Iowa: Iowa Geol. Survey, Vol. XXXV, pp. 153-154, 1931.

4-foot deposit of loess overlying the gravel is oxidized to the usual buff (17" 'i, Buffy-Brown) color of loess, and leached of its carbonates. At one place in the exposure there are pebbles scattered through the lower 10 inches of the loess and slight stratification in the lower 6 inches. This suggests that the loess and gravel were deposited in close succession.

In an extensive terrace about 22 feet above Dry Run, in the southeast part of Cedar Falls, there are several exposures of Iowan terrace gravel. The best exposure is in the northeast quarter of section 13, Cedar Falls township (T. 89 N., R. 14 W.), Black Hawk county. This exposure shows 13 feet of gravel overlain by 2 to 3 feet of loesslike silt.

Iron oxide coating the grains has colored most of the deposit to light-buff (15'i, Ochraceous-Tawny), although different colors within separate beds and lenses of the exposure range from grayish-buff (17"b, Cinnamon-Buff) to medium-buff (17"i, Tawny-Olive). Leaching has removed the carbonates from the overburden and gravel to a depth of 4 feet, and weathering has disintegrated some of the weaker crystalline rocks. The gravel is well stratified in almost horizontal beds, but in some places these beds contain considerable cross-bedding and many lenses and pockets. Aside from several boulders between 35 and 45 centimeters in diameter, the maximum size of the coarse gravel is between 3 and 6 centimeters in diameter. Almost all of the material consists of sand and fine gravel such as is shown in the mechanical analysis of No. 8 of figure 42. The percentage of rounding of each size grade is given in No. 8 of figure 43. The rock content is shown in No. 8 of figure 44. There is a slight gradation between the gravel and the overlying loesslike silt. The overburden is colored chocolate-brown (17" ', Wood-Brown) by iron oxide and humus.

In the southwest quarter of the northwest quarter of section 6, Paris township (T. 97 N., R. 12 W.), Howard county, Iowan terrace gravel is exposed along Crane Creek 6 miles east of Elma, in a terrace which stands 24 feet above the stream. This exposure represents an average of the exposures along this stream in the southern part of Howard county.

The gravel is colored to a light-buff (15', Ochraceous-Tawny) by the iron oxide which coats the grains. Leaching has removed the carbonates to a depth of 5 feet including the 1 foot of overburden. The well sorted gravel shows good horizontal stratification, interrupted by cross-bedding and lens-and-pocket structures. The material consists chiefly of sand and fine gravel with only about 12 per cent larger than 8 millimeters in diameter. There is also coarser gravel which has a maximum diameter of about 5 centimeters, and in addition to this there are about 20 boulders in the bottom of the pit which average about 15 centimeters in diameter. The percentage of each size grade as determined by a mechanical analysis of the average gravel is shown in No. 9 of figure 42. The percentage of rounding is shown in No. 9 of figure 43. The lithology is shown in No. 9 of figure 44. The overburden is loesslike silt which is between 1 and 2 feet thick. Pebbles are scattered through it and increase in number toward its base. It is colored chocolate-brown (13'' ''i, Benzo-Brown) by iron oxide and humus. The material underlying the gravel was not exposed in this section, although in another exposure farther down stream oxidized and unleached till was exposed at the base of the gravel.

The Relations of the Gravel

Terraces of Iowan gravel are along almost every stream, large and small, within the Iowan drift areas. In those valleys extending across the Iowan drift area and into the Mankato drift area the water from the melting Mankato ice carried sand and gravel which also was deposited in these valleys. Besides the Mankato and Iowan gravels, Loveland gravel may also be present, representing deposition in these pre-Iowan valleys before the advent of the Iowan ice. It is possible for gravel of all three of these ages to occur within the same valley.

The characteristics of the gravels of the Loveland, Iowan, and Mankato ages are so similar within northwestern Iowa that in many places it is difficult to distinguish one from the other. The only accurate basis upon which these deposits can be differentiated is that of their relationship to other materials.

During the interval following the formation of the gumbotil on the Kansan drift and before the advance of the Iowan ice, the Kansan drift surface underwent erosion which developed a complete drainage system. In the valleys developed, the Loveland gravel was deposited. Loveland gravel was more extensive in northwestern Iowa than in northeastern Iowa, because of the more extensive erosion which the area had undergone. In fact, the presence of Loveland gravel in northeastern Iowa has never been proven. This period of erosion continued until the advance of the Iowan ice which deposited its load on the fresh erosional and depositional surfaces.

Streams flowing down these valleys during the advance of the glacier might either deposit their load on top of the underlying Loveland deposits or, if the volume of water was large enough might rework the Loveland deposits and incorporate them with those of Iowan age. In neither case, however, would there necessarily be a distinguishable break between these deposits.

If the streams continued to flow down these valleys during the time that the area was covered by ice, then sedimentary processes were continuous throughout all the time that the ice was present. This seems highly improbable, however; instead the glacier may have removed some of these deposits left in front of the advancing ice, incorporating them in its load of detrital material. In either case, as the ice melted the deposition in the valleys would either be on the surface of the previously deposited gravel or the Iowan till, or it would rework the underlying deposits, forming one new deposit. Hence the deposition of Loveland and Iowan could be either continuous or separated by Iowan till, glacial erosion, or even weathered zones. Or, as stated above, the gravel in the valleys before the advance of the Iowan ice might have been reworked and incorporated into that deposited as the ice retreated.

In those valleys which crossed the Iowan drift area and headed up in the Mankato drift area, a problem similar to the one between the Iowan and Loveland deposits is involved. The streams flowing from the melting Mankato ice carried a vast amount of material which was deposited along the valleys as was the Iowan gravel. Thus in all of these valleys it is possible to have gravel of two ages, the Loveland and the Iowan, and in some valleys the Mankato gravel may also be present.

Since the gravel was deposited the streams have entrenched themselves in these wide, flat areas leaving the remnants as terraces. In northeastern Iowa, within the Iowan drift area, the terraces range from almost the level of the present stream to about 30 feet above the stream, but beyond the Iowan drift margin some of the terraces are as high as 50 to 75 feet above the level of the stream. The Iowan terraces of northwestern Iowa have a wider range in height above the streams. This fact is well illustrated by Carman [54] in his discussion

[54] Carman, J. Ernest, Further Studies on the Pleistocene Geology of Northwestern Iowa: Vol. XXXV, pp. 157-166, 1931.

of the valley gravels. Near the heads of some of the valleys within the Iowan drift area, the terraces are almost at the stream level, while some terraces such as those along the southern part of Waterman Creek, also within the Iowan area, are more than 100 feet above the level of the stream.

Terraces along those streams which did not carry drainage from the Mankato ice must be either Iowan or Loveland. In some, it is impossible to exclude the possibility that the Loveland deposits are deeply buried or reworked and incorporated in the Iowan deposits. However, in some exposures the gravel overlies oxidized and unleached till which appears to be Iowan in age, and in others it overlies leached Loveland silt. In most of the exposures the gravel extends below the ground water surface, thus eliminating the possibility of observing its relationship to older deposits. Contacts along the sides of the exposures are few, since the gravel deposits are so extensive that only the coarser and more valuable material is removed and the exposures do not crowd the margin of the terraces where the overburden is generally thicker.

Iowan gravel can be definitely differentiated from the Mankato gravel when it is directly related to the Iowan till or covered by Peorian loess. The loess is extremely important in correlation, since it is pre-Mankato in age. Besides loess, the gravel is covered by loess-like silt within which pebbles are sparsely distributed, generally in increasing numbers toward the base. Both of these types of overburden sometimes show a gradational zone between them and the gravel.

The Age of the Gravel

Early investigators believed the Iowan terrace gravel to have been deposited during the retreat of the Kansan glacier, and called them the valley phase of the Buchanan.[55] Not until after 1910 were they referred to as Iowan terrace deposits.

These gravel deposits are in valleys eroded in the Kansan drift during the post-Kansan gumbotil pre-Iowan interval and could not be Kansan in age. In some places they are observed overlying and interbedded with Iowan till; here they were either deposited simultaneously with or following the deposition of the till. The overburden of loess which is immediately post-Iowan in age grades into the gravel

55 Calvin, Samuel, Geology of Howard County: Iowa Geol. Survey, Vol. XIII, pp. 67-68, 1903.

in some exposures, which shows that the loess was being deposited during the last stages of gravel deposition.

The age of the gravel of these terrace deposits cannot in all cases be so closely determined as in those mentioned. Where the underlying material is not exposed, as is generally the case, the deposit may also include gravel of Loveland age, gravel deposited as the ice advanced, or even both. If so, the older material was probably reworked and redeposited during the retreat of the Iowan glacier.

THE MANKATO GRAVELS

The hemi-eliptic lobe of the late Wisconsin glacier (the Mankato) extended into Iowa as far south as Des Moines, which is a distance of 140 miles. Where it crossed the Iowa-Minnesota line the width of the lobe was about 135 miles, the east margin crossing in the east side of Worth county near Northwood, and the west margin crossing in Osceola county, north of Sibley (see figure 2).

The surface of the Mankato drift is generally a flat or gently undulating plain except for the more or less well-developed constructional terminal moraine topography and moundlike hills and depressions on the ground moraine surface. The drainage is youthful, and undrained lakes and marshes are numerous. Most of the streams are in broad swales and have developed only the small narrow channel in which they flow, the larger valleys being the partly filled remnants of an older drainage system. Some of the larger streams have cut deep, narrow valleys in the Mankato drift plain, but even these streams have formed the topography of only a small part of the area they drain.

As the Mankato ice melted, gravel was deposited in two general positions as were the Iowan gravels: (1) as irregular masses of gravel within the till and as kamelike knobs standing above its surface; and (2) as outwash in the valleys in front of the ice margin. These two types of deposits will be discussed separately, since they differ in practically every aspect.

THE MANKATO UPLAND GRAVEL

The Distribution of the Gravel:

The Mankato upland gravel is distributed throughout the area of Mankato drift as shown in figure 46. Most of the exposures are either near the drift margin within what has been called the terminal moraine

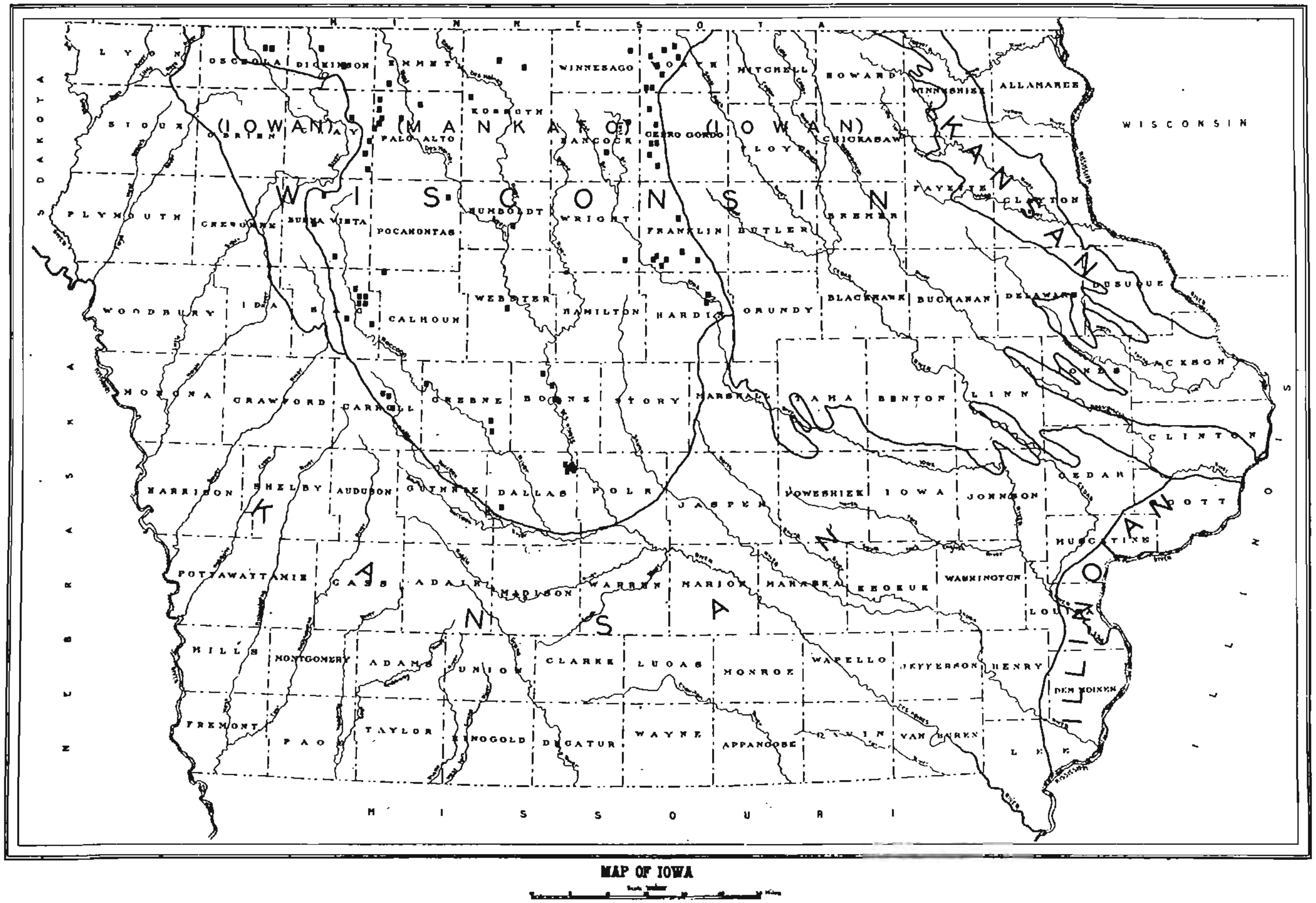


FIG. 46. — The squares show the locations of Mankato upland gravel exposures within Iowa.

or within groups distributed over the drift surface as recessional moraines. Within the moraine areas, both terminal and recessional, the deposits are generally small. One notable exception is Ocheyedan mound, which stands 150 feet above the valley bottoms and covers an area of about 40 acres. Other exposures of gravel, both within and outside of the terminal and recessional moraines areas, occur as irregular masses within the till; some are buried deeply and others are close to the surface.

The locations of the exposures represented in figure 46 show that the deposits are unevenly distributed throughout the drift area. There are other exposures within this area from which the gravel has been removed and which are now concealed by slumped material. Still other masses of gravel have never been opened, because of excessive thickness of overburden, low commercial value, or the lack of demand for the gravel; the last is caused by the abundance of the easily available and uniform-textured valley gravel deposits along most of the streams.

The Characteristics of the Gravel

General Characteristics:

The Mankato upland gravel was deposited during the melting of the Mankato glacier and the deposition of the till. The exposures of this type which were studied show gravel deposited as irregular masses deep within the till, as lenses and thin beds interstratified with the till, as irregular masses just below the surface of the till, and as deposits in kamelike hills which stand above the surface of the till.

The Mankato drift, of which the Wisconsin upland gravel is a part, represents deposition by the last ice invasion and consequently is not overlain by younger deposits. Since it occupies a position at the surface it has been subjected to weathering processes during all subsequent time. These have leached the carbonates from the till to an average depth of between 2 and 3 feet, and have oxidized the iron compounds still deeper. Thus the till can be divided into three zones on the basis of weathering: the upper zone of oxidized and leached; next, the oxidized but unleached; and below this the fresh unaltered till. The period of weathering has not been sufficiently long to form gumbotil at the till surface.

Where gravel instead of till occupied a position within the zone of weathering, it underwent changes comparable to those in the till.

Leaching has removed the carbonates from the gravel and overburden to a combined depth of 2 to 3 feet, below which there are both primary and secondary carbonates. The secondary carbonates form lime concretions, but it is very unusual that they cement the gravel into a conglomeritic mass.

The coloration of the gravel by iron oxide varies both within single exposures and with different exposures. Some exposures appear fresh, uncolored by oxidation except possibly within narrow bands which are generally along bedding planes. Other exposures are colored dark-buff (15'i, Ochraceous-Tawny) throughout most of the gravel but in places contain beds of gray unoxidized gravel interstratified with that which is oxidized. Still others contain beds or irregular masses of gravel which are colored dark reddish-brown (11'k, Hazel) and are firmly cemented by iron oxide. In addition to the many shades of brown and buff produced by the iron oxide, in a few exposures thin layers along bedding planes and irregular masses are colored black by the manganese dioxide which coats the grains and in some places cements them together.

The general structure of the gravel is very irregular. Much of it is in horizontal beds within which are minor irregularities such as cross-bedding, lenses, pockets, clay-balls, steeply dipping beds, and boulders. In some parts of the exposures the gravel is unstratified and poorly sorted.

There is a wide size range within these gravel deposits. The greatest percentage of gravel is smaller than 5 centimeters in diameter, but cobbles and boulders as large as 75 centimeters in diameter are common. The percentage of each of the different size grades, determined by a mechanical analysis of samples of average material from different exposures, is shown in figure 47. The percentage of rounding of the size grades between 1/16 and 32 millimeters in diameter is shown in figure 48. Rock analyses of pebbles between 16 and 32 millimeters in diameter are shown in figure 49.

The material overlying this gravel is either Mankato till or loesslike silt. The till is generally less than 3 feet thick but in one exposure observed it was 25 feet thick. The loesslike silt observed was not thicker than 3 1/2 feet and was generally less than 2 feet. In both types of overburden weathering has developed the zones previously mentioned. They are leached to a depth of from 2 to 3 feet where unaffected by subsequent erosion. However, oxidation extends much deeper and

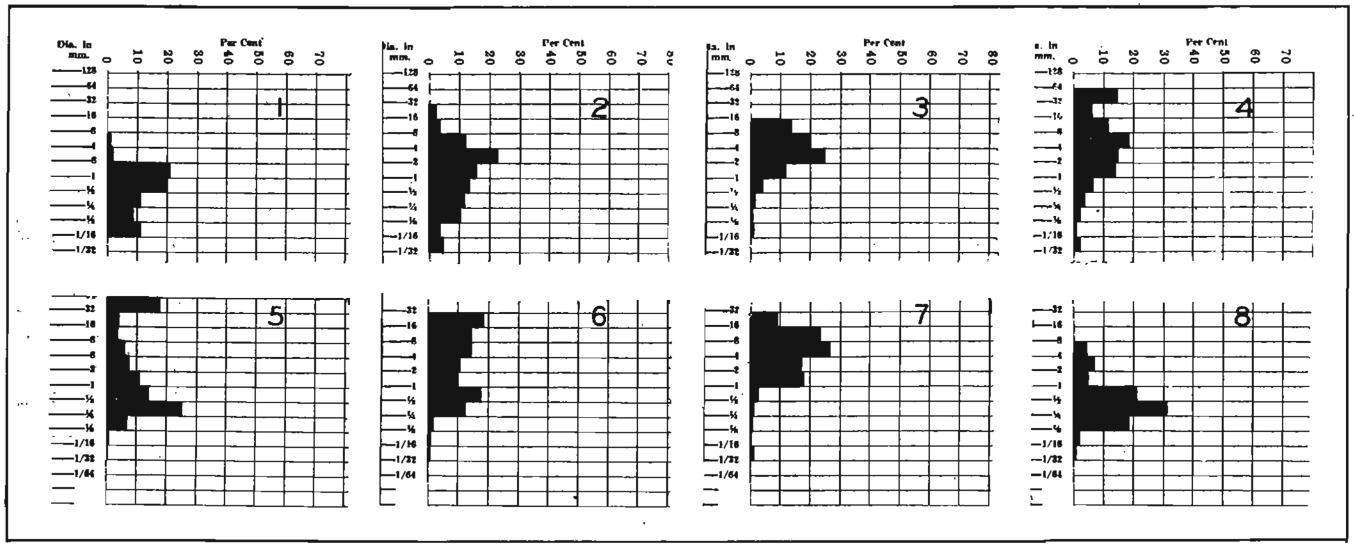


FIG. 47. — Graphs showing mechanical analyses of Mankato upland gravel. The numbers of these analyses correspond with those of figures 48 and 49.

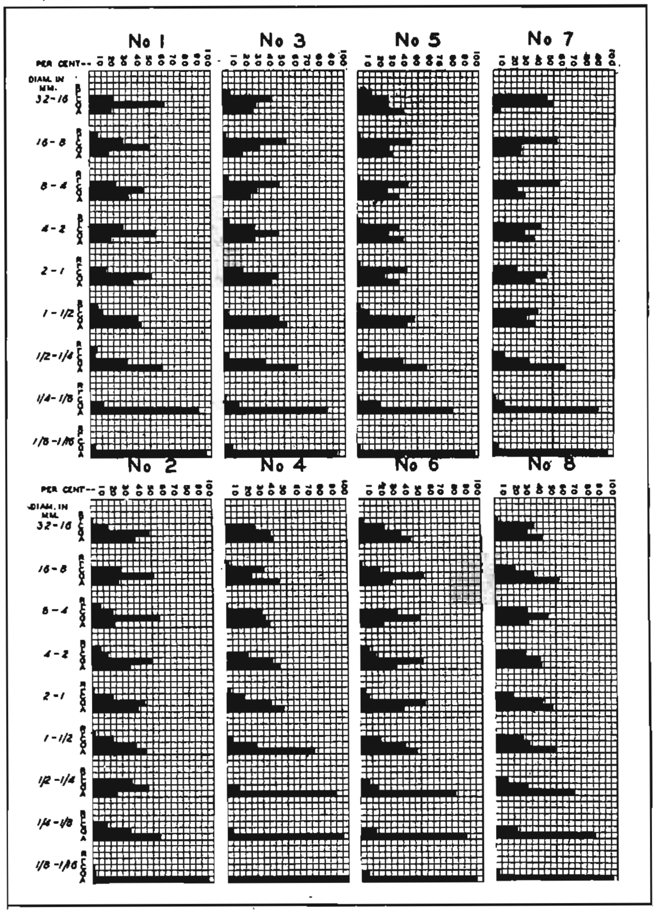


FIG. 48. — Graphs showing shape analyses of each size grade between 1/16 and 32 millimeters in diameter of Mankato upland gravel. The numbers of these analyses correspond with those of figures 47 and 49. R = rounded; r = sub-rounded; C = curvilinear; a = sub-angular; A = angular.

colors the overburden dark-buff (17'' 'd, Vinaceous-Buff). The addition of humus colors the soil zone to a darker shade of brown (13'' ''i, Benzo-Brown) than the normal oxidized material.

Characteristics of Exposures

Almost all of the exposures are in gravel pits which have been used during recent years to obtain road surfacing material. One of the most typical exposures in the northeastern part of the Mankato drift area is in Worth county. It is in the southwest quarter of section 27, Hartland township (T. 100 N., R. 21 W.), along the north side of

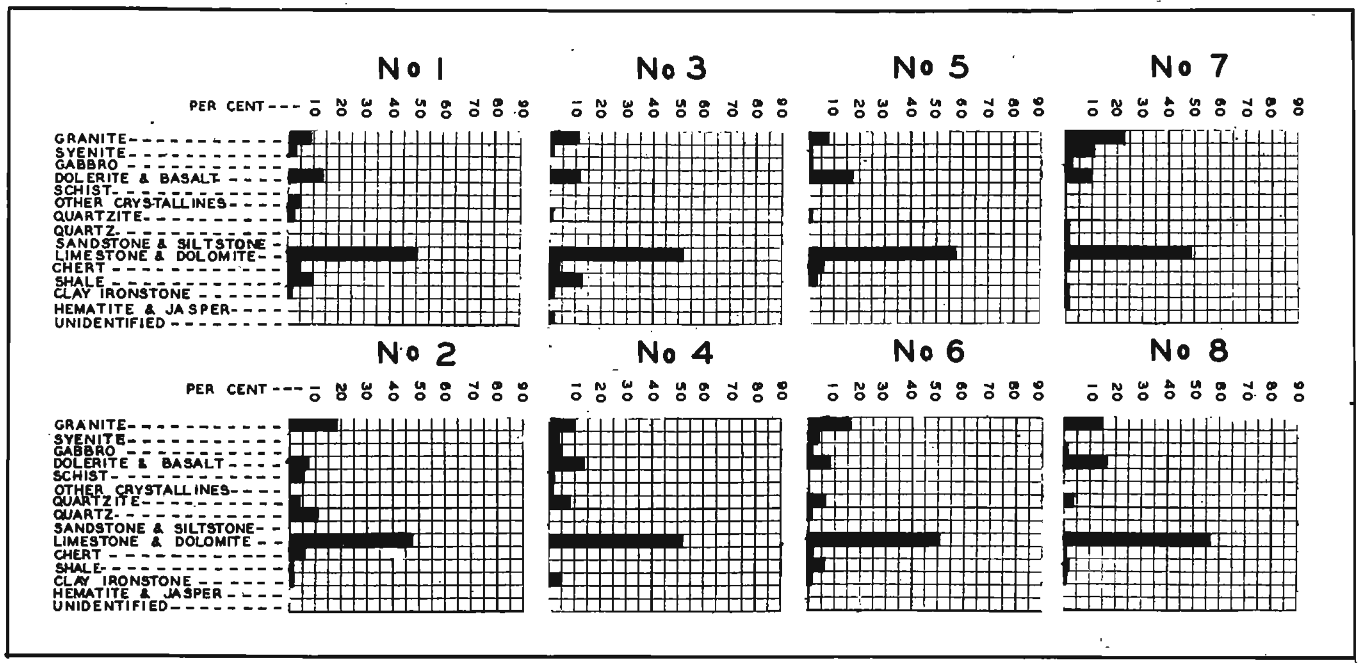


FIG. 49. — Graphs showing lithology of pebbles between 16 and 32 millimeters in diameter. The numbers of these analyses correspond with those of figures 47 and 48.

primary No. 105, west of Northwood. Here the gravel occurs in a kame on the surface of the Mankato drift. This is within the terminal moraine area and represents only one of the many kames within this area.

The gravel is gray (17"b, Cinnamon-Buff) and shows no oxidation except in the thin gradational zone between it and the overburden. This zone is colored light chocolate-brown (17" ', Buffy-Brown) by the fine material from the overburden. In one part of the pit the overburden is only 16 inches thick and leaching extends 1 foot into the gravel, making the total depth of leaching 28 inches. A few of the rocks, especially coarse crystalline ones, have been disintegrated along their margins by weathering so that they crumble readily with slight pressure. However, all of the gravel appears fresh. The central part of the pit is composed chiefly of well-stratified sand and gravel which is practically all smaller than 3 centimeters in diameter. Within these beds are various minor irregularities such as cross-bedding, lens, and pocket structures. Toward the margin the gravel becomes coarser, containing some cobbles as large as 20 centimeters in diameter. It is poorly stratified in some places and in others it is a heterogeneous mass. A few boulders, the largest 40 centimeters in diameter, are scattered sparsely throughout both coarse and fine gravel. The percentage of each size grade of a sample of average material is shown in No. 1 of figure 47. The percentage of rounding is shown in No. 1 of figure 48. The rock content is given in No. 1 of figure 49. The overburden is sandy silt that is colored by humus and oxidation of the iron compounds to chocolate-brown (13" "i, Benzo-Brown) in the upper 15 to 24 inches below which it is lighter colored. Pebbles are scattered throughout the overburden. No contacts at the base of the gravel were exposed, although the pit extends down more than 4 feet below the general surface of the drift plain.

Another exposure of the Mankato upland gravel is in the southeast quarter of section 5, Bristol township (T. 99 N., R. 22 W.), Worth county, along primary road No. 105, near the west side of the county. Here the gravel occurs in a pit which is in an elongate ridge that resembles an esker. This ridge is on the hummocky surface of the ground moraine and has a general northwest-southeast elongation. Since the pit has not been worked for several years, the slumping of overlying material has covered most of the exposure.

Within the gravel mass the oxidation of the iron compounds is very slight. The gravel is gray (17"b, Cinnamon-Buff), but the large number of small clay-balls included in the gravel are buff colored, giving a light-buff tint to the entire mass. Leaching has removed the carbonates from the 2 feet of overburden and from the upper 6 to 10 inches of the highly calcareous gravel. The gravel is poorly stratified and contains some cross-bedding. There are a few large boulders in the bottom of the pit which are residual from either the gravel removed or the overburden, but aside from these the material is practically all smaller than 3 centimeters in diameter. The percentage of each size grade is shown in No. 2 of figure 47. The percentage of rounding is shown in No. 2 of figure 48. A rock analysis of pebbles is shown in No. 2 of figure 49. In the base of the pit is a resistant ridge of gravel, colored dark reddish-brown (11'k, Hazel) and cemented into a firm conglomeritic mass by iron oxide. Closely associated with the reddish-brown beds are some beds colored black by manganese dioxide and similarly cemented, forming part of the resistant material of the masses. The material forming the resistant ridge is highly calcareous and lithologically the same as the rest of the gravel exposed. There seems to be no doubt that this represents cementation of the Mankato gravel and that it is not part of an older deposit on which the later Mankato gravel was deposited. This conclusion is further substantiated by another exposure of gravel in this same elongate hill about 30 rods southeast of the one just described, in which the same type of highly cemented material is exposed. This type of cementation has been observed in three other Mankato upland gravel exposures within this part of the state, but in none of the others was it as well developed. The overburden here is about 2 feet thick, colored to the usual chocolate-brown by humus and iron oxide, and leached of its carbonates. No material underlying the gravel was exposed.

In Hardin county, about 6 miles southeast of Iowa Falls, in the southeast quarter of the southwest quarter of section 36, Hardin township (T. 89 N., R. 20 W.), a gravel pit exposes 9 feet of Mankato upland gravel. This gravel is an irregular mass inclosed in the till and covered by only about 18 inches of overburden. This is within a region of considerable relief along the Iowa river near the margin of the Mankato drift.

The gravel is gray (17'' 'b, Avellaneous), and the only coloration by iron oxide is within the gradational zone between it and the light chocolate-brown colored overburden. Leaching has removed the carbonates to a depth of about 27 inches including the 18-inch layer of overburden. The material consists chiefly of gravel finer than 2.5 centimeters in diameter and coarse sand. The percentage of fine sand is low. Only 4 cobbles and boulders were found in the base of the pit, but in a similar pit a short distance away the cobbles and boulders were abundant within the finer gravel and sand. The stratification is good throughout the exposure. Within the thick strata cross-bedding and lenses of coarser gravel and finer sand are common. The percentage of each size grade is shown in No. 3 of figure 47. The coarser sand and gravel, as in the other exposures of this type, show little rounding by stream action, and some of the pebbles have striated surfaces. A shape analysis is shown in No. 3 of figure 48. The rock content is shown in No. 3 of figure 49. The overburden is loesslike sandy silt, which has been leached of its carbonates. A few pebbles scattered throughout the 18-inch layer increase in number toward the top of the gravel. It is colored medium chocolate-brown (13'' ''i, Benzo-Brown) at the surface by humus and iron oxide, but grades into a light chocolate-brown (17'' 'i, Buffy-Brown) toward the top of the gravel because of the decrease in the amount of humus.

One of the most conspicuous glacial topographic features of northwestern Iowa is the Ruthven terminal moraine which extends from south of the town of Ruthven into southern Minnesota. It has a typical terminal moraine topography with a relief of 50 to 100 feet. The small hills are generally steep sided and show gravel at their tops and sometimes along their sides. Swamps and small lakes are common in the lowland areas. Gravel has been exposed in many places throughout this morainic area, but most of the exposures have since been concealed by slumping of the overlying material.

An exposure of this gravel is about 1 1/2 miles east of Ruthven, near the center of the north side of section 21, Highland township (T. 96 N., R. 34 W.), Palo Alto county, in the Ruthven morainic area. The gravel is on a flat upland but does not form a kamelike knob.

The material consists primarily of sand and fine gravel. Not more than 10 per cent of the entire mass is larger than 6 millimeters in diameter. Three boulders between 22 and 35 centimeters in diameter were found about the base of the pit. All of the sand and gravel is well stratified in almost horizontal, wavy beds. However, cross-bedding and lens-and-pocket structures make up practically all of some of the beds, especially those toward the base of the pit. In the main face of the exposure a fault with a vertical displacement of about 8 inches extends from top to bottom. The structure and general characteristics of the gravel exposed are shown in figure 50. The section exposed is as follows:

	Feet	Inches
6. Overburden: loesslike silt containing only an occasional pebble; leached, colored chocolate-brown (13''''i, Benzo-Brown) by iron oxide and humus, unstratified; grades into similar material containing a much greater percentage of pebbles, and lighter brown color (17''', Wood-Brown) from oxidation alone	2	3
5. Gravel: light-brown (17''i, Tawny-Olive) leached only in the upper part; consists of interbedding of sand and fine gravel. Gravel beds are generally 1 to 2 inches thick and sand beds about 6 inches thick; neither is of uniform thickness over any horizontal distance and they often represent large thin lenses. Cross-bedding dipping toward the southwest is present in the sand	5	
4. Gravel: interbedding of coarse and fine material. The coarse material is almost all smaller than 5 centimeters in diameter and only a low percentage is larger than 2 centimeters in diameter; beds of coarse gravel are about 5 inches thick, fairly continuous throughout the exposure, horizontal but slightly wavy. Some lens-and-pocket structures; cross-bedding is distinct within the finer gravel and sand beds	6	
3. Sandy silt: bed 6 to 10 inches thick, generally continuous but lenses out along the margins; contains no coarse material; beautifully stratified with a fine delicate structure consisting essentially of cross-bedding, lens-and-pocket structures		10
2. Gravel and sand: chiefly sand, including fine stringers of fine gravel; structure essentially cross-bedding, lenses, and pockets which dip generally toward the southwest. In the upper one foot of this zone the material is chiefly in horizontal beds within which are few irregularities such as cross-bedding, lens-and-pocket structures. Interbedded with this are beds of finer gray sand, sometimes colored dark-brown by iron oxide. The coloration is parallel to the stratification	6	
1. Gravel: coarser than the rest of the exposure; upper and lower 3-foot members are medium coarse gravel while the middle 1-foot member is coarse. Stratification is poor, especially in the middle member. Some material is as large 20 centimeters in diameter and much of it larger than 8 centimeters in diameter	7	

A mechanical analysis of the average material of zone No. 4 of the above section is shown in No. 4 of figure 47. The shape is shown in No. 4 of figure 48. A rock analysis is shown in No. 4 of figure 49. In the coarser material of the pit, reddish-pink quartzites are abundant.

Another exposure of Mankato upland gravel is in a gravel pit in the southwest quarter of section 2, Jackson township (T. 88 N., R. 36

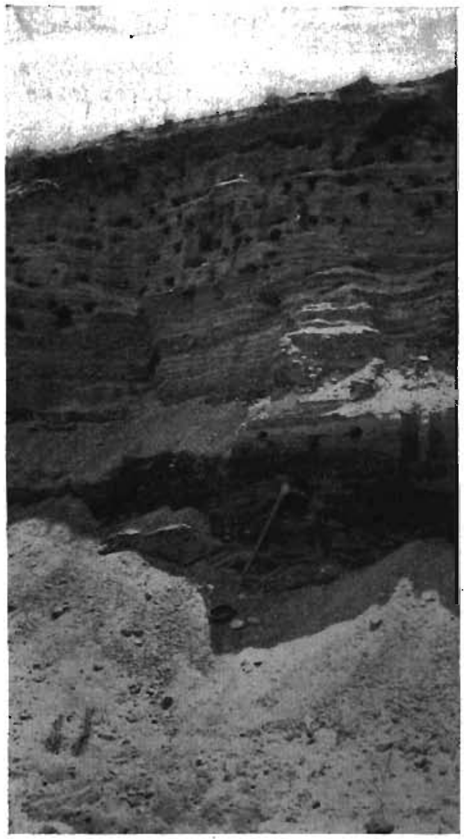


FIG. 50. — Exposure of Mankato upland gravel.

W.), Sac county, about 3 miles north of Sac City. This exposure is within 6 miles of the Wisconsin drift margin. It is an irregular mass of gravel entirely enclosed within Wisconsin till. The exposure is 19 feet deep.

The gravel of the entire exposure appears fresh, colored only slightly (17'' 'b, Avellaneous) by iron oxide. Leaching has removed the carbonates from only the upper 2 feet of the overburden, the underlying gravel containing an abundance of limestone and dolomite. The gravel is well stratified in beds which dip toward the south and southeast at an angle of about 35 degrees. Some cross-bedding and lens-and-pocket structures are found in the major beds, but only in small amounts in comparison with other pits of this type. Most of the gravel is fine, as is shown in the mechanical analysis No. 5 of figure 47. The coarser gravel forms thin stingers through the finer material. All of the gravel exposed in the east side of the pit is slightly coarser than that of the west side. Only 11 boulders, between 25 and 40 centimeters in diameter, are in the bottom of the pit. Some of these probably came from the Wisconsin till which overlies the gravel. All of these boulders are angular, showing no rounding along the sharp fractured edges. The percentage of rounding is shown in No. 5 of figure 48. The lithology of pebbles is given in No. 5 of figure 49. The overburden ranges in thickness from 2 to 9 feet. It is Wisconsin till covered in a few places by loesslike silt. The thickness of the overburden varies, because of the irregular surface at the top of the gravel. It is leached to a depth of about 2 feet. Oxidation has colored it to a light-buff (19"i, Isabella Color) and by addition of humus the upper soil zone is darker brown (17" ', Wood-Brown).

Mankato upland gravel is exposed in the northeast part of Dallas county on the surface of the Mankato drift about 20 miles from its most southern margin in Iowa. Here in a hummocky morainic topography the gravel deposits are exposed in and near the tops of several hills. The best exposure is in the northwest quarter of section 23, Grant township (T. 80 N., R. 26 W.), about 3 miles southwest of Granger.

The coloration of the gravel varies throughout the pit. Most of it is only slightly colored by iron oxide to light-buff (19"i, Isabella Color) but certain beds are much darker brown. At the base of the 20-foot exposure the gravel is colored grayish-green, and is immediately overlain by about 16 inches of rusty-brown (15'i, Ochraceous-Tawny) gravel. This in turn is ovelain by a 6-inch layer of gravel colored black by manganese dioxide. Leaching has removed the carbonates to a depth of about 30 inches, almost all of which is within the overburden. The structure of the gravel of this section is quite irregular. In one part of the pit the gravel is well stratified in horizontal beds, but the remainder is practically an unstratified heterogeneous mass. In some places the poorly stratified material resembles beds which have slumped following deposition. Clay-balls and inclusions of till are common throughout the exposure. The gravel shows a wide size range, from till and fine sand to boulders 25 centimeters in diameter. Many of the cobbles between 12 and 18 centimeters in diameter are scattered throughout the gravel. However, the material smaller than these cobbles is almost all smaller than 3 centimeters in diameter. A mechanical analysis of this fine material is shown in No. 6 of figure 47. The percentage of rounding is shown in No. 6 of figure 48. A rock analysis of pebbles is shown in No. 6 of figure 49. The overburden is from 2 to 2 1/2 feet thick. It is loesslike silt, throughout which small pebbles are sparsely scattered. Leaching has removed the carbonates and oxidation of the iron compounds colors the overburden medium-brown (17'' ', Wood-Brown) in the lowest part, and in the soil zone above it is colored darker brown (13'' ''i, Benzo-Brown) by the addition of humus.

Several exposures of Mankato upland gravel are in gravel pits along the northeast side of the Des Moines river about 1 mile southwest of Boone, in Boone county. These exposures represent irregular masses of gravel buried deep within the Mankato drift. In addition to these exposures, there are several in which small masses or lenses of gravel only a few feet in diameter are included within the till.

Along the west side of primary road No. 30, in the extreme northwest quarter of section 31, Des Moines township (T. 84 N., R. 26 W.), Boone county, the gravel is exposed in three gravel pits. In two of the pits very little can be seen, as they have not been worked for several years. In the other pit 40 feet of gravel is exposed, overlain by 25 feet of Mankato till (see figure 51).

FIG. 51. — Exposure of Mankato upland gravel covered by a thick layer of Mankato till.

The gravel is colored to medium-buff (17''i, Tawny-Olive) by the small amount of iron oxide coating the grains and by the high percentage of limestone, dolomite, and chert which is present. Along some of the bedding planes a thin seam of gravel is colored black by manganese dioxide which coats the grains and sometimes forms a weak cement. All of the gravel is highly calcareous. The entire section is well stratified in horizontal beds ranging in thickness from less than 1 inch to more than 1 foot. Cross-bedding, lenses and pockets occur within some of the horizontal beds. The clastic texture of the gravel is quite uniform throughout the pit. Aside from a few boulders, practically all of the gravel is smaller than 2 centimeters in diameter. It has been reported that at its base the gravel lies on a conglomerate of boulders and fine light-gray sand. A mechanical analysis of a sample of average gravel is shown in No. 7 of figure 47. The percentage of rounding is shown in No. 7 of figure 48. The only observed relationship of the gravel to surrounding material is to the overlying till, which is 25 feet thick. Since this exposure is along a steep slope the oxidation and leaching are not to uniform depths. Leaching extends to a depth of more than 4 feet in the till and the oxidized zone to a depth of more than 17 feet. The lower 8 feet of the till overlying the gravel is neither leached nor oxidized although the underlying gravel does show oxidation. There is no gradation from the gravel into the overlying till. The two are separated only by a 6-inch bed of sand containing clay and fine material. The upper surface of the gravel shows no indication of being plowed up by the glacier which passed over it and deposited the overlying Mankato till.

Two more gravel pits occur east of primary road number 30, along the northeast side of the Des Moines river, a short distance east of the exposure just described. In the west one of these two pits the gravel is overlain by fresh, unleached and unoxidized Mankato till which in turn is overlain and interbedded with stratified sand and silt in which the laminae have a maximum thickness of 1/2 inch. In some places the sand is in pockets several inches thick but becomes thin along the margins. This zone of interbedded till and sand and silt is overlain by distinct till. In the other pit the sequence is the same as that just given but not as distinct.

Relations of the Gravel

The relationship of the Mankato upland gravel to the associated materials and the topography is shown in several exposures. Some of these relationships were described at the same time the characteristics of the gravel were discussed. The exposures show the gravel as irregular masses which may be either deep within or near the surface of the till, as kamelike hills or eskerlike ridges on the surface of the till, as irregular masses included within till of kamelike hills, and as lenses and thin beds interbedded with till.

In the northwest quarter of section 31, Des Moines township (T. 84 N., R. 26 W.), Boone county, Mankato upland gravel is exposed in three gravel pits as irregular masses buried deeply within the Mankato till. In only one, however, are the relations to the till exposed. In it the gravel is 40 feet thick, unleached of its carbonates but colored some by oxidation. Overlying the gravel is 25 feet of Mankato till, leached and oxidized in the upper part, below which it is unaltered. No distinct gradation separates the gravel from the overlying till. The nearest approach to this is a thin bed of well-stratified sand containing considerable clay. Otherwise the break between them is a distinct line. The upper surface of the gravel appears just as deposited, undisturbed by the movement of an overriding ice sheet which deposited the 25 feet of overlying till.

East of the primary road number 30, only a short distance from the exposures just described, are two gravel pits which have not been worked for several years. Their relations to the Mankato till are the same as those described in the preceding section. However, overlying this gravel there is an interbedding of well-stratified beds and lenses of sand and silt with the till. The relations, the structures, and the shapes of these deposits show that they represent primary deposition in their present position. Furthermore, none of them show signs of having been disturbed by overriding ice action. Several small irregular masses of oxidized but calcareous gravel only a few feet in diameter and completely surrounded by unaltered Mankato till are exposed in cuts within this same vicinity.

In the northeast part of Dallas county, in the east central part of Grant township (T. 80 N., R. 26 W.), there are several exposures of Mankato gravel, all in or near the tops of the hills. The gravel exposed is calcareous below the 2- to 3-foot leached zone in the overburden and gravel. Mankato till has been observed along the sides and below the gravel, but the overburden is loesslike silt that contains pebbles which become more numerous toward the surface of the gravel. One of the best exposures in which to observe these relations is in the northwest quarter of section 23. Many other deposits distributed throughout the Mankato area show these same relations to the Mankato till. Some of the best areas in which they can be observed are in Palo Alto county, in the western part of Worth and Cerro Gordo counties, and in the southwest part of Franklin county.

Within the Mankato area there are large kamelike hills in which gravel is contained within the Mankato till. One of these is Ocheyedan Mound, in the southwest quarter of section 12, Ocheyedan township (T. 99 N.; R. 40 W.), in the northeast part of Osceola county. In this mound which stands about 150 feet above the main drainage lines, and conspicuously above the surrounding topography, two gravel pits have been opened. One of the pits is near the top and the other is along the north slope; both show sand and gravel. Another mound, similar to the Ocheyedan Mound, is Pilot Knob, in the extreme northeast part of Hancock county, Ellington township (T. 97 N., R. 23 W.), in sections 3 and 4. In it several sand and gravel masses, surrounded by Mankato till, are exposed.

Small kamelike hills are abundant in the morainic areas on the Mankato drift. These small hills consist of till and gravel, although some are almost entirely gravel, covered by a thin veneer of till or loesslike silt. Good exposures of this type may be observed in many places throughout the Mankato drift area, especially within the terminal moraines. One is in the southwest quarter of section 27, Hartland township (T. 100 N., R. 21 W.), Worth county. Many similar kames occur in this same area within Worth and Cerro Gordo counties.

An exposure of gravel in an eskerlike ridge has been described in the northeast quarter of section 5, Bristol township (T. 99 N., R. 22 W.), Worth county. This ridge stands above the ground moraine plain close to the margin of the terminal moraine. It is slightly sinuous and varies in height from place to place, finally merging into the ground moraine surface. At the location of the above exposure the ridge was higher, thus forming a kamelike knob. The trend of the ridge is in a southeast-northwest direction. The gravel is covered by a thin layer of silty till-like material where observed near the top of the ridge, and a thicker typical till along the flanks. No gradation from one into the other was observed. The base of the gravel is below the ground water surface; thus no contact with underlying material was exposed.

The Age of the Gravel

The characteristics and relations of the Mankato upland gravel show them to be closely related in age to the till. Those deposits entirely inclosed within Mankato till must have been deposited at the same time the till was being let down from the melting ice. Some small masses may have been picked up in a frozen condition from the overridden surface by the advancing glacier and deposited as gravel boulders within the till. The irregular masses of gravel at the surface of the till and the kamelike hills on the surface of the till may have been deposited either at the same time as the associated till or as outwash at the margin of the melting ice.

MANKATO TERRACE GRAVEL

Distribution of the Gravel

Mankato terrace gravel deposits are distributed widely throughout much of the northern part of the state both within and beyond the Mankato drift area, but, as stated under the discussion of the Iowan terrace gravel, they can be differentiated from the older gravels, the Iowan and Loveland, which were probably deposited in most of the valleys only by their relations to associated materials. This being true, only those deposits within the drift area will be included here; the others are described as undifferentiated gravel. The distribution of the gravel deposits within the Mankato drift area is shown in figure 52.

The Mankato terrace gravel deposits within the Mankato drift area occur along almost every stream, regardless of size, and extend practically to its head. The present stream channels are cut in these valley fillings, while the parts which remain form terraces which vary greatly in height, some being as much as 120 feet above the stream. In places, small patches of gravel along the valley wall are all that remain of these gravel deposits; but more commonly the terraces are wide, sometimes more than a mile, and continuous for several miles. Along many of the smaller streams they are continuous almost the entire length of the valley.

Some of the valleys in which these terraces were deposited were developed by consequent streams flowing across the unevenly distributed Mankato drift surface. Other valleys were formed before the

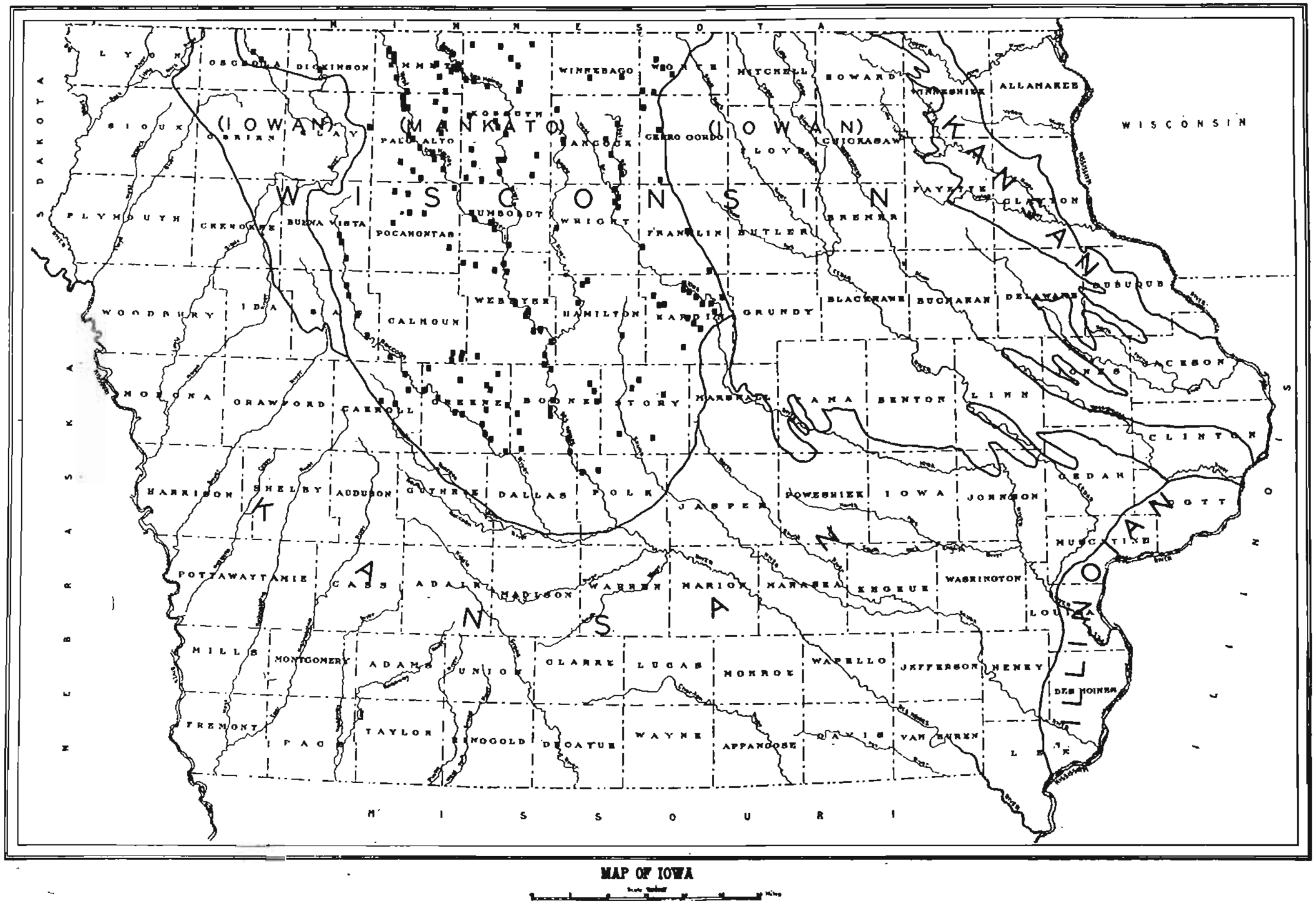


FIG. 52. — The squares show the locations of Mankato terrace gravel exposures within the Mankato drift area in Iowa.

advance of the Mankato glacier and were not entirely filled by the Mankato drift but afforded broad shallow valleys in which the streams from the melting Mankato ice flowed and deposited vast amounts of gravel. As shown by the lack of erosion on the surface of the Iowan drift outside the Mankato drift area, it seems doubtful that these valleys below the Mankato drift were formed during post-Iowan, pre-Mankato time; it is more probable that they were developed during post-Kansan gumbotil, pre-Iowan time and not entirely filled by the till deposition of the Iowan and Mankato ice sheets. This is further verified by the fact that these pre-Iowan drainage lines are more distinct within the Iowan area, where they are covered only by the thin Iowan drift and loess, than where they are also covered by the later Mankato drift.

Like the Iowan terrace deposits, the locations represented on the map are almost all gravel pits from which the gravel has been removed for road surfacing. Some, however, are artificial cuts and others are natural cuts along streams. As previously stated, these gravel terraces are practically continuous along the valleys, and the number of exposures is no definite criterion by which to determine their abundance but merely shows their presence and the fact that the gravel is more adaptable to commercial demand at that location.

The Characteristics of the Gravel

General Characteristics:

The Mankato gravel deposited along those streams which flowed from the melting Mankato glacier formed terraces which range in height from the level of the flood plain to more than 120 feet above the level of the stream. However, most of them are between 25 and 35 feet above the stream.

The overburden is unstratified silt, in some places sandy and in others loesslike, generally but not everywhere containing sparsely scattered pebbles which increase in number toward the base. It has a maximum observed thickness of 6 feet but may be a very thin layer or entirely absent. At the base it grades into the underlying gravel through a thin zone in which the interstices of the gravel are filled with the overburden, and generally the lower part of the overburden contains a few pebbles from the underlying gravel. This gradational zone is no doubt more pronounced in some exposures as the result of leaching which removed the carbonates from the upper part of the gravel, leaving spaces which the overburden might fill. Oxidation of the iron compounds colors the silt medium chocolate-brown (about 17" ', Buffy-Brown) and by the addition of humus in the soil zone, the silt is colored to a darker brown (about 13" "i, Benzo-Brown). The carbonates are generally absent from the entire thickness of the overburden, although in some places only to a depth of about 30 inches. The apparent leaching to depths of 4 to 5 feet may be partly due to the topographic position, but it is more likely due to the small amount of carbonates in the original material. This is further substantiated by the fact that the depth of leaching extends just to the surface of the gravel in almost all of the exposures in which the overburden is more than about 30 inches thick, and into the gravel where it is thinner.

The gravel is highly calcareous except in a narrow leached zone at the surface of some exposures where the overburden is less than 30 inches thick, as described above. In addition to the primary carbonates, secondary lime forms concretions and cements some of the gravel in several of the exposures. The oxidation of the iron compounds colors some of the gravel rusty-brown (generally about 15'i, Ochraceous-Tawny) but it may be any shade from light grayish-buff to dark reddish-brown. Most of the gravel is gray to grayish-buff; however, that which is colored darker by iron oxide is in one of the following places: overburden, in thin layers parallel to the bedding, or perhaps within a lens of coarser gravel. Only a few of the igneous rocks such as granites, greenstones, and schists are weathered so that they crumble with application of slight pressure, but the gray shales fall to pieces soon after exposure to the atmosphere. The structure is fairly uniform throughout most of the exposures. The major stratification is in gently dipping beds ranging from less than an inch to several feet thick. Most of these beds are continuous but some extend only a few feet. Within the major horizontal beds cross-bedding is abundant and in places makes up the entire bed. Within the typical stratified material almost all of the gravel is smaller than 32 millimeters in diameter, as shown in the mechanical analyses of figure 53. However, included within this material are beds and lenses of coarser gravel in places containing cobbles as large as 20 centimeters in diameter mixed with smaller cobbles, pebbles, and only a small percentage of sand. Other coarse material is scattered through the finer material, and is unrelated to the stratification. Especially in northeastern Iowa

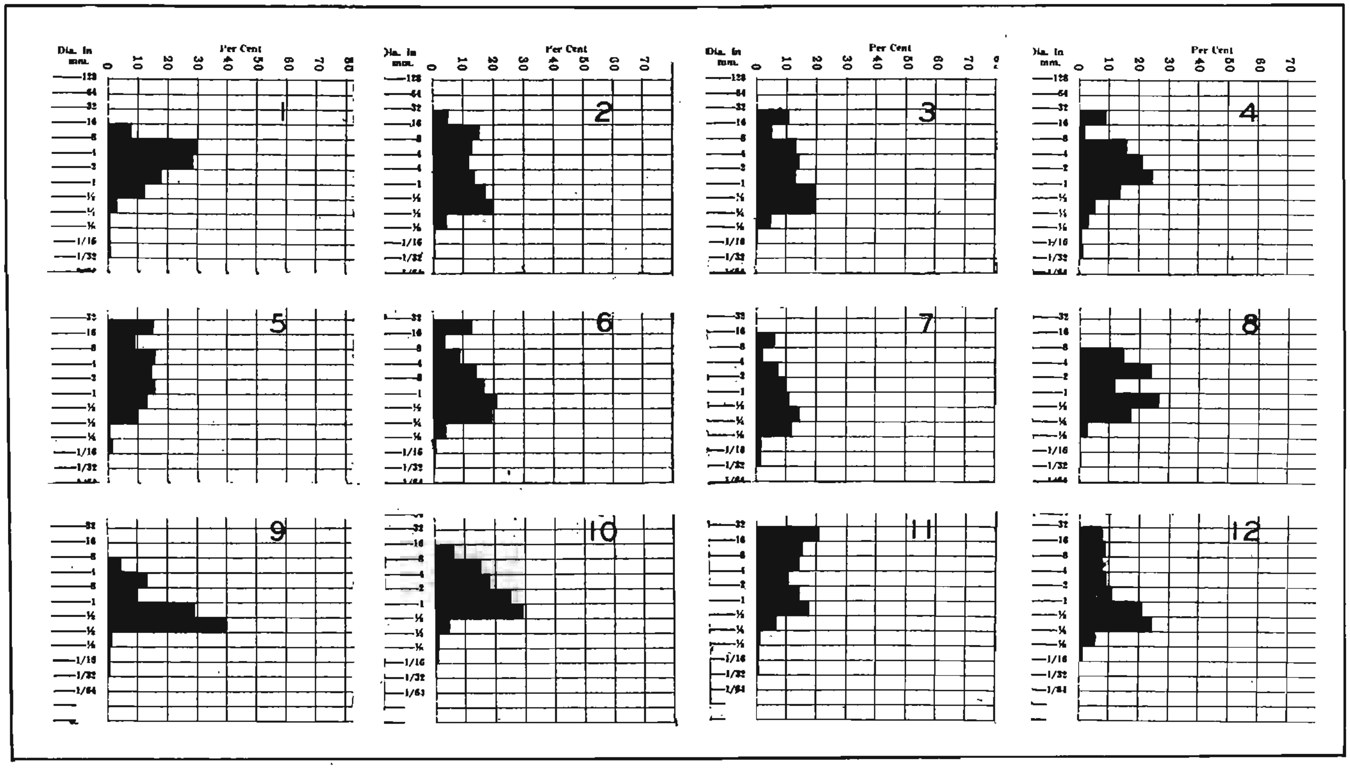


FIG. 53. — Graphs showing mechanical analyses of Mankato terrace and undifferentiated gravels. The numbers of these analyses correspond with those of figures 54 and 55.

the gravel contains a high percentage of limestone plates which comprise most of the coarse material. Generally they lie with their greatest diameters parallel to the bedding and thus make the stratification more distinct. The mechanical analyses of samples of average gravel from several exposures are shown graphically in figure 53. The percentage of rounding of each size grade between 1/16 and 32 milli-

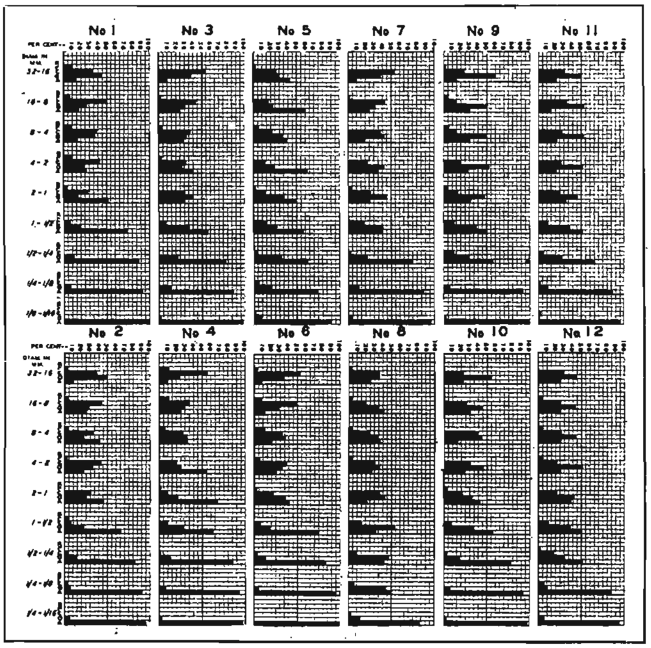


FIG. 54. — Graphs showing shape analyses of each size grade between 1/16 and 32 millimeters in diameter, of Mankato and undifferentiated gravels. The numbers of these analyses correspond with those of figures 53 and 55. R = rounded; r = sub-rounded; C = curvilinear; a = sub-angular; A = angular.

meters in diameter is shown in figure 54. Lithologic analyses of the pebbles between 16 and 32 millimeters in diameter are shown in figure 55.

In some exposures the gravel has been observed to overlie either till or loess. The loess appears to be Peorian and the till either Mankato or Kansan.

Characteristics of Exposures:

Mankato terrace gravel is exposed in a large gravel pit in the northeast quarter of section 19, Hardin township (T. 89 N., R. 20 W.),

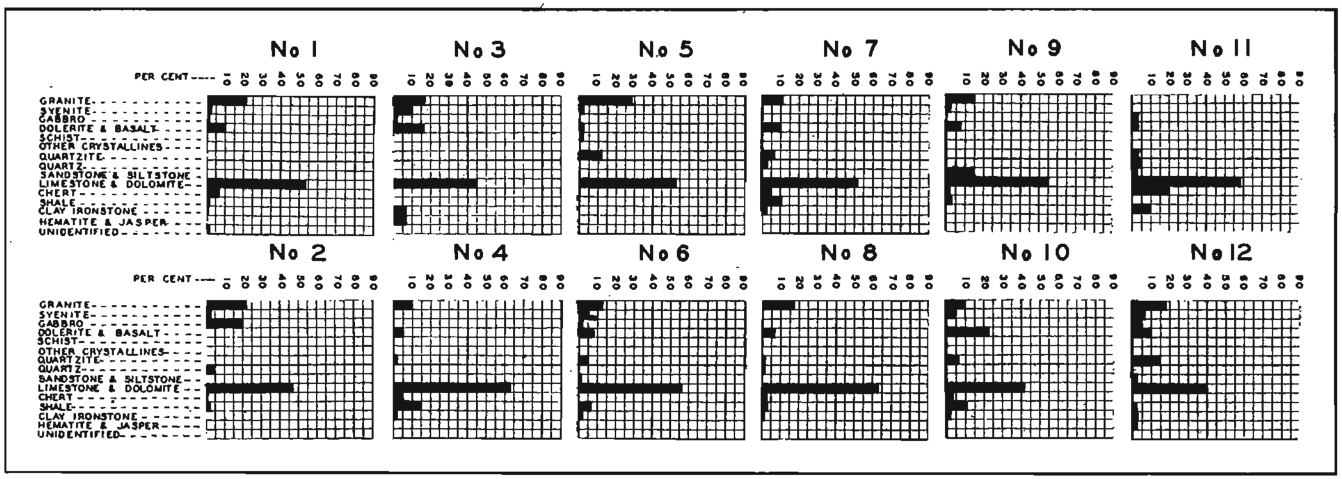


FIG. 55. — Graphs showing lithology of pebbles between 16 and 32 millimeters in diameter from the Mankato and undifferentiated terrace gravels. The numbers of these analyses correspond with those of figures 53 and 54.

Hardin county, along the south side of the Iowa river near the southeast corner of Iowa Falls. The gravel is in a terrace 50 to 55 feet above the river. The thickness of the gravel exposed ranges from 13 to 18 feet.

The light buffish gray gravel has almost no coloration by iron oxide. Most of the color is from the high percentage of grayish-buff limestone and dolomite. Leaching has removed the carbonates to a depth of 24 to 30 inches, primarily from the overburden; but where the overburden is thin, it may extend a few inches into the underlying gravel. No rocks observed in the section showed disintegration from weathering. The gravel in the west end of the pit is distinctly different from that in the remainder of the pit. Here, it resembles a river bar deposit and contains a high percentage of limestone and dolomite plates which make up more than 60 per cent of the deposit. Some of these plates attain an average maximum diameter of 30 centimeters. These coarse fragments are surrounded by a matrix of calcareous gravel which is practically all smaller than 2 centimeters in diameter. Although these plates are not stratified or interbedded with the finer material, as shown in figure 56, they tend to lie with their greatest

FIG. 56. — Mankato terrace gravel in an exposure near the southeast corner of Iowa Falls, along the Iowa river.

diameters parallel and also parallel to the poor stratification of the finer material; thus they give the entire mass a well-stratified appearance. The remainder of the pit, which constitutes abouts nine-tenths of the exposure, is much more uniform in both texture and structure than that just described. The clastic texture of the average gravel is more nearly like the matrix in which the limestone and dolomite plates are imbedded. It is well stratified in horizontal beds which overlap the southward dipping beds of the coarse material previously described. Within these average beds there are minor irregularities such as cross-bedding, and lens-and-pocket structures. About 85 per cent of the average gravel is between the size grades 1/2 and 8 millimeters in diameter. Some boulders are scattered through this finer material. There are also coarse pebbles, some approaching the size of cobbles, which occur in thin beds only one pebble thick along some of the bedding planes. The coarse material of the entire exposure consists almost entirely of platy fragments of limestone and dolomite. Likewise, most of the calcareous material is the same as that exposed in the quarries and limestone bluffs along the river in this same locality. A mechanical analysis of the average material is shown in No. 1 of figure 53. The percentage of rounding is shown in No. 1 of figure 54. The lithology is shown in No. 1 of figure 55. The overburden is fine unstratified silt which contains some pebbles scattered throughout the lower 1 foot. It is from 18 to 30 inches thick, leached of its carbonates, and colored medium-brown (17'' 'd, Vinaceous-Buff) by iron oxide and humus. In the east end of the pit the gravel overlies unleached and unoxidized till which thins out toward the west, where the oxidized but unleached loess below the till lies immediately below the gravel.

Less than 1/2 mile from the pit there are two quarries and three other exposures of gravel. Both the quarries, one on each side of the river, are at the same elevation as the terrace in which the gravel pit just described is located, 50 to 55 feet above the stream. One gravel pit along the north side of the river is also at this same level but the other is in a terrace about 25 feet lower. The third gravel pit is along the south side of the river in a terrace almost at the upland, 70 feet above the river. The characteristics of all these gravel exposures are quite similar.

Several exposures of Mankato terrace gravel in Polk county, near Polk City, show relations similar to those of the gravel pit described near Iowa Falls, in Hardin county.

The best of these exposures is near the center of section 1, Madison township (T. 80 N., R. 25 W.), in the east part of Polk City, on a terrace along the south side of Big Creek. Here the gravel has been removed to a depth of 26 feet from a terrace about 55 feet above the river.

The overburden is 2 feet thick. It is unstratified fine silt through which pebbles are scattered sparsely but in increasing numbers toward the base, where the overburden grades into the underlying gravel through a 4-inch transitional zone. The iron oxide colors the upper 6 inches of the gravel to the same color as the base of the overburden. Below this zone the gravel is practically uncolored by iron oxide, ranging from a very light-buff (15'i, Ochraceous-Tawny) in the coarser material to gray (17"b, Cinnamon-Buff) in the finer and almost white (21" 'f, Pale Olive-Buff) in the fine sand. Leaching has extended only about 6 inches into the gravel below the overburden. The upper 4 feet of gravel is poorly stratified and includes many lenses of both coarser and finer material as well as considerable cross-bedding. Pebbles as large as 5 centimeters in diameter are scattered through the poorly sorted coarse gravel. The 18 feet of gravel exposed below this is finer, well sorted, and stratified in beds seldom more than 8 inches thick, within which lenses, pockets, and alternating beds of sand are common. Practically nothing is larger than 2 centimeters in diameter. A mechanical analysis of an average sample from the lower 18 feet of gravel is shown in No. 2 of figure 53. The percentage of rounding is shown in No. 2 of figure 54. A lithologic analysis is shown in No. 2 of figure 55.

Another exposure of gravel is in an extensive terrace along the opposite side of Big Creek, in the southeast quarter of section 36, Madison township (T. 81 N., R. 25 W.). The gravel pit covers a wide area. Although no gravel has been removed for many years, it and related material can still be observed in a few places. In general the gravel and overburden are much the same as those along the opposite side of the stream, which have just been described. The gravel was deposited upon a very irregular surface, and except for one hole from which it has been removed to a depth of about 25 feet, the gravel was less than 15 feet thick. Unleached and unoxidized till is exposed in several places in the base of this pit.

Another exposure of gravel showing relations to associated deposits similar to those just described is in a terrace about 55 feet above the level of the Des Moines river. It is in the northeast quarter of section 30, Jefferson township (T. 81 N., R. 25 W.), Polk county. Here 15 feet of gravel is exposed below the usual silty overburden. The gravel differs from other exposures just described, near Polk City, in that it is coarser and poorly stratified. The upper 3 feet is coarser than that below, containing much material as large as 8 to 10 centimeters in diameter. At the base of the gravel, there is a single layer of cobbles, each cobble having an average diameter of about 15 centimeters. Underlying the gravel several feet of fresh till is exposed in the ditches along the road.

At Belmond, Iowa, at the confluence of the West Branch of the Iowa river with the East Branch of the Iowa river, there is an extensive terrace in which the gravel is exposed in four large pits and several small pits. The gravel here has been removed from several acres, but at present the workings are abandoned and most of the worked faces are concealed by vegetation and slumped material. All of the pits are in a terrace about 25 feet above the streams.

The best one of these exposures in which to study the gravel is in the south part of town, in the southwest quarter of section 30, Pleasant township (T. 93 N., R. 23 W.), Wright county, along the east side of the Iowa river.

The overburden is of the usual type, unstratified silt 18 to 40 inches thick. It contains pebbles scattered throughout the mass, but becoming more numerous at the base, where the silt grades into the underlying gravel. Leaching has removed the carbonates from all of the overburden. Where it is only 18 inches thick, leaching has extended to a depth of 10 inches into the underlying gravel, but where it is 4 feet thick, the gravel is calcareous to the base of the overburden. Where the gravel is leached below the overburden there is a more distinct gradation between the two than where it is unleached. Oxidation and humus color the upper part of the overburden dark chocolate-brown (13" "i, Benzo-Brown). Below the humus zone the overburden is lighter-brown (17" ', Wood-Brown). In the transitional zone between the gravel and overburden, the gravel is colored rusty brown (17"i, Tawny-Olive) about the same as the overburden, but lower down the gravel is only slightly colored by iron oxide. Only a few of the rocks show signs of disintegration by weathering, except the gray shale which falls to pieces readily when exposed to the atmosphere. The gravel is well stratified in horizontal beds within which cross-bedding and lens-and-pocket structures are common. The gravel is well sorted and even textured throughout the exposure. About 80 per cent is between 1/4 and 8 millimeters in diameter, and practically nothing observed was larger than 8 centimeters in diameter except one boulder in the bottom of the pit which was 30 centimeters in diameter. A mechanical analysis of a sample of average material is shown in No. 3 of figure 53. The percentage of rounding of each size grade between 1/16 and 32 millimeters in diameter is shown in No. 3 of figure 54. The lithology determined from an analysis of pebbles is shown in No. 3 of figure 55. The gravel in the pit is 17 feet thick but no underlying material is exposed.

The other exposures in this terrace near Belmond show the same relations to the overburden and terrace as the one just described but vary in some other aspects such as lithology and textural range.

Many exposures of gravel are in a terrace about 1/2 mile square and standing about 30 feet above the East Branch of the Des Moines river, in the east part of section 26, Armstrong Grove township (T. 99 N., R. 31 W.), Emmet county. The gravel is practically the same in all of the exposures studied.

The characteristics of the material exposed in these pits are quite similar to those of the other terrace deposits described. The 15 feet of gravel overlies unoxidized and unleached till which was observed in the bottom of one pit. Analyses of texture, shape and lithology are shown in No. 4 of figures 53, 54, and 55.

Mankato terrace gravel is exposed in many places in the broad terraces along the West Fork of the Des Moines river, especially in Emmet and Palo Alto counties, but the terraces are continuous from north of the Minnesota line south into Humboldt county.

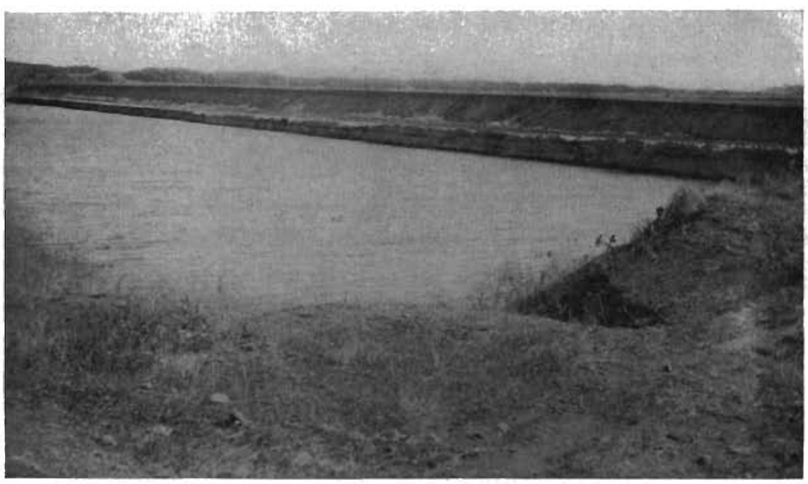


FIG. 57. — Large exposure of Mankato terrace gravel along the Des Moines river north of Graettinger, Emmet county.

A large exposure of gravel is in a pit north of Graettinger, operated by the Chicago, Rock Island Railway Company. It is a narrow elongated pit, as shown in figure 57, which extends from the south central part of section 29 to the center of section 32, High Lake township (T. 98 N., R. 33 W.), Emmet county. Here the gravel is reported to have been removed to a maximum depth of 45 feet. However, 20 feet is the greatest thickness exposed above the water in the pit.

The overburden of the usual silty material is about 4 feet thick. It contains pebbles scattered throughout the entire thickness but becoming more numerous toward the surface of the underlying gravel. There is only a slight gradational zone between the overburden and the gravel. Leaching has removed the carbonates to a depth of 24 inches, below which there is an occasional limestone pebble in the overburden and the average gravel is about 50 per cent carbonates. Except for a few lenses and thin beds which are colored rusty-brown (15'i, Ochraceous-Tawny) by iron oxide, the gravel is light buff-gray (17"ib, Avellaneous). It is well stratified in beds averaging about 2 feet thick which dip slightly toward the southwest. Within beds of finer material there is a small amount of cross-bedding and lens-and-pocket structures. Most of the gravel is smaller than 3 centimeters in diameter and only one boulder was seen. It is possible, however, that there were other boulders and cobbles which have either been hauled away or thrown back into the pit. A mechanical analysis of the average material is shown in No. 5 of figure 53. The percentage of rounding is shown in No. 5 of figure 54. The lithology is shown in No. 5 of figure 55.

Gravel is exposed in many other places in the terrace along this part of the Des Moines river. Around Graettinger there are several exposures along the west side of the stream in this terrace. Similar exposures are found in the west side of Emmetsburg, in one of which the gravel has been reported to have been removed to a depth of more than 40 feet. At Wallingford the gravel has been removed from a considerable area. Here the underlying till is reached in several places at various depths, generally less than 30 feet. Other large pits in and near Estherville have been described by previous writers. [56] Lees [57]

56 Macbride, T. H., Geology of Emmet, Palo Alto, and Pocahontas counties: Iowa Geol. Survey, Vol. XV, pp. 245-250, 1905.
Beyer, S. W., The Road and Concrete Materials of Iowa: Iowa Geol. Survey, Vol. XXIV, pp. 507-508, 1914.

57 Lees, James H., Physical Features and Geologic History of Des Moines Valley: Iowa Geol. Survey, Vol. XXV, pp. 423-615.

has described the Des Moines river valley in all of its aspects from its source in Minnesota to its mouth at the southeast corner of Iowa.

One of the many exposures of gravel along the Raccoon river is near the center of section 13, Jackson township (T. 83 N., R. 31 W.), Greene county, about 1/2 mile from the southwest corner of Jefferson. Here 13 feet of gravel is exposed in a terrace 20 feet above the level of the river.

The surface of the gravel is irregular, which makes the layer of overburden range from 2 to 4 feet in thickness. Leaching has removed the carbonates to a depth of about 40 inches in the overburden, below which there are limestone pebbles, but where the overburden is only 2 feet thick the carbonates are removed from the upper few inches of the gravel. Oxidation and humus color the upper 16 inches of the overburden to a dark chocolate-brown (13" "i, Benzo-Brown), below which the oxidation alone colors the remaining overburden and the underlying transition zone between it and the gravel to a lighter brown (17" ', Buffy-Brown). A layer of coarse gravel 1 to 4 feet thick immediately below the overburden is colored by iron oxide to a light rusty-brown (15'i, Ochraceous-Tawny). It is poorly stratified except in certain beds and lenses of finer gravel and sand. Almost all of this gravel is finer than 3 centimeters in diameter and nothing larger than 10 centimeters in diameter was observed. The remaining 9 to 12 feet of gravel is finer, almost all smaller than 8 centimeters in diameter. It is colored light grayish-buff (19"i, Isabella Color) by the light-gray rocks and slight oxidation of the iron compounds. The beds are about 30 inches thick and dip at a low angle toward the north. Cross-bedding is abundant in some of the beds. It dips at an angle of about 40 degrees in any direction but mostly toward the southeast. A mechanical analysis of a sample of average material from this lower part of the section is shown in No. 6 of figure 53. The percentage of rounding is shown in No. 6 of figure 54. The lithology of the pebbles is shown in No. 6 of figure 55. An analysis of cobbles between 6 and 15 centimeters in diameter from the base of the pit shows the following kinds and shapes of rocks:

		Number of cobbles of each shape				
	Per Cent	A	a	C	r	R
Limestone and dolomite	71.3	60	77	50	100	
Granite	19.1	40	15			
Dolerite and basalt	9.6		8	50		

The gray shale in the gravel weathers so readily on exposure that it does not appear in its correct proportion in a lithologic analysis. Besides the shale, some of the granites and schists are weathered in the upper layer of coarse gravel. Unleached and unoxidized till is exposed in the base of the pit.

Relations of the Gravel

The Mankato terrace gravel was deposited in valleys in front of the melting Mankato glacier. Some of the valleys were developed by consequent streams on the surface of the freshly deposited Mankato drift, others were pre-Wisconsin valleys only partly filled by the Mankato till, and still others were a combination of both.

The relationship between the Mankato terrace gravel and other materials is determined primarily by the erosional and depositional history of the valleys.

The erosion which began dissecting the Kansan gumbotil plain during late Yarmouth time continued until the advance of the Iowan ice in practically all of the state except that covered by the Illinoian glacier. During this interval, the Loveland, deep valleys were developed in which gravel was deposited. In northwestern Iowa, where so much erosion took place, deposits of Loveland gravel can be differentiated in those valleys which do not contain Iowan or Mankato gravel.

The thin Iowan drift did not fill these valleys but only spread over the surface as a blanket. Thus during both the advance and retreat of that ice sheet these valleys carried the water and received the outwash gravel from the melting ice. When the Mankato glacier advanced over this area these unfilled valleys again received the drainage and outwash gravel from the melting ice.

In northwestern Iowa where gravels of these three ages have been deposited in the same valleys it is impossible to differentiate one from the other on the basis of characteristics. However, in northeastern Iowa the Loveland gravel has not been recognized but the characteristics of the Iowan and Mankato are quite similar. Since it is possible for three ages of gravel to occupy some of the valleys the basis for determining their age depends upon their relationship to the surrounding till and loess deposits.

In Hardin county, in the southeast quarter of section 19, Hardin township (T. 89 N., R. 20 W.), along the south side of the Iowa river, near the southeast corner of Iowa Falls, Wisconsin terrace gravel is exposed about 25 feet below the upland and 50 to 55 feet above the river. Along this same side of the river and a few hundred yards farther east similar gravel is exposed in a terrace 20 feet higher. Across the river to the north is another exposure in a terrace at the same elevation as the first, 50 to 55 feet, and another about 25 feet lower; all of the exposures have similar characteristics. No evidence would lead toward the conclusion that any of these terraces were other than of Mankato age.

In the first exposure mentioned, along the south side of the stream, the gravel is covered by the usual type of unstratified silty overburden. The gravel overlies both unleached and unoxidized till and unleached and oxidized loess. The fresh, dark-colored till is exposed in the east part of the pit but becomes thinner toward the west, where it is replaced by the loess. Two possible interpretations could be placed on the till and loess below the gravel. They could be Iowan till from which the weathered zone had been eroded away, overlying unleached Loveland loess, or Mankato till overlying Peorian loess. No evidence conflicts with the latter interpretation, but the former is difficult to support.

Another exposure of Mankato terrace gravel overlying unleached and unoxidized till is along the south side of the Des Moines river, in the northeast quarter of section 30, Jefferson township (T. 81 N., R. 25 W.), Polk county. Here 15 feet of gravel is exposed in a terrace 55 feet above the stream. It is covered by the usual unstratified silty overburden and overlies fresh till which can be definitely correlated with the Mankato till which forms the upland.

About 5 miles southeast of here, in the southeast quarter of section 36, Madison township (T. 81 N., R. 25 W.), Polk county, is another exposure of Mankato terrace gravel which overlies unaltered Mankato till.

Still another exposure in which the gravel can be observed overlying unaltered Mankato till is along the Raccoon river near the center of section 13, Jackson township (T. 83 N., R. 31 W.), Greene county, about 1/2 mile southwest of Jefferson. Here about 13 feet of gravel occurs in a terrace 20 feet above the level of the river.

In the gravel pits and prospect holes made by the Iowa State Highway Commission along the Des Moines river just east of Wallingford the fresh Mankato till has been observed below the gravel in many places and the exact relations of the two have been studied.

Within the Iowan drift area beyond the Mankato drift, in the central part of the north side of section 33, Eldora township (T. 87 N., R. 19 W.), Hardin county, just across the Iowa river east of Secor, the Mankato gravel is exposed in a terrace about 45 feet above the stream. Here the 10 feet of gravel lies below 4 to 5 feet of oxidized and leached loesslike silt. The gravel lies upon oxidized but in most places unleached loess. The relations are comparable to those described near Iowa Falls except that this is beyond the Mankato drift area and consequently no unaltered till occurs between the loess and gravel. There can be no doubt but that the loess is of Peorian age and the gravel outwash from the Mankato glacier.

Several other exposures of Mankato terrace gravel show relations similar to those just described. However, in most of the exposures the relations with the associated material other than the overburden are not visible. The overburden covering the Mankato terrace gravel is of practically no value in correlation, because it is a deposit which might be found above gravel of any age or type.

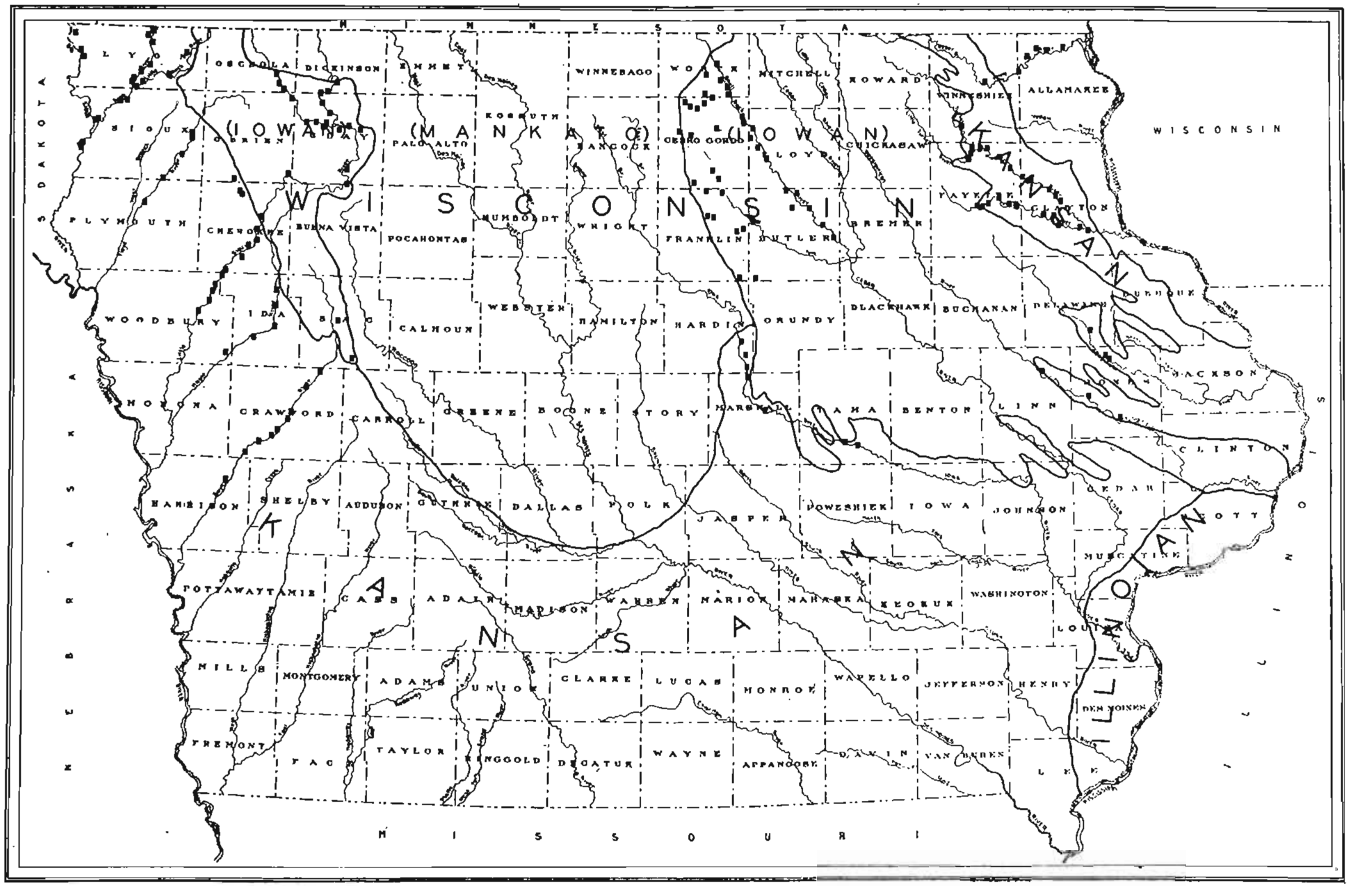
The Age of the Gravel

The relations of the deposits of Mankato terrace gravel within the Mankato drift area have been observed in several places. In these exposures the gravel overlies unaltered Mankato till so must have been deposited during the retreat of the glacier. Some gravel, no doubt, was deposited during the advance of the ice, but no such exposures were observed.

The Undifferentiated Terrace Gravel of Iowa

The Distribution of the Gravel

Terrace gravel is found in almost every valley in the northern part of Iowa and in many of those of southern Iowa. They represent three different periods of deposition — Loveland, Iowan, and Mankato. In some of the valleys the gravel of these different ages can be differentiated but in other valleys this has not been possible. In as much as it has not been possible to separate the gravel of the different ages; they will be described as undifferentiated gravel. The locations of these deposits are shown in figure 58.



MAP OF IOWA

FIG. 58. — The squares show the locations of exposures of undifferentiated terrace gravel.

The Characteristics of the Gravel

General Characteristics:

There are no distinct characteristics by which this gravel can be differentiated from the Loveland, Iowan, or Mankato.

The exposures along most of the streams which head up within the Iowan area have characteristics comparable to those of Iowan terrace gravel. However, even though Loveland gravel were present it would be very similar to the Iowan, because in those valleys where the age is known, the two cannot be differentiated on the basis of the characteristics of the material.

Those valleys whose heads are within the Mankato drift area more commonly have characteristics like the Mankato terrace gravel of the Mankato drift area. However, along Otter Creek and Little Rock River, both of which head up within the Mankato drift area, some of the exposures are definitely Iowan in age.

Although these generalizations can be made, the characteristics of the Loveland, Iowan, and Mankato terrace gravel deposits are so much alike that one would in most cases hesitate to attempt to separate one from the other if their relations to other materials were not known.

Characteristics of Exposures

A large exposure of this type of gravel is within the Iowan drift area just beyond the margin of the Mankato drift, in the southwest quarter of section 8, Lake township (T. 96 N., R. 21 W.), Cerro Gordo county, along the valley of Willow Creek, 1 mile east of Clear Lake. Here the gravel is exposed in a terrace which stands 25 feet above Willow Creek and has a width of about 1 mile. The gravel has been removed to a depth of 40 feet, the lower 25 feet from below the water standing in the pit.

The overburden is unstratified sandy silt from 2 1/2 to 4 feet thick and contains small pebbles in the lower part. Leaching has removed the carbonates from its entire thickness but the underlying gravel and the narrow transition zone separating the two are highly calcareous. Oxidation of iron compounds colors the overburden and the transition zone to medium chocolate-brown (17"I, Wood-Brown) but the addition of humus colors the upper part of the overburden darker brown (13" "i, Benzo-Brown). The gravel below the transition zone is gray-buff (17" 'b, Avellaneous) except for a few thin beds and lenses which are colored rusty-brown (15'i, Ochraceous-Tawny) by iron oxide. Weathering has disintegrated a few of the coarse crystalline rocks, and the large amount of shale falls to pieces soon after exposure to the atmosphere. The gravel exposed above the water is only fairly well sorted but well stratified in almost horizontal beds from 6 to 20 inches thick, within which is much cross-bedding and lens-and-pocket structure. The material is primarily sand and fine gravel (see figure 59). None of the stratified material is larger than

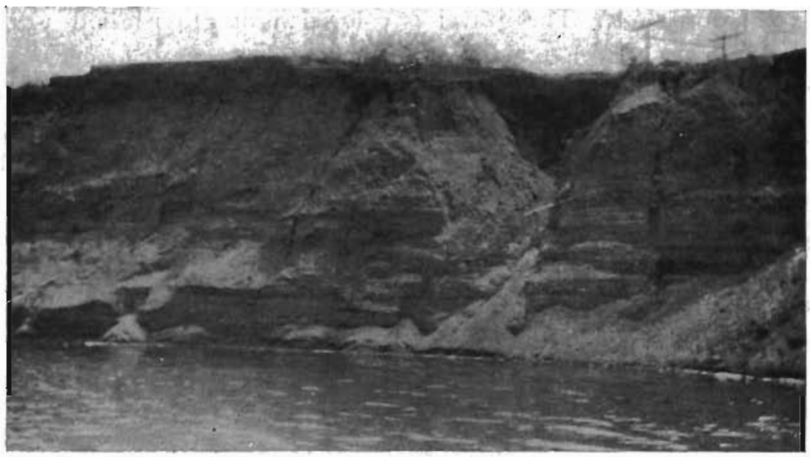


FIG. 59. — Undifferentiated terrace gravel exposed along Willow Creek near the margin of the Mankato drift, Cerro Gordo county.

10 centimeters in diameter and more than 90 per cent of it is below 3 centimeters in diameter. In this large pit only three boulders were observed but no doubt several had been dumped back into the pit and are now covered by water and rejected fine material. The percentage of each size grade, determined by a mechanical analysis, is shown in No. 7 of figure 53. The percentage of rounding of each size grade is shown in No. 7 of figure 54. A pebble count shows the percentage of the different kinds of rock as given in No. 7 of figure 55.

There is another large pit in Cerro Gordo county in the northeast part of Mason City, Mason township (T. 96 N., R. 20 W.), along the west side of Lime Creek. Here the terrace gravel is exposed in an extensive terrace which stands about 28 feet above the river. The gravel has been removed from an area which covers about 1/2 square mile, and to a depth of about 25 feet, which is partly below the water standing in the base of the pit.

The overburden is unstratified silt with an average thickness of about 2 feet, containing pebbles smaller than 3 centimeters in diameter scattered throughout its entire thickness but in increasing numbers toward the base. It is separated from the underlying gravel by a transition zone only a few inches thick. Leaching has removed the carbonates from all of the overburden and the upper 3 to 9 inches of the gravel. Oxidation and humus color the upper 12 to 16 inches of the overburden dark chocolate-brown (13" "i, Benzo-Brown) while that below and the transitional zone are colored (17" ', Wood-Brown) by oxidation alone. The gravel is colored light grayish-buff (19"i, Isabella Color) by iron oxide. Weathering has disintegrated some of the igneous rocks and the gray shale falls to pieces soon after exposure to the atmosphere. Aside from some of the coarsest gravel which forms a poorly stratified mass, the gravel is all stratified in horizontal beds within which there is cross-bedding and lens-and-pocket structures. Most of the material is coarse sand and fine gravel with only a narrow size range. Other than one boulder, nothing larger than 13 centimeters in diameter was observed and only a small percentage is larger than 3 centimeters in diameter. Of this coarse material, about 85 per cent is limestone plates of which about 65 per cent is sub-angular, and the remainder is about equally divided between the angular and curvilinear shapes. A mechanical analysis of average material is shown in No. 8 of figure 53. The percentage of rounding is shown in No. 8 of figure 54. The rock content of pebbles is shown in No. 8 of figure 55. Water stands in the base of this pit; thus no underlying material is exposed.

This same type of gravel has been removed from this terrace at many locations in the east side of Mason City and from along the valley of Lime Creek both to the north and south. The exposure just described is near the union of Lime Creek and Willow Creek, both of which carried vast amounts of sand and gravel from the melting Mankato glacier. This deposit is not more than 17 miles from the Mankato drift margin by either river course.

In Butler county, in the southeast quarter of the northwest quarter of section 35, Butler township (T. 92 N., R. 15 W.), 1 mile north of Shellrock, gravel is exposed in a terrace which stands 25 feet above the stream. The gravel has been removed to a depth of 60 feet but what occurs below that depth is not known; it is probably bedrock.

The overburden is a 2-foot bed of unstratified silt with small pebbles scattered sparsely throughout its thickness. The upper 2 feet of gravel is colored by iron oxide to almost the same light-brown color as the lower part of the overburden but below this it is distinctly fresh; the color is only slightly darker gray than the limestone which makes up a high percentage of the material. The gravel is leached of its carbonates in only the upper few inches. It is well stratified in horizontal beds generally between 6 and 18 inches thick within which there are cross-bedding, lens, and pocket structures. The material is chiefly coarse sand and fine gravel, and extremes in either coarser or finer material are rare. An analysis of the material as it comes from the pit shows the following: sand, 82 per cent; gravel, 1 to 2 centimeters in diameter, 7 per cent; gravel, 2 to 5 centimeters in diameter, 11 per cent; and a small amount larger than 5 centimeters in diameter. The percentage of each size grade, determined by a mechanical analysis of a sample of average gravel, is shown in No. 9 of figure 53. The percentage of rounding is shown in No. 9 of figure 55.

Along this part of the stream some of the terrace gravel differs from that described. Some consist almost entirely of sand within which the coarse material is almost all platy limestone, while others contain a high percentage of pebbles between 1 and 5 centimeters in diameter interstratified with the sand and fine gravel as well as being scattered throughout the finer gravel. One of these pits from which the gravel has been removed over a wide area is in the northwest quarter of section 1, Jackson township (T. 92 N., R. 16 W.), Butler county, about 2 miles north of Clarksville. Here a high percentage of the gravel is larger than 3 centimeters in diameter and is almost all limestone much of which is platy. The terrace stands 26 feet above the Shellrock river.

Undifferentiated terrace gravel deposits similar to those described in northeastern Iowa are exposed in many places in northwestern Iowa along those streams which carried the water from the melting Mankato ice. Along Rock River there are many exposures; some of the best and most abundant are near Doon. Here the town is built on a wide gravel terrace which is about 28 feet above the stream. Gravel is exposed in several pits in and near Doon; the best exposure is in the northwest part of town. This is in the northeast quarter of section 26, Doon township (T. 98 N., R. 46 W.), Lyon county.

The overburden is about 3 feet thick. It consists of unstratified silt which contains some small pebbles scattered throughout the lower

1 foot. It grades into the underlying gravel through a narrow transition zone. Oxidation of the iron compounds colors the overburden to the usual shade of brown. The gravel is gray (17"b, Cinnamon-Buff) except for one bed about 6 inches thick at a depth of 11 feet, which is partly colored black by manganese dioxide and the remainder colored rusty-brown (15'i, Ochraceous-Tawny) by iron oxide. These oxides coat the grains and in some places form a weak cement. Leaching has removed the carbonates from all of the overburden but the underlying gravel is highly calcareous. Some of the crystalline rocks such as schists and granites are weathered so that they crumble along their margins. Prospects show the gravel to extend 16 feet below the bottom of the pit, making its total thickness 35 feet. The gravel overlies unleached and unoxidized till. All of the stratification and cross-bedding dip in a general southerly direction. A mechanical analysis of the average gravel of this section is shown in No. 10 of figure 53. The percentage of rounding is shown in No. 10 of figure 54. The lithology is shown in No. 10 of figure 55.

Another exposure along the Rock river is only a few miles from its confluence with the Big Sioux river. It is near the center of section 17, Garfield township (T. 96 N., R. 47 W.), Sioux county, about 1 mile east of Hudson, South Dakota. Here the gravel is exposed in a gravel pit in the terrace which stands 35 feet above the level of the

FIG. 60. — Undifferentiated terrace gravel exposed in a gravel pit about 1 mile east of Hudson, South Dakota. The terrace which stands about 35 feet above Rock River can be seen in the background.

stream (see figure 60). As shown in Plate I of Carman's report,[58] the gravel terrace here is as much as 4 miles wide covering all of the divide between the Rock and the Big Sioux river. The grader ditches along the roadsides have exposed this gravel below the thin overburden in many places. The gravel is exposed in a pit to a depth of 18 feet.

The overburden ranges from a few inches to 2 feet in thickness. It is fine unstratified silt, leached of its carbonates and colored dark chocolate-brown (13" "i, Benzo-Brown) by humus and oxidation of the iron compounds. Only a narrow gradational zone separates the gravel from the overburden. The gravel ranges in color from buffish-gray (19"i, Isabella Color) to dark brownish-red (11'm, Chestnut-Brown), and some is colored black by manganese dioxide. Secondary lime cements the gravel into a weakly coherent conglomerate in the upper 4 feet. Most of the gravel is well sorted and stratified. A few almost horizontal beds of coarse gravel are continuous throughout the pit but cross-bedding, lenses, and pockets are common. The gravel beds all dip toward the southeast and some cross-bedding dips as much as 50 degrees. An average of the material is represented in the mechanical analysis of No. 11 of figure 53. The shape of each size is shown in No. 11 of figure 54. The lithology of pebbles is given in No. 11 of figure 55. At the base of the 18 feet of gravel is a 2-foot layer of blue-gray, unleached and unoxidized, fossiliferous silt, which is continuous throughout the bottom of the pit. It includes thin stringers of gravel and a few scattered pebbles. This is underlain by highly calcareous gravel similar to that above the silt.

The Little Sioux valley north of Spencer, in Clay county, is bordered by what appear to be Mankato outwash terraces throughout most of its course. These have been described by Carman [59] as follows:

"This gravel area extends as a terrace down the Little Sioux valley to the county line and south to Spencer. At Milford the terrace is 70 to 80 feet above the river, but it declines to 50 feet at the county line, and to 20 feet at Spencer, as shown in figure 19. In this distance the river falls 70 feet while the terrace drops about 120 feet. The fall of the terrace measured along the center line of the filled belt is 6⅔ feet per mile, and the fall of the river along this same line is about four feet per mile. The fall

58 Carman, J. Ernest, Further Studies on the Pleistocene Geology of Northwestern Iowa: Iowa Geol. Survey, Vol. XXXV, 1931.
59 Carman, J. Ernest, Further Studies on the Pleistocene Geology of Northwestern Iowa: Iowa Geol. Survey, Vol. XXXV, p. 150, 1929.

of the river from west of Milford to Spencer, measured along its winding course, is 2⅔ feet per mile."

One of the exposures along this terrace is in the southwest quarter of section 21, Lakeville township (T. 99 N., R. 37 W.), Dickinson county, about 5 miles northwest of Milford. The gravel here is exposed to a depth of 15 feet in the outwash terrace which stands 70 feet above the river.

The overburden is unstratified loesslike silt; it contains a few scattered pebbles, and grades into the underlying gravel through a narrow transitional zone. It is less than 2 feet thick, leached of its carbonates, and colored to the usual color by iron oxide and humus. None of the gravel is leached below the transitional zone and near the base of the pit some of it is cemented by secondary lime. Iron oxide which occurs in thin belts which are seldom more than 1/2 inch thick, colors much of the gravel rusty-brown (15'i, Ochraceous-Tawny) within the upper 8 feet of the exposure. Some of the igneous rocks are weathered so that they crumble along their margins, and the gray shale falls to pieces soon after exposure to the atmosphere. A mechanical analysis of average material is shown in No. 12 of figure 53. The percentage of rounding is shown in No. 12 of figure 54. An analysis of pebbles is shown in No. 12 of figure 55.

Other exposures similar to this occur along the terrace between here and Spencer. The greatest difference is that they show more uniform structures farther from the Mankato drift margin.

In Lyon county, in the west central part of section 33, Dale township (T. 98 N., R. 43 W.), there is a group of exposures of gravel in a terrace about 25 feet above the level of the stream.

The coloration of the gravel by oxidation varies from gray (17'' 'b, Cinnamon-Buff) to medium-buff (15'i, Ochraceous-Tawny). The differences in color are generally within the lenses, pockets, or thin beds of material which are either finer or coarser than the surrounding material. None of the gravel is leached below the 7 feet of overburden and the only disintegration by weathering is within a few coarse crystalline boulders. The upper 4 feet of the 10 feet of gravel exposed is finer than the gravel of the lower 6 feet, but both show practically the same structure. The gravel is well stratified in horizontal beds about 14 inches thick, within which cross-bedding is common, dipping toward the southwest in places at an angle of as much as 45 degrees.

In these exposures there is very little coarse material; only two boulders were observed and both were smaller than 30 centimeters in diameter. Practically all of the gravel is smaller than 4 centimeters in diameter. The gravel is overlain by about 7 feet of typical Peorian loess, and the two are separated by a sharp but irregular surface. The loess is colored to light chocolate-brown in the upper soil zone by iron oxide and humus, below which it is the usual buff color (17" 'd, Vinaceous-Buff) of loess. Leaching has removed the carbonates to a depth of 4 1/2 feet, below which there are many lime concretions.

In northeastern Iowa there are many exposures of gravel beyond the Iowan drift area which are covered by Peorian loess as the exposure just described in northwestern Iowa. They probably represent Iowan deposits but they could be either Loveland, Iowan, or both.

The Relations of the Gravel

The undifferentiated terrace deposits include gravel of three distinct ages. They are the Loveland interglacial gravel, the Iowan glacial outwash gravel, and the Mankato glacial outwash gravel. The relations of each of these to associated materials have been discussed in this report for the areas in which only that gravel occupies the valleys. However, along certain valleys where gravel of more than one age was probably deposited, it is impossible to differentiate the gravel of one age from that of another.

The Loveland gravel was deposited in the valleys cut in the Kansan drift and older deposits during the Loveland interval. Thus their age is post-Kansan gumbotil erosion and pre-Wisconsin.

The Iowan ice advanced over part of this eroded Kansan drift surface which has Loveland gravel deposited along its valleys. The thin Iowan drift did not fill these valleys and level the surface but spread over the irregularly eroded surface like a blanket. The water from the melting ice carried gravel that was deposited along these valleys. In the region covered by Iowan drift which partially filled the valleys, the Iowan terrace gravel was deposited above the Iowan drift. Within the Kansan drift area, beyond the Iowan margin, the Iowan terrace gravel must have been deposited above the Loveland gravel. However, the large volume of water from the melting Iowan ice probably removed and reworked much of the Loveland. In either case gravel of both ages would be included in the deposits. Even if the Iowan had not reworked the Loveland, the two were so close to the same age that one would not expect to observe a weathered zone between them. Peorian loess was spread widely over this state after Iowan time and before Mankato time.

Some of these valleys extend from the Kansan drift area, across the Iowan and into the Mankato, but where the Iowan is missing the valleys extend from the Kansan area directly into the Mankato. The valleys whose heads are within the region covered by the Mankato glacier received outwash gravel as the ice melted. Where the streams flowed from the Mankato drift area across the Iowan drift area and out into the Kansan drift area, they either deposited Mankato outwash gravel over the older deposits within the valley or reworked and redeposited them all as a single unit. Where the streams flowed directly from the Wisconsin drift region into the Kansan, no Iowan gravel could be included.

No contact between gravel of different ages was observed in any exposure. This would suggest that the older deposits were reworked and redeposited by the water transporting the younger gravel. However, the terraces are not commonly more than 35 feet above the stream and the contacts with older gravel might be below the level of the ground-water surface. However, it seems probable that they were reworked and incorporated into a single deposit during deposition of the younger gravels, since in some exposures within the Iowan area where the gravel has been removed or prospected to the bedrock surface there is no indication of more than one deposit.

THE ORIGIN OF THE PLEISTOCENE GRAVEL

As the glaciers moved outward from their centers of dispersion they removed vast amounts of detrital material from the surfaces over which they passed and transported it to where it was later deposited as drift as the ice melted. The drift includes heterogeneous material — till — let down in situ from its transported position within the glacier as the ice melted, and stratified sand and gravel transported and deposited by streams flowing from the melting ice. As the ice melted any concentrations of water, forming streams, were able to acquire a ready load either from the glacier itself or from the freshly deposited drift surface in front of the melting ice margin. These streams must have transported a maximum load at all times, and any change in conditions along their course caused a change of load which resulted in deposition from place to place. Sand and gravel deposited on the older drift surface and later overridden by the advancing glacier were in many cases picked up and reincorporated in the younger glacier's load. The sand and gravel deposited beyond the active ice margin, as the ice front was stationary or retreating, remained undisturbed where it was deposited.

The following distinct types of gravel deposits have been observed: (1) irregular masses — "gravel boulders" — seldom more than 15 feet in average diameter were observed at several locations in Iowa. In most places they are in the lower part of the till sheet (see figure 61). In these gravel boulders the bedding planes are inclined at angles sometimes greater than the angle of repose, and could not represent original deposition in place. In some of these masses the lithology is similar to that of the surrounding till but in others it is distinctly different. While some are unleached masses within unaltered till, others are leached masses within unaltered till. All of the characteristics indicate that these are fragments of larger deposits of gravel which, while in a frozen condition, were broken up by the advancing glacier; and the fragments were incorporated as boulders in the till. (2) Irregular masses of gravel sometimes more than 100 feet in horizontal diameter and more than 40 feet thick are inclosed within the till. They are generally within a few feet of the upper till surface but may be

FIG. 61. — Sand and gravel boulders in the Kansan drift in Lucas county.

at any depth (see figure 51). Although in a few exposures the bedding planes are tilted, they are generally approximately horizontal like those of original deposition. In some exposures there is a distinct break between the gravel and surrounding till while in others the two are separated by a gravelly till transitional zone. The lithology is similar to that of the till and both clay-balls and masses of till are often present. If these gravel masses are within the altered zone of the including till, their alteration is comparable to that within the till. However, if they are within unaltered till they also are unaltered except for oxidation. In none of those exposures observed were the upper beds plowed up by an overriding ice sheet which deposited the overlying till. (3) At several locations lenses and thin beds of sand and gravel are buried within the till. Like the masses described under No. 2, these appear to represent deposition in place and show no signs of distortion of the beds by a readvance of the ice. In places there are as many as ten of these layers or lenses of sand and gravel separated by thin layers of till. Along the margins, some of these lenses feather out in a delicate manner. Their alteration is in harmony with that of the surrounding till. (4) One of the most common types of gravel is irregular masses included within but at the upper surface of the including till sheet. The gravel of these masses is generally in the position of original deposition but in some exposures it appears to have been tilted since deposition. All of the characteristics and relations of these masses are the same as those of No. 2 except that these are not covered by till of the same age. In several exposures which have been overridden by a younger ice sheet, the surface gravel is plowed up and the beds are folded by the overriding ice. The largest mass of gravel of this type observed is 55 feet thick and more than 75 yards in average horizontal diameter (see figure 21). (5) Kames, sometimes elongate and eskerlike, and masses of gravel in kamelike hills have been observed in many places, especially on the surface of the Iowan and Mankato drifts. The gravel of these masses may be similar to that of masses described in Nos. 2 and 4, or the beds may show slumping along the margins of the deposit. The bases of these deposits may be on the upper drift surface but generally extend several feet into the till. (6) In some places the deposits of outwash gravel have been observed on the surface of the drift. These may be either in depressions or on the flat surface. However, none of them show slumping or tilting of beds subsequent to deposition. (7) Distinctly different from the types of gravel described are those which occur as outwash terraces along streams. These terraces occur either along the valleys which were developed before the advance of the glacier or along consequent streams on the freshly deposited drift surface. This material is well stratified, generally in horizontal beds. In most of the exposures the base of the gravel is below the ground water surface and the underlying material is concealed, but in those where it is exposed the gravel generally overlies till of the same age. The gravel is overlain by unstratified silt or loess of practically the same age as the gravel and in some exposures the overburden is interbedded with the gravel showing that they were being deposited at the same time. In no exposure was the gravel overlain by till of the same age. (8) In extinct Lake Calvin, lacustrine deposits form terraces along the streams which have cut their valleys in these lake beds. The lacustrine beds consist of well-stratified sand and silt which were deposited under quiet water conditions. (9) Loveland interglacial gravel forms terraces along some of the valleys of southern and western

Iowa. These materials represent fluvial deposits along streams. In those exposures where the base of the gravel is exposed it overlies oxidized and unleached Kansan till. These gravel deposits are covered by Peorian loess in most of the exposures and in one place the loess and gravel are interbedded. In a discussion of the origin of these nine types of deposits several hypotheses will be introduced. The first six types of gravel will be discussed together and the last three types will be taken up individually.

In discussing the first six types of gravel deposits, the following hypotheses will be considered: (1) They are outwash and kamelike masses deposited on the surface of the drift at the margin of the retreating glacier. Some of them were deposited as outwash in depressions while others were deposited on the flat drift surface. (2) They are outwash and kamelike masses deposited as in No. 1 and later buried by till which was deposited by a readvance of the ice front. (3) They are older gravel deposits on the surface over which the glacier advanced, picked up in a frozen condition and later deposited as gravel boulders, within the till. (4) They are gravel deposited in front of the advancing glacier, then picked up and deposited as gravel boulders, within the till. (5) They are gravel deposited in great moulins, tunnels, and other cavities within an active glacier and later let down to their present position as the ice melted. (6) They are deposition in great moulins, tunnels, and other cavities within stagnated ice, either let down to their present position as the ice melted or originally deposited in their present positions. No one of the preceding hypotheses is capable of explaining the origin of each type of gravel nor are all the types of gravel limited to a single hypothesis to the exclusion of the others.

Hypothesis No. 1 is most commonly used to explain the origin of those gravels, at and near the till surface, deposited during glacial retreat. The streams flowing through tunnels in the glacier were subjected to the pressure of the surrounding active ice and consequently had a greater transporting power than they had when they emerged into the open channels beyond the margin; thus the streams were forced to deposit part of their load as soon as they left the glacial tunnels. If the till surface was flat, the gravel was deposited as a kamelike mound on its surface, but if irregular, the gravel was deposited in a depression and may or may not have been piled up in kamelike mounds. These depressions were the result either of uneven distribution of the till or of the melting of a block of ice which had been deposited within the till. The only notable difference between those deposits in depressions and those on a flat surface is their present position either entirely above the till surface, partly below the till surface, or entirely below the till surface. If an appreciable amount of gravel is deposited on the uniform surface it will form a kamelike mound. If the gravel is deposited within a depression it may be partly or completely below the till surface as an irregular mass within the till, or after the depression is filled, further deposition might form a kamelike feature. In this case the base of the kame would be within the till. This hypothesis alone cannot explain pockets or lenses of gravel buried within a single till sheet.

The second hypothesis is the same as the first except that it allows also a later readvance of the melting glacier, its deposition covering the gravel with till. This would explain the origin of those masses buried within the till sheet.

These hypotheses together can explain outwash and kame deposits on the till surface and irregular masses of gravel within the till, both at its surface and completely buried. Although hypotheses Nos. 1 and 2 can explain the deposition of each type of gravel within the till, except the gravel boulders, it is difficult to explain certain features such as the deposition of thin beds and lenses of sand and gravel interbedded with the till. If a readvance of the ice is necessary to explain the deposition of the till, there must have been many minor rapid advances and retreats of the retreating margin. Furthermore, it is inconceivable that the glacier could pass over these freshly deposited sands and gravels and not disturb the structure or remove part of the deposit. In several exposures of Kansan gravel, the Iowan glacier which advanced over them has removed the gravel from the surface and folded some of the beds. Assuming deposition within stagnated ice, interbedded till and gravel could be deposited without minor advances and retreats of the ice margin.

The third hypothesis explains the origin of some of the irregular masses of gravel buried within the till which have a different lithology than the till and may be leached although within unaltered till. These represent older gravel deposits occupying a position on the drift surface over which the glacier advanced. Large fragments of this deposit were picked up, transported, and deposited in a frozen condition as "gravel boulders." These gravel boulders range in size from a few inches to more than 25 feet in diameter. Gravel of this type — even though deposited originally in horizontal beds — may, following transportation, be redeposited with the beds tilted in any position. Having been picked up from the surface over which the ice advanced, and transported only a short distance, it would commonly occupy a position in the lower part of the glacial load and consequently be deposited within the lower part of the till sheet.

The fourth hypothesis differs from the third only in that it postulates that the gravel was deposited originally at the margin of the advancing glacier. The lithology of this gravel would be the same as that of the enclosing till, and the till and gravel would have undergone comparable alteration. This explains the "gravel boulders" within the till which cannot be explained by the third hypothesis.

The fifth hypothesis would have the gravel deposited in great moulins, tunnels, or other cavities on or within the ice. As the ice melted, these deposits were let down along with the rest of the glacial load. If they had been deposited high within the glacier, above the glacial load, they would be let down on the surface of the till. If they were deposited originally near the base of the glacial load they would form a mass near the base of the till. In all cases their position within the till would be determined by their position of deposition within the ice in respect to the glacial load. During lowering of, or during further transportation after deposition, the mass might be tilted in a plane different from that of original deposition.

Carman discusses this hypothesis as explaining one of the possible origins of certain gravel deposits of northwestern Iowa.[60] However, he states: "The chances of such deposits being formed were probably greatest near the edge of the glacier where the ice was thin, and where holes could extend even through to the ground beneath." From this statement it seems that he had difficulty in conceiving deposition to any extent within the active ice and probably thought of the thin ice near the margin as more or less stagnated and inactive.

The sixth hypothesis differs from the fifth only in that it assumes deposition within inactive "stagnated" ice along the margin of the glacier.

60 Carman, J. Ernest, Further Studies on the Pleistocene Geology of Northwestern Iowa: Iowa Geol. Survey, Vol. XXXV, p. 101, 1931.

As a result of studies in the Connecticut valley, Flint [61] explained the origin of the terraces on the basis of stagnation of the Wisconsin glacier. In a more recent report he describes evidence of stagnation in northwestern Illinois.[62] White [63] has described glacial stagnation in Ohio. In Europe stagnation has also been recognized by various students, including Koernke, B.,[64] Von Bülow, K.,[65] and Woldstedt, P.[66] Andersen [67] in a recent paper discusses the melting of the last ice sheet in Denmark and the origin of certain glaciofluvial deposits. He accounts for the origin of the glaciofluvial deposits on the basis of a stagnated ice border around the active ice center. Within this stagnated ice, tunnels and cavities would remain open, unaffected by ice movement.

In discussing the hypotheses for the origin of the glaciofluvial deposits in Iowa, one should not omit the possibilities of deposition within a stagnated ice sheet. The greatest difficulty in explaining gravel deposition by the fifth hypothesis (within moulins, tunnels, and cavities within the active glacier) is overcome in the sixth hypothesis, in which the ice is stagnant. Since deposition by both hypotheses is in the same manner, the merits of one can be brought out along with a discussion of the difficulties of the other.

Within an active ice sheet, the internal pressure-producing movement would operate against least resistance, tending to close any openings which might develop. But assuming that some streams were able to maintain channels, the pressure and likewise the transporting power would be so great that deposition of sand and gravel could not take place along the stream courses within active ice. However, if streams of this type existed, the release of pressure at the margin of the active ice would cause decrease in transporting power; thus gravel would be deposited outside this active ice margin. This gravel would be included under the first hypothesis. No doubt streams flowed on

61 Flint, R. F., Pleistocene Terraces of the Lower Connecticut Valley: Geol. Soc. America, Bull. 39, pp. 955-984, 1928. The Stagnation and Dissipation of the Last Ice Sheet: Geog. Review, Vol. XIX, pp. 256-289, 1929. The Glacial Geology of Connecticut: Conn. Geol. and Nat. Hist. Survey Bull., Vol. XLVII, 1930.

62 Flint, R. F., Glaciation in Northwestern Illinois: Am. Jour. Science, Vol. XXI, pp. 244-439, 1931.

63 White, George W., An Area of Glacier Stagnation in Ohio: Jour. Geol., Vol. XL, pp. 238-258, 1932.

64 Koernke, B., Letztglazialer Eisabbau und Fluszgeschichte im Nördlichen Ostpreuszen und sienen Nachbargebieten: Zeitschrift der Deutschen Geologischen Gesellschaft, Vol. 82, pp. 14-32, 1930.

65 Von Bülow, K., Die Rolle der Toteisbildung beim letzten Eisrüchkzug in Norddeutschland: Zeitschrift der Deutsch. Geol. Gessel., Monatsber., Vol. 79, pp. 273-283, 1927.

66 Woldstedt, P., Das Eiszeitalter: Stuttgart, 1929.

67 Andersen, S. A., The Waning of the Last Continental Glacier in Denmark as Illustrated by Varved Clay and Eskers: Jour. Geol., Vol. XXXIX, pp. 609-624, 1931.

and near the surface of the glacier; but even if they found an available load, and deposited gravel along their courses, it would be let down on top of the till and could not form masses within the till without another glacial advance to deposit a layer of till over the gravel.

If it is assumed that the margin of the ice was stagnant, the pressure tending to close any openings within the ice would be relatively small, and moulins, channels, and cavities once developed could exist. Gravel deposited within this stagnant ice would be let down along with the rest of the glacial load as the ice melted, its final position within or on the till depending upon its position at the time of deposition in respect to the glacial load. If deposited above the glacial load it would be let down on the surface of the till but if within the load, it would be included within the till.

From the preceding discussion of the six hypotheses, it is evident that no one can explain the origin of all types of upland gravel.

The first hypothesis explains outwash gravel with no difficulty and masses of gravel within but at the surface of the till can be explained if one assumes a depression in the surface of the till into which the gravel was deposited. The second hypothesis explains those deposits buried within the till, their deposition originally being on the surface of the till then later buried by a readvance of the ice. The third and fourth hypotheses explain "gravel boulders" picked up from the surface over which the ice advanced and deposited within the till. The fifth hypothesis seems impossible. The sixth hypothesis explains each type of gravel except those explained by the third and fourth hypotheses. In fact, deposition by this hypothesis eliminates difficulties involved in the explanation by the other hypotheses.

The glacial outwash terrace deposits in Iowa were deposited during the Iowan and Mankato glacial time. The Iowan glacier advanced over the freshly eroded surface developed on the Kansan drift plain during the Loveland interval. The thin Iowan drift sheet deposited within the area covered by the Iowan ice did not fill these valleys but spread over the surface like a blanket. The streams flowing from the melting ice followed these partially filled valleys. Since the valleys were not filled by Iowan deposition, the Mankato glacier also advanced over an irregular surface upon which well-developed drainage lines still existed. Within the Iowan area the valleys were partly filled by Iowan drift but beyond the Iowan margin no drift was deposited in these pre-Iowan valleys. The drift sheet deposited by the Mankato ice was thicker than that deposited by the Iowan and filled many of the more shallow valleys, but some of the larger ones remained open. Where unfilled by Mankato drift, the streams followed these previously developed drainage lines, but in other places the streams flowed in broad, shallow valleys developed upon the newly deposited irregular drift surface.

The streams flowing through the glacier were transporting a maximum load. As they flowed out of the ice, the release of pressure and increased friction decreased the velocity, which necessitated the deposition of the coarsest material. This did not mark the final deposition, because as the increased volumes of water flowed down their restricted valleys all of the processes of transportation and deposition were active. The fluctuation of the water supply, the wear on the load, and all the variations in the channel brought about continuous change in load. The only coarse material transported directly for any long distance was that carried by the floating cakes of ice. Other coarse material was moved by rolling or saltation. Aside from the glacier the only other source of material was in the valley itself, which in some cases afforded abundant material. As the glaciers advanced, they picked up the loose material from the surface and later deposited it as till. The streams flowing over this till surface found only a small amount of gravel and sand which had not been reduced to fine dimensions during transportation within the ice. The softer material, including limestone, had suffered most. Thus limestone fragments in the till were only moderately abundant in relation to the other fragments which had been transported greater distances. The wear of the stream upon its load destroyed the less resistant material most readily just as did the glacier. This also decreased the percentage of limestone in relation to the other rocks.

A study of exposures of gravel shows that some contain no limestone while others contain a high percentage. Some of the limestone was removed by leaching but extreme variations of this type could be based only upon the type of material deposited. Furthermore, if an abundance of limestone had been deposited in those exposures in which it is now absent, and was removed by leaching, the contraction of the beds resulting from the removal would destroy the perfect stratification often observed. As previously stated, the gravel is from only two sources: 1) that carried out from the glaciers by the waters from the melting ice, 2) that removed from the valleys through which the streams flowed. The kinds of material supplied from the glacier should be relatively constant. Likewise, where the stream flows over the till the gravel obtained should be similar to that coming from the glacier; but aside from the till the streams sometimes encountered resistant ridges of limestone along their courses.

Those exposures of gravel showing an abundance of limestone are usually located along the valley near exposures of limestone along the valley wall. This leads to the conclusion that the gravel along the valleys is not derived directly from the glacier; much of it comes from local sources. Also, in most cases the limestone material which forms the terraces is like that of the limestone exposures nearby and the angular shape shows that it has not been transported far by the stream.

Most of the valley outwash terraces represent glaciofluvial deposition in the bottom of the valley filling it to the level of the present terraces, which have been partly removed by the subsequent erosion of streams which incised their valleys in these flats. The surface of these old plains is marked only by the terraces which stand above the streams. However, in a few places along some of the deeper, more constricted valleys, terraces occur high up along the valley wall and sometimes with their upper surfaces almost at the level of the upland. In those exposures where the underlying material was observed the gravel of the terrace overlies fresh Mankato till or Peorian loess. These terraces are of two possible origins: they represent either outwash terrace gravel that filled the valley to this height and later was all removed except the narrow patches along the valley wall, or outwash gravel deposited along the margin of the valley after the ice had melted from the higher land but still remained in the valleys. In the latter case the ice would form one side of the valley and the major valley wall the other side. There seems to be little question as to which is the more logical assumption. These terraces stand higher than those in the broad open valleys along the same stream, suggesting deposition of gravel to greater depths within this part of the valley. Such deposition is difficult to explain. Even if this valley was so constricted that it could not accommodate all of the drainage but backed the water up to this level, the height of the water in comparison to what it would be on either side would make this an eroding rather than a depositing stream. Furthermore, there are no comparable terraces along the broader parts of these valleys. There are no serious objections to the hypothesis that these terraces along the sides of the valleys were formed before the ice filling the valley had melted. Most of the outwash terraces are not of this type but represent glaciofluvial deposition in the bottoms of the open valleys in front of the retreating glacier.

The Illinoian glacier advanced into the southeastern part of Iowa, damming the Mississippi river and several smaller streams within this part of the state. This ice dam forced the Mississippi to follow a channel marginal to the ice, and 10 to 30 miles west of its present course. The waters of the Mississippi and the smaller streams across whose channels it had flowed — the Maquoketa and Wapsipinicon — all flower into the Cedar river at Moscow. As the valley of the Iowa-Cedar river also was blocked by the Illinoian ice sheet, the valley formed a great basin in which the now extinct Lake Calvin was formed. Water flowed into this basin from the melting Illinoian glacier and from all of the previously mentioned streams — the Mississippi, Maquoketa, Wapsipinicon, Cedar, and Iowa. The water level was raised in this basin until it reached the height of the now abandoned outlet southwest of Columbus Junction.

Each source of water supply for this lake carried in and deposited sand and silt in the quiet water of the basin. Three terraces have been formed in the basin as shown in figure 29: the high, intermediate, and low. After extensive study of this lake basin, Schoewe [68] concluded that the two upper terraces are lacustrine deposits of simultaneous origin and the lower terrace is glaciofluvial outwash from the melting Iowan glacier.

Except in a few places, the high terrace is confined to the Iowa river valley arm of the lake basin and the intermediate terrace to the Cedar river arm. This difference in elevation is explained on the basis of a greater supply of sediment in the Iowa river arm than in the Cedar river arm in relation to the size of the valley basins. Although the Cedar river valley was much wider than the Iowa river valley, the latter had more large tributaries, which brought in material and thus filled the Iowa river valley to a higher level than the Cedar river valley. The only high terrace remnants within the Cedar river arm are within the main tributaries, which were bringing in considerable material.

The lower terrace consists of coarser material than the two upper

68 Schoewe, Walter H., The Origin and History of Extinct Lake Calvin: Iowa Geol. Survey, Vol. XXIX, pp. 49-222, 1924.

terraces. Instead of having a structure characteristic of quiet water lacustrine deposition, it has that of river terrace deposition, including cross-bedding and lens-and-pocket structures. The origin of this terrace can be traced directly to glaciofluvial outwash from the melting Iowan glacier.

The Loveland gravel is within the valleys cut in the Kansan drift sheet during the Loveland interval. Where differentiated, the gravel is within valleys entirely within the Kansan drift area and could not represent outwash from the younger Iowan or Mankato glaciers. The only possible source of this gravel is the erosion of the drift. It is believed that as erosion continued, the finer material was carried out, leaving the coarser material concentrated along the valleys. However, the thick deposits in some of the valleys — especially small valleys like Deep Creek, in Plymouth county — are difficult to explain. Furthermore, although all of the Loveland gravel of northwestern Iowa appears to have been deposited at the same time, the loess on the uplands differs in the amount of weathering and appears to have been deposited at different times during the interval. Likewise a comparison of the gravel of southern Iowa with that of northwestern Iowa would suggest that they represent deposition during different parts of the interval.

At the present time the only definite statement that one can make is that the Loveland gravels were derived from the erosion of the Kansan drift during the Loveland interval and were deposited in their present positions before the deposition of the Peorian loess which overlies them in many places.

CONCLUDING STATEMENTS

The field and laboratory studies presented have extended over many years. The senior author has spent much time during the past 25 years in studies of different phases of the Pleistocene deposits in Iowa, and has examined hundreds of sections distributed throughout the state. The junior author has assisted in the field and collected samples from many exposures of each type and age of gravel from the Pleistocene deposits of the state. These samples were subjected to sedimentary studies in the laboratory in the hope that some laboratory procedure would prove valuable in differentiating gravel of different ages and in interpreting their origin.

In the laboratory the generally accepted method of mechanical analysis was used, with some necessary modifications. The samples were split into a convenient size, 40-300 grams, depending on the clastic texture of the material. In many of the non-calcareous samples iron oxide coated the grains and cemented some of them together. This was removed by boiling the sample five minutes in a 15 per cent solution of hydrochloric acid and then adding sufficient stannous chloride to reduce the iron oxide so that it passed into solution. The material in solution and the size grades finer than 1/32 millimeter in diameter (never exceeding 3 per cent of the sample) were removed by decantation. The removal of the iron oxide coating was necessary to enable accurate sieving and optical studies of the shapes of the grains. The mechanical analyses were made by sieving and subsidation. The percentage of rounding was determined for each sieved size grade between 1/16 and 32 millimeters in diameter, the smaller grades being studied with the microscope. The lithology was determined from pebbles between 16 and 32 millimeters in diameter. Definite determinations of the different varieties of crystalline rocks, many of which were much weathered, was not attempted; only the main groups were differentiated. In making the lithologic analyses, calcareous concretions and clay-balls were not included, since they were not regarded as primary material.

From these laboratory studies only negative results were obtained. The clastic texture of the gravel varies widely, not only between different exposures but also within a single exposure. Even within a terrace deposited by a single stream, almost every bed has a different texture. Mechanical analyses, even when made from representative samples of gravel which were separated by only a few yards of horizontal distance, may bear practically no resemblance to each other. The thickening and thinning of beds which resulted from differences in conditions of deposition along the stream course, and the differences in kind and origin of material, are all active in producing lack of uniformity. Inasmuch as gravel deposits of like types were deposited under similar conditions, no diagnostic differences in clastic texture would occur within those of different ages. As long as there is no basis for determining the distance that upland deposits have been transported, or the amount of rounding either by the ice or before it was picked up by the ice, and further since there is no reason to believe that the amount of rounding was comparable even in like deposits of the same age, the percentage of rounding would be of no value in their correlation. It was hoped that along the valleys the percentage of rounding would enable one to determine the distance the gravel had traveled, and that thus it would be possible to differentiate between gravels of different ages within the same valley. However, this could not be done. The lithology of the gravel, like that of the till sheets, is similar for all ages, and only within local areas can differentiations be made on this basis. The Pleistocene gravel deposits in Iowa are of four distinct types, as has been determined by field investigations. These are: (1) upland gravel, deposited either within or on the surface of the till as the ice melted; (2) terrace gravel, deposited as outwash in the valleys beyond the margin of the melting ice; (3) interglacial terrace gravel, deposited in the valleys during the Loveland interval; and (4) lacustrine sand and silt, deposited in "Extinct Lake Calvin."

Upland gravel was deposited during the melting of each of the ice sheets which invaded the state. These occur in several positions: (1) irregular masses picked up in a frozen condition as gravel boulders and deposited intact within the till; (2) irregular masses buried within the till but representing glaciofluvial gravel deposited in place as the till was deposited; (3) irregular masses similar to those of number 2, but at the surface of the till sheet; (4) outwash gravel on the surface of the till; and (5) kamelike knolls on the surface of the till. The first type of gravel may have been deposited either in front of the advancing glacier or during an earlier part of the Pleistocene period. The latter four types are glaciofluvial gravel deposited either as the ice margin remained stationary or retreated.

The glacial terraces were deposited during the melting of the Iowan and Mankato invasions of the Wisconsin glacier. These terraces are along the valleys within the area covered by that ice sheet and extend farther down the valleys across older drift areas. Along those valleys which have received terrace gravel of more than one age, it is generally impossible to differentiate the ages, but where possible, the determination is largely on the basis of relationship to associated materials. Terrace gravel deposits along such streams have been described as undifferentiated gravel.

The Loveland interglacial gravel was deposited during the Loveland interglacial interval in those valleys developed during that interval. It is not possible to state during what part of the interval the gravel was deposited, but no doubt the deposition represents a considerable range of time.

The Illinoian glacier, which invaded southeastern Iowa, dammed the Mississippi river and several of its tributaries and forced them to flow around the west margin of the glacier. The Iowa and Cedar rivers were blocked and their valleys afforded a large basin into which these waters flowed to form Extinct Lake Calvin. All of the streams that flowed into this basin, either from the melting Illinoian glacier or from the area drained by these river systems, carried material which formed thick deposits in the bottom of the lake. Just before the advance of the Iowan ice the lake was drained and streams then cut their valleys into the lake beds which now stood as broad, relatively flat plains.

In the field, the differentiations of the upland gravels are based upon the alterations the deposits have undergone and upon their relations to other deposits. Oxidation has practically no significance since it varies greatly within different exposures of the same age, and is as pronounced in a few of the exposures of the youngest gravel as in the exposures of the oldest gravel. Weathering and disintegration of rocks are likewise variable, since many of the rocks were much weathered even before the final deposition. The only alteration of real significance in making differentiations is the leaching of carbonates, which is relatively uniform throughout the exposures of the same age, which occur at similar positions in respect to the surrounding deposits. The Nebraskan gravel deposited at the surface of Nebraskan till — the

Nebraskan gumbotil horizon — has been leached during the Aftonian age to a depth of at least 20 feet. If the gravel were buried within the till the leaching would be much less or even lacking, depending upon the depth. The Kansan gravel, deposited at the surface of the Kansan till, was leached to a depth of about 30 feet during the Yarmouth age. In the Illinoian gravel leaching during the Sangamon age was to a depth of about 12 feet. Since deposition, the Iowan gravel has been leached to a depth of about 5 1/2 feet, and the Mankato only 30 inches. Even though the depth of leaching is quite uniform in upland gravels, in the terrace gravels it may vary, either because of greater freedom of ground water circulation or because of the absence of carbonates at the time of deposition. Some exposures of Iowan terrace gravel are free from carbonates to a depth of more than 15 feet, but most of the exposures are leached to about the same depth as the Iowan upland gravel.

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POLLEN ANALYSIS OF INTERGLACIAL PEATS OF IOWA

by

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INTRODUCTION

In Iowa there are a number of locations from which fossil materials of the Pleistocene period have been collected. Several papers have been published which describe these interglacial deposits and their plant remains.[2] Most of the plant materials described were coniferous and the conclusion has developed that interglacial ages in this state were uniformly cool. Nielsen [3] discusses Aftonian interglacial material from Minnesota. He finds chiefly coniferous materials but draws no general conclusions about the vegetation for the whole Aftonian interval. Voss [4] has described Yarmouth and Sangamon materials from Illinois. Further reference to his work will be made later in this paper.

In this paper the results are reported of studies of fossil pollen preserved in interglacial peats from the state of Iowa. Percentages of various kinds of pollen found at successive depths in the peat are taken to represent the composition of the vegetation nearby at the time each layer of peat was formed.

The evidence of pollen analysis indicates that the coniferous materials described by earlier workers must have come from near the beginning or end of the interglacial interval and that in the middle part of the interval a vegetation very much like the present was probably developed.

Although it is well known that pollen may be transported for long distances in the air it seems likely, if those distant contributions were in any considerable numbers, that successive layers of peat materials would show little variation in pollen composition. On this assumption it follows that changes in pollen composition necessarily represent

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2 Beyer, S. W., Evidence of a Sub-Aftonian Till Sheet in Northeastern Iowa: Proc. Iowa Acad. Sci., Vol. IV, pp. 58-62, 1897.
Finch, G. E., Drift Section at Oelwein, Iowa: Proc. Iowa Acad. Sci., Vol. IV, pp. 54-58, 1897.
Macbride, Thos. H., A Pre-Kansan Peat Bed: Proc. Iowa Acad. Sci., Vol. IV, pp. 63-66, 1897.
Calvin, Samuel, Interglacial Deposits of Northeastern Iowa: Proc. Iowa Acad. Sci., Vol. V, pp. 64-70, 1898.
Savage, T. E., A Buried Peat Bed in Dodge Township, Union County, Iowa: Proc. Iowa Acad. Sci., Vol. XI, pp. 103-109, 1904.

3 Nielsen, E. L., A Study of a Pre-Kansan Peat Deposit: Torreya, Vol. XXXV, pp. 53-56, 1935.

4 Voss, John, Pleistocene Forests of Central Illinois: Bot. Gaz., Vol. XLIV, pp. 808-814, 1933.
———, Forests of the Yarmouth and Sangamon Interglacial Periods in Illinois: Ecology, Vol. XX, pp. 517-528, 1939.

changes in local flora. Likewise, grass pollen, in the absence of much tree pollen, may be assumed to represent upland grassland vegetation rather than swamp grasses of the bog surface even though the genera of grasses represented cannot be determined.

In no case is it to be implied that the pollen record from a particular peat deposit necessarily represents the entire interglacial time. Peat formation may have begun long after the opening of the interglacial age and may have closed at any time. In addition, the plowing action of an advancing ice sheet may have erased any amount from a small part, or none, to the major portion or all of the record. If one is fortunate enough to get a series which indicates climatic change it may be possible to put it, at least tentatively, in its place in the interglacial time.

Materials and Methods

During the summer of 1931 the writer visited all of the places from which interglacial peat deposits had been reported in Iowa. In several instances the peat deposits could not be located. Collections were made from all deposits found.

The common practice in sampling post-glacial peats for pollen analysis is to take samples at intervals of 6 inches or more. It is obvious that interglacial peat deposits must have been greatly compressed by the ice sheet and load of glacial till with which they have been covered so that a smaller interval between samples is advisable in order to get results as informative as possible. Accordingly, the interval between samples was reduced to 2 inches in interglacial material, the sample consisting of a rough cube of peat approximately 2 inches on a side. In the graphs the figures designating the samples represent the distance of the bottom edge of the sample from the top surface of the peat.

These samples were subjected to the standard treatment for deflocculating the peat and separating the pollen grains, using 10 per cent, or weaker, KOH and centrifuging the material to concentrate the pollen. In all cases where the frequency of pollen on the microscope slide was high enough to warrant it the materials were studied with the high, or 4-millimeter objective lens of the microscope and identification of the pollen was checked by reference to it with the oil-immersion lens. Certain of the deposits were low in pollen content. To facilitate counting, these slides were surveyed with the low power, or 16-millimeter objective lens of the microscope and the identity of the pollen was checked with the oil-immersion lens. Sears' [5] key and drawings and the drawings of Meinke [6] as well as slides of fresh pollen were used in determining the forms found. Structures resembling grains of grass pollen but lacking the characteristic single germinal pore of grass were encountered at certain levels. These were not counted as pollen. The pollen grains counted in the individual slides ranged from 7 to 209. The low figure represents study of the whole area of a slide while the higher figures were usually obtained from a small part of a slide. Conclusions are based only on counts of approximately 100 or more pollen grains for each level.

Acknowledgments

The thanks of the writer are due to Dr. H. S. Conard of Grinnell College, to Dr. R. B. Wylie, and to Dr. H. A. Mattill, of the State University of Iowa for laboratory space and use of apparatus; to Dr. P. B. Sears of Oberlin College, for encouragement, advice and technical assistance, both in the course of the study and in the preparation of the manuscript; and to Dr. Geo. F. Kay, former Director of the Iowa Geological Survey, whose interest has made possible this study.

The Pleistocene Period

The present classification of the Pleistocene period for Iowa [7] is given below.

Epoch (series)	Ages (stages)		Substages	
	Glacial	Interglacial	Glacial	Interglacial
		Recent		
Eldoran	Wisconsin		Mankato Iowan	Peorian
		Sangamon		
Centralian	Illinoian			
		Yarmouth		
Ottumwan	Kansan			
		Aftonian		
Grandian	Nebraskan			

5 Sears, Paul B., Common Fossil Pollen of the Erie Basin: Bot. Gaz., Vol. LXXXIX, pp. 95-106, 1930.

6 Meinke, H., Atlas und Bestimmungsschlüssel zur Pollenanalytik: Bot. Arch., Vol. XIX, pp. 380-449, 1927.

7 Kay, G. F. and Leighton, M. M. Eldoran Epoch of the Pleistocene Period: Bull. Geol. Soc. Am., Vol. XLIV, pp. 669-673, 1933.

Interglacial Peats of Iowa

Only two interglacial ages, the Aftonian and the Sangamon are represented by interglacial peat exposures in Iowa although many instances of peat from the Yarmouth have been reported in well records from the southeastern part of the state.

Of the six exposures of interglacial peat discussed in this paper five are of the Aftonian interval and one is placed, on stratigraphic evidence, late in the Sangamon age.

One of the Aftonian beds is near Oelwein, in Fayette county, eastern Iowa; two are near Denison, Crawford county, western Iowa; and two are in Union county near Thayer and Afton, in the southwestern part of the state.

The Sangamon bed is in Louisa county, in southwestern Iowa, not far from the town of Wapello.

THE OELWEIN PEAT

Near Oelwein, in Fayette county, eastern Iowa, Beyer [8] discovered a bed of Aftonian peat in a railroad cut in 1896 or 1897. In this cut, the banks of which have since slumped, he reported a discontinuous peat bed ranging up to 4 feet in thickness. The writer attempted to reach the original face of the cut by digging trenches through the slumped material. One of these trenches reached the peat, a layer about 16 inches thick, brown with considerable clay intermixed. Although Macbride [9] mentions moss leaves below and fragments of wood above which were not altered in form, no macroscopic plant parts were found at this place. Two series of samples were collected from the peat, one from each side of the face of the trench, perhaps 15 to 18 inches apart. It is recognized that this furnishes only a minimum of material for pollen analysis but it was all that was available under the circumstances.

The four upper samples, representing 8 inches of section, were of cocoa brown peat, easily crumbled, non-calcareous; not at all coal-like and with a large proportion of silt mixed with the vegetable material. They were moderately high in pollen content.

The four lower samples were of grayish-brown, silt-like material of texture similar to upper part and bearing little or no pollen.

8 Beyer, S. W., Evidence of a Sub-Aftonian Till Sheet in Northeastern Iowa: Proc. Iowa Acad. Sci., Vol. IV, pp. 58-62, 1897.

9 Macbride, Thos. H., A Pre-Kansan Peat Bed: Proc. Iowa Acad. Sci., Vol. IV, pp. 63-66, 1897.

It perhaps should be emphasized that although the trench reached the peat, the thickest part of the deposit according to Beyer's [10] report was not found.

TABLE Ia
Oelwein Peat, Series "A"

Kinds of pollen	Percentages at different depths							
	2″	4″	6″	8″	10″	12″	14″	16″
Conifers								
Abies	4	2	5	2	No pollen	—	—	No pollen
Larix	3	1	1	—		—	—	
Picea	24	23	41	38		25	—	
Pinus	29	35	36	46		51	(100)	
Tsuga	1	—	—	—		—	—	
Monocots								
Cyperaceae	—	1	—	—		—	—	
Gramineae	16	6	1	2		6	—	
Sparganium	1	—	—	—		—	—	
Dicots								
Carya	—	1	—	—		—	—	
Platanus	—	1	—	1		—	—	
Quercus	19	29	15	11		14	—	
Unknown	4	2	2	1		4	—	
No. of pollen grains counted	140	178	147	132	0	49	1	0
Pollen frequency per sq. mm.	2.4	2.2	3.7	2.5	0.0	0.4	0.004	0.0

TABLE Ib
Oelwein Peat, Series "B"

Kinds of pollen	Percentages at different depths							
	2″	4″	6″	8″	10″	12″	14″	16″
Conifers								
Abies	1	—	1	1	—	—	—	—
Larix	—	—	2	—	—	—	—	—
Picea	25	11	23	15	(11)	29	(33)	—
Pinus	27	30	36	37	(78)	51	(67)	—
Monocots								
Gramineae	6	9	7	1	—	1	—	—
Potamogeton	—	1	—	—	—	—	—	—
Typha	—	—	—	—	—	1	—	—
Dicots								
Betulaceae	—	—	1	—	—	1	—	—
Platanus	1	1	1	—	—	2	—	—
Quercus	39	49	28	44	—	13	—	—
Unknown	2	1	2	4	(11)	2	—	(100)
No. of pollen grains counted	191	165	162	145	9	101	3	1
Pollen frequency per sq. mm.	5.8	6.3	3.5	2.2	0.06	0.73	0.01	0.007

Tables 1a and 1b show the percentages of all kinds of pollen found at each level in the two series of samples taken from the Oelwein peat bed.

10 *Op. cit.*

Figure 1 is a graphic representation of the relative importance of the principal forms present in each level. The figures used are a

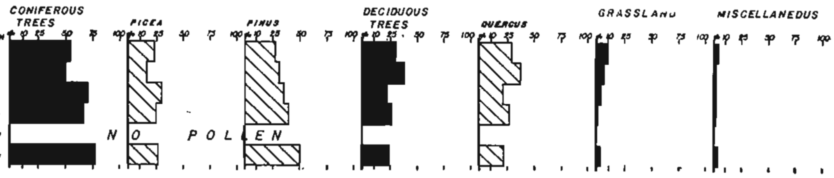

FIG. 1. — Oelwein Peat. Percentages of each group of fossil pollen are indicated along the top and the depth in inches at the left. The percentages used are based on a summation of the number of each kind of pollen found at corresponding levels in Series "A" and "B" from this peat.

summation of the number of pollen grains found at corresponding levels of the two series. In this figure and all other text figures of this paper the genera and families are grouped as follows:

Coniferous	*Deciduous*	*Grassland*	*Miscellaneous*
Abies	*Acer*	Gramineae	Unknown
Larix	Betulaceae	Compositae	*Rumex*
Picea	*Carya*	Amaranthaceae-	Cyperaceae
Pinus	*Fagus*	Chenopodiaceae	*Sparganium*
Tsuga	*Fraxinus*		*Typha*
	Juglans		*Salix*
	Platanus		*Potamogeton*
	Quercus		*Juncus*
	Tilia		

In addition, each diagram shows the percentage of *Pinus*, *Picea*, and *Quercus* in separate columns. These are crosshatched to indicate that they are different from the solid black columns.

Neither the 16-inch level nor the 14-inch level contained enough pollen to be significant. The 12-inch level, although the pollen frequency was not high still affords significant numbers of grains. Pine appeared to be the dominating form here, and there is a considerable quantity of spruce and some oak. The complex suggests the mixed forest of northern Minnesota.

At the 10-inch level again there was insufficient evidence but the 8-inch level appears to be much the same as the 12-inch. Oak gained a little at the expense of pine. At 6 inches oak was unchanged, total conifers were practically unchanged but the proportion between pine and spruce was altered.

In northern Minnesota spruces now occupy the wet soils, pine the somewhat dryer locations and oak the exposed hillsides. *Thuja* is found in the bogs. A slight increase in moisture might cause an increase in the area of wetter soils and account for the increase in spruce.

A second possibility is that an increase in spruce resulted from invasion of bog areas as water levels lowered during a dryer period or following the filling of the open bog with peat.

In the next level, the 4-inch, the strong increase in oak and the loss in number of spruce pollen suggest a definite loss of moisture supporting the second possibility suggested above. This may have been the culmination of a cycle of drying and moderate warming which began in the 6-inch level.

This peat might be interpreted either as the gradual warming of an early interglacial or possibly as the fluctuating climate of the waning interglacial age.

Such a brief amelioration of climatic conditions toward the end of the interglacial age has been reported by Jessen and Milthers [11] for the last two interglacial ages in Denmark and northwest Germany and by Premik and Piech [12] for the penultimate interglacial in Poland. A similar late interglacial amelioration is faintly suggested by Trela's figures for the Hamarnia peat in Poland.[13]

The 2-inch level suggests a fluctuation toward glacial conditions, either a return of cooler climate briefly in the early interglacial or the end of the interglacial age. Spruce pollen had regained part of its losses, pine had changed but little, oak was receding.

THE CRAWFORD COUNTY PEAT BEDS

In Crawford county in west-central Iowa there are two interglacial peat exposures, both Aftonian in age.

The smaller of these, described by Kay and Apfel,[14] is exposed in the bank of a small creek about 3 miles north of the town of Ricketts, about 20 miles from Denison. It is referred to here as the Ricketts bed.

The other, called here the Denison bed, was discovered by Kay [15] in 1931 in a cut along the paved road west of the town of Denison. It lies in the SE1/4 of sec. 32, Goodrich township and the NE1/4 of

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11 Jessen, K. and Milthers, V., Stratigraphical and Paleontological Studies of Interglacial Fresh-water Deposits in Jutland and Northwest Germany: Danm. Geol. Unders., Ser. II, No. 48, pp. 1-379, atlas with Plates 1-40, 1928.

12 Premik, J. and Piech, K., Zur Kenntnis des Diluviums im Süd-Westlichen Mittelpolen: Ann. de la Soc. Geol. de Pologne, Vol. VIII, Pt. 2, pp. 1-132, 1932.
Sears, Paul B., Glacial and Postglacial Vegetation: Bot. Rev., Vol. I, pp. 37-51, 1935.

13 Szafer, W., The Oldest Interglacial in Poland: Bull. Acad. Pol. Sci. et Lett., B *1*, pp. 19-50, 1931.

14 Kay, G. F. and Apfel, E. T., The Pre-Illinoian Pleistocene Geology of Iowa: Iowa Geol. Survey, Vol. XXXIV, pp. 1-305, 1929.

15 Kay, G. F., Personal Communication.

TABLE IIA

Denison Peat, Series "A"

Kinds of pollen	Percentages at different depths																				
	2″	4″	6″	8″	10″	12″	14″	16″	18″	20″	22″	24″	26″	28″	30″	32″	34″	36″	38″	40″	42″
Conifer																					
Abies	5	2	8	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Larix	8	2	4	1	—	—	—	—	—	1	—	—	—	1	—	—	—	—	—	—	2
Picea	23	10	24	13	2	2	—	—	—	1	—	—	—	1	—	—	—	—	—	—	—
Pinus	15	4	21	20	3	—	—	—	—	1	1	—	1	—	—	—	—	—	—	—	4
Tsuga	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—
Monocots																					
Cyperaceae	1	1	—	—	1	—	1	—	3	2	2	—	—	1	—	—	—	—	—	—	—
Gramineae	29	62	39	59	80	86	95	86	76	63	68	82	91	66	(50)	(100)	—	—	—	—	90
Sparganium	1	—	2	1	—	—	—	—	1	—	1	—	—	—	—	—	—	—	—	—	—
Dicots																					
Acer	—	—	—	—	—	—	—	—	—	—	—	1	—	1	—	—	—	—	—	—	—
Amaranthaceae-Chenopodiaceae	—	1	—	—	—	2	—	—	—	—	—	1	2	1	—	—	—	—	—	—	—
Betulaceae	1	—	—	1	2	2	—	1	3	3	4	3	—	1	—	—	—	—	—	—	—
Carya	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—
Compositae	1	1	—	—	1	—	—	—	1	3	1	1	1	—	—	—	—	—	—	—	2
Fagus	—	—	—	—	—	—	—	—	1	1	—	—	—	—	—	—	—	—	—	—	—
Fraxinus	—	—	—	—	—	—	1	—	—	2	—	1	—	—	—	—	—	—	—	—	—
Juglans	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—
Platanus	2	2	—	1	4	2	—	4	2	3	4	4	—	—	(50)	—	—	—	—	—	—
Quercus	11	5	—	1	7	6	3	4	5	11	10	1	1	4	—	—	—	—	—	—	2
Rumex	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—
Tilia	—	1	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—
Unknown	5	9	4	2	2	1	1	5	9	9	8	7	2	24	—	—	—	—	—	—	0
No. of pollen grains counted	209	184	136	149	114	126	120	135	119	176	134	132	128	102	2	7	0	0	0	0	50
Pollen frequency per sq. mm.	5.59	5.58	0.86	5.64	2.47	2.2	3.03	5.15	2.58	2.76	1.69	1.82	1.04	1.93	—	0.036	0.0	0.0	0.0	0.0	0.15

sec. 5, Denison township. (SE1/4, sec. 32, T. 84 N., R. 40 W. and NE1/4 sec. 5, T. 83 N., R. 40 W.)

The peat in these two beds is very much alike although the Ricketts peat is a much shallower deposit than the Denison bed. The plant material is much compressed, dark brown to black, containing only a little silt, appearing unlaminated when wet but separating or flaking with comparative ease when dry. The Ricketts peat shows laminations in the bed in some parts.

TABLE IIb
Denison Peat, Series "B"

Kinds of pollen	Percentages at different depths						
	2″	4″	6″	8″	10″	12″	14″
Conifers							
Abies	9	9	16	20	1	1	—
Larix	1	2	3	5	1	1	1
Picea	9	2	3	2	—	1	—
Pinus	7	4	8	9	1	—	—
Tsuga	—	—	—	1	—	—	—
Monocots							
Cyperaceae	15	15	10	16	9	13	—
Gramineae	32	33	36	28	68	67	94
Sparganium	1	—	—	—	—	—	—
Dicots							
Acer	—	1	1	1	—	—	1
Amaranthaceae-Chenopodiaceae	—	1	—	—	—	1	1
Betulaceae	6	6	7	6	2	3	—
Compositae	2	1	1	1	—	3	—
Platanus	—	1	3	2	2	1	1
Quercus	7	6	3	1	1	3	1
Salix	1	10	1	2	2	1	—
Unknown	10	9	9	7	13	6	2
No. of pollen grains counted	149	140	146	176	166	162	169
Pollen frequency per sq. mm.	2.82	1.78	6.32	3.33	5.03	6.14	8.54

Tables 2A, 2B and 2C show percentages of different pollens at each level of the three series of samples from the Denison bed. This peat is exposed in the bank on both sides of the paved road for a total distance of about 50 yards. Series "A" comes from the north bank and series "B" and "C" from the south bank of the road, "B" about 5 yards east of "A" and "C" about 25 yards west of "B".

Description of the Peat

Denison "A"

2″– 4″ dark brown peat, little silt
4″– 6″ cocoa-brown peat, more silt
6″–12″ gray-brown peat, considerable silt

12″–14″ darker gray-brown peat, less silt
14″–30″ very dark brown (almost black) peat, scarcely any silt
30″–34″ gray with brownish spots and streaks, somewhat mud-like contains some organic material
34″–36″ like above but with less of the organic matter
36″–38″ no brownish streaks or organic material
38″–40″ similar to 36″–38″
40″–42″ similar to 36″–40″, but with some spots of peaty material

The deepest level of Series "A," the 42-inch depth, was very low in pollen content, affording only 50 grains on the whole studied area of the microscope slide, or a pollen frequency of only 0.1535 pollen grains per square millimeter. However, 90 per cent of these 50 pollen grains were grass pollen so it seems safe to assume that these represent the major part of the vegetation.

Samples from levels of 40 inches to 30 inches were also very sparse in pollen, in fact no pollen at all was found in any of these except the 30- and 32-inch levels where only 2 and 7 grains respectively were found on the slide. At the 28-inch and 26-inch levels, however, the pollen frequency rose abruptly to 1.93 and 1.04 pollen grains per square millimeter and remained high thereafter except in one level. The cause for the failure of pollen preservation in these levels while peat formation was going on is not known although absence of pollen from grassland peat is not uncommon.

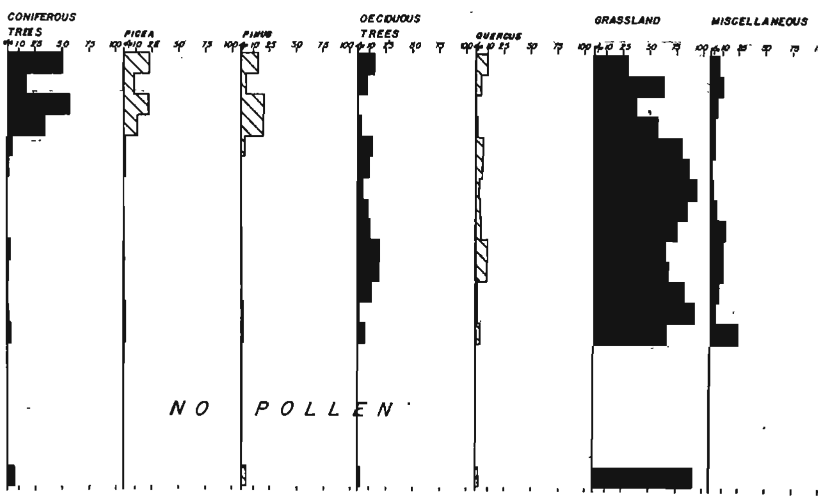

FIG. 2. — Denison Peat, Series "A". Percentages of each group of fossil pollen are indicated along the top and the depth in inches at the left. Levels 30 inches to 40 inches inclusive were devoid of pollen.

TABLE IIc

Denison Peat, Series "C"

Kinds of pollen	Percentages at different depths													
	3″	6″	8″	10″	12″	14″	16″	18″	20″	22″	24″	26″	28″	30″
Conifers														
Abies	2	5	15	16	3	6	4	8	—	2	1	1	—	—
Larix	1	—	1	1	3	1	1	4	—	—	—	—	—	—
Picea	1	—	34	29	1	4	1	2	—	—	—	—	—	—
Pinus	1	5	14	19	2	3	7	1	—	1	—	—	—	—
Tsuga	—	—	—	—	—	—	—	1	—	—	—	—	—	—
Monocots														
Cyperaceae	1	1	5	5	7	6	13	4	2	8	10	7	—	2
Gramineae	55	33	11	13	66	63	58	61	90	74	83	79	98	96
Juncus	—	—	—	1	—	—	—	—	—	—	—	—	—	—
Sparganium	4	1	—	—	—	1	—	—	—	—	—	—	—	1
Typha	2	—	—	—	—	—	—	—	—	—	—	—	—	—
Dicots														
Amaranthaceae-Chenopodiaceae	—	—	—	—	1	—	1	—	—	1	—	—	—	—
Betulaceae	7	6	3	3	1	3	4	8	2	2	4	3	—	2
Carya	—	—	—	—	—	1	—	—	—	—	—	—	—	—
Compositae	1	—	1	2	1	1	—	—	—	—	—	1	—	—
Fagus	—	4	—	—	—	—	—	—	—	—	—	—	—	—
Fraxinus	—	1	—	—	—	—	—	—	—	—	—	—	—	—
Platanus	1	2	1	—	1	—	1	1	1	2	1	3	—	—
Quercus	14	26	10	5	8	7	6	3	4	5	2	5	—	—
Salix	1	1	1	—	1	1	1	1	—	4	2	1	—	—
Unknown	12	17	7	6	7	5	5	6	2	2	—	2	2	2
No. of pollen grains counted	130	145	169	172	153	174	144	146	192	172	251	157	111	121
Pollen frequency per sq. mm.	2.46	4.39	4.27	6.52	5.8	4.39	3.64	2.77	14.55	8.69	19.02	6.95	4.2	2.62

Figure 2 is a graphic representation of the major vegetation groups as shown in the "A" series from this bed. The grassland formation was dominant at the lowest level. There are no data between 42 inches and 28 inches but above that the grassland continued to play the leading role up to the 8-inch level where although grasses still appear to have been dominant, conifers were present in sufficient numbers to be recognized as an important part of the vegetation.

According to Sears [16] the absence of pollen between the 28- and 42-inch levels is excellent confirmation of a grassland maximum, since the accompanying climate is notoriously bad for pollen preservation. The low organic content of the sediment at this level is likewise in keeping.

Oaks had brief increases at the 22-inch and 20-inch and at the 12-inch and 10-inch strata, but do not appear to have been of major importance at any of those places.

At the 6-inch level coniferous pollen was most abundant, about equally divided between pine and spruce, grass pollen was abundant and the pollen of deciduous trees was completely absent.

The next stage, the 4-inch, seems to indicate a warmth fluctuation with slight increase in oak and other deciduous forms and large increases in grasses. One might conclude that this stage was probably also dry since most of the gain has been in grass pollen. The top sample, or the 2-inch, indicates a return of coniferous forms, particularly spruce.

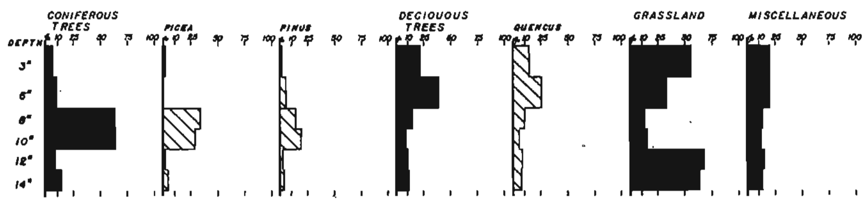

FIG. 3. — Denison Peat. The upper levels of Series "C" — Percentages of each group of fossil pollen are indicated along the top and depth in inches at the left. The 3- and 6-inch levels here are thought to correspond to the 4-inch level of the preceding figure in which coniferous pollen gives way to oak and grass for a brief period.

Figure 3, in which the upper levels of Series "C" are illustrated, seems to indicate (the 3-inch and 6-inch levels) that the climatic amelioration shown in the 4-inch level of Series "A" was of somewhat longer duration and that oaks and other deciduous trees were of considerable importance in that period. Peat corresponding in age to the

16 Sears, P. B., Personal Communication, 1940.

2-inch level of Series "A" seems to be absent in this series. Possibly it was graded away by the advancing ice sheet.

The similarity between the pollen figures for the lower levels of the Oelwein bed and the upper levels of the Denison peat suggests that these beds may represent a nearly continuous series. On the other hand if one regards the Oelwein beds as representing an early part of the interglacial then there must have been considerable lapse of time between the close of the Oelwein record and the beginning of peat accumulation at the Denison bed. In any case it seems likely that the Denison peat represents the climax vegetation of the Aftonian interglacial interval.

TABLE III
Ricketts Peat

Kinds of pollen	Depth in inches					
	2″	2″	4″	4″	6″	6″
	Percent	No. of grains	Percent	No. of grains	Percent	No. of grains
Conifers						
Picea	—	—	—	—	1	1
Monocots						
Gramineae	71	5	81	26	93	92
Sparganium	—	—	6	2	1	1
Dicots						
Acer	—	—	3	1	—	—
Betulaceae	—	—	—	—	1	1
Compositae	—	—	—	—	1	1
Platanus	—	—	3	1	2	2
Quercus	—	—	6	2	1	1
Unknown	29	2	0	0	0	0
No. of pollen grain counted		7		32		99
Pollen frequency per sq. mm.		0.27		0.81		3.0

Table 3 shows quantities and percentages of different pollens at each level of the Ricketts bed. Although only the 6-inch or deepest level provides enough pollen grains to furnish a basis for reliable conclusions, it seems probable that the whole bed represents but one phase, the grassland, of the interglacial interval. The spores found were almost exclusively grass pollen, which represented about 89 per cent of all the pollen found in all parts of the bed.

THE UNION COUNTY PEAT BEDS

In Union county, which lies 75 to 80 miles south and east of Crawford county, are found two exposures of interglacial peat, one near Thayer and the other in Dodge township north of Afton. Both are of the Aftonian interglacial interval.

The Thayer bed is exposed in the bank of a road cut along the paved highway about half a mile west of the town of Thayer. The peat here is light brown, contains considerable silt and strikingly resembles that of the Oelwein bed. There follows a detailed description of the profile.

0″– 4″	cocoa brown peat showing some oxidation and containing considerable silt
4″– 6″	cocoa brown color, somewhat grayish, less oxidation
6″– 8″	as above but not grayish, still less oxidized
8″–12″	cocoa brown peat, some silt
12″–14″	as above, but somewhat grayish
14″–16″	darker cocoa brown
16″–18″	as in 12″–14″

Three series of samples were obtained from this peat bed. Two were but 4 inches in depth, the third was 18 inches deep. Tables 4a, 4b, and 4c, show the percentages of each kind of pollen found at each level in these samples.

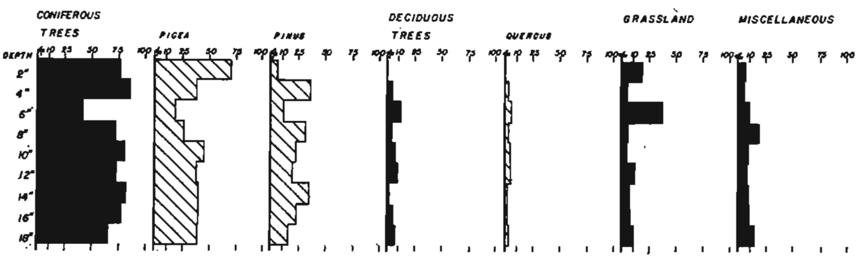

FIG. 4. — Thayer Peat, Union County, Series "C." Percentages of each group of fossil pollen pollen are indicated along the top and the depth in inches at the left. Figures for the 2-inch, 4-inch, and 14-inch levels are based on a small number of pollen grains and should not be regarded as conclusive.

Figure 4 is a diagram of the percentages of the major plant groups in the "C" series. In this diagram the 2-inch, 4-inch, and 14-inch levels are sparse in pollen. They are included in this diagram for the sake of completeness, but are not to be regarded as conclusive because they are based on a small number of pollen grains. If the series "A" and "B" could be correlated with the 2- and 4-inch levels of Series "C" it would be possible to add these levels together to make a significant figure. It seems likely, however, judging from the pollen frequencies and percentages, that the "A" series corresponds to the 6- and 8-inch levels of series "C" and that the "B" series corresponds to the 4- and 6-inch levels of "C." (See Tables 4a, 4b, 4c.)

TABLE IVa AND IVb

Thayer Peat, Series "A" and "B"

Kinds of pollen	A		B	
	Percentages at different depths			
	2″	4″	2″	4″
Conifers				
Abies	6	9	28	4
Larix	1	3	—	1
Picea	35	33	35	17
Pinus	13	17	24	30
Tsuga	—	1	—	—
Monocots				
Cyperaceae	5	5	3	6
Gramineae	20	10	4	18
Juncus	2	—	—	—
Sparganium	1	—	—	1
Typha	—	—	—	1
Dicots				
Amaranthaceae-Chenopodiaceae	—	—	—	1
Betulaceae	2	5	—	4
Compositae	—	—	—	1
Fagus	—	1	—	1
Platanus	1	—	—	1
Quercus	6	3	2	7
Unknown	10	12	4	8
No. of pollen grains counted	128	138	68	158
Pollen frequency per sq. mm.	1.21	1.9	0.18	1.28

TABLE IVc

Thayer Peat, Series "C"

Kinds of pollen	Percentages at different depths								
	2″	4″	6″	8″	10″	12″	14″	16″	18″
Conifers									
Abies	—	11	10	12	10	12	2	11	10
Larix	—	—	1	1	2	2	4	2	—
Picea	71	39	19	27	46	39	41	41	40
Pinus	6	37	12	32	23	20	35	24	16
Monocots									
Cyperaceae	—	—	1	10	3	—	—	3	5
Gramineae	12	5	37	5	5	11	7	8	10
Sparganium	—	—	—	1	—	1	2	—	5
Typha	—	—	1	—	—	—	—	—	—
Dicots									
Acer	—	—	1	—	—	—	—	—	—
Amaranthaceae-Chenopodiaceae	6	—	—	—	—	—	—	—	1
Betulaceae	—	2	4	1	2	2	—	2	2
Compositae	—	—	1	—	—	1	—	—	—
Fagus	—	—	—	—	1	—	—	—	1
Platanus	—	—	1	—	—	2	—	1	1
Quercus	—	2	5	3	4	5	2	2	3
Rumex	—	—	—	—	—	—	—	—	1
Tilia	—	—	1	—	—	—	—	—	—
Unknown	6	5	8	8	6	7	7	7	4
No. of pollen grains counted	17	57	147	158	128	133	46	121	116
Pollen frequency per sq. mm.	0.04	0.35	1.11	2.99	2.15	1.83	0.46	1.83	0.93

The climatic significance of this deposit is less clear than that of the Denison peat. Coniferous pollen was predominant throughout the peat bed. At the 6-inch level grassland forms and deciduous trees show a material increase but are not important in the two upper levels.

It seems likely that this peat was formed at about the same time as the Oelwein peat. Both show a brief amelioration of climate in the upper levels with a subsequent degradation, both show a similar pattern of pollen frequency and a similar group of pollen percentages.

TABLE V

A comparison of pollen frequencies from the "A" series of the Oelwein peat and the "C" series of the Thayer peat. The significance lies in the similarity of pattern of increases and decreases of the pollen frequency rather than in direct correspondence of figures.

Pollen frequency per sq. mm.			
Oelwein "A"		Thayer "C"	
		0.04	2″
		0.35	4″
2″	2.4	1.11	6″
4″	2.2	3.0	8″
6″	3.7	2.2	10″
8″	2.5	1.8	12″
10″	no pollen	0.46	14″
12″	0.4	1.8	16″
14″	0.004	0.9	18″
16″	no pollen		
18″	no pollen		

The Dodge township bed was described in 1904 by T. E. Savage.[17] In the bank of a small stream tributary to the Grand river, the peat is exposed considerably above the water line.

The peat-containing material has a total thickness of about 10 feet but the actual amount of peat is very much less. In this bed there are thin layers of carbonaceous material separated by thick bands of fine sand. The peat here is much less consolidated than the other interglacial peats, and the plant parts are considerably less altered, particularly in the upper layers. In the lower part of the bed the peat is more compact and plant materials are more difficult to recognize though they are not altered and consolidated as they are in the Denison and Ricketts peats. Moss plants, conifer leaves and stems of water plants are conspicuous.

Table 6 shows the kinds of pollen and the percentage of each kind found at each 6-inch level of the "B" series from this peat bed. Because of the scarcity of pollen, which makes the significance of figures from this peat somewhat doubtful, only every third sample was studied.

17 Savage, T. E., A Buried Peat Bed in Dodge Township, Union County, Iowa: Proc. Iowa Acad. Sci., Vol. XI, pp. 103-109, 1904.

TABLE VI

Dodge Township Peat Bed, Series "B"

Kinds of pollen	Percentages at different depths																				
	2″	6″	12″	18″	24″	30″	36″	42″	48″	54″	60″	66″	72″	78″	84″	90″	96″	102″	108″	114″	120″
Conifers																					
Abies	3	5	7	17	22	11	33	No Pollen	9	19	9	—	16	8	14	—	26	17	—	21	27
Larix	—	5	1	—	—	—	—		—	—	—	—	—	4	—	—	5	—	—	—	—
Picea	41	42	50	50	28	11	44		36	38	64	22	44	31	50	50	16	11	—	36	33
Pinus	14	16	6	8	22	14	—		9	31	9	22	26	39	7	25	32	28	71	36	37
Tsuga	—	—	—	—	—	—	—		—	—	—	—	2	—	—	—	—	—	—	—	—
Monocots																					
Cyperaceae	1	—	1	—	—	—	—		—	—	—	—	—	—	—	—	—	—	—	—	—
Gramineae	30	21	24	17	11	18	22		9	6	—	33	10	8	7	13	5	28	14	—	—
Potamogeton	—	—	—	—	—	—	—		—	—	—	—	—	—	—	—	5	—	—	—	—
Sparganium	—	—	—	—	—	—	—		—	—	—	—	—	—	14	—	—	—	—	7	—
Typha	—	—	—	—	—	—	—		—	—	—	—	—	—	—	—	—	—	—	—	—
Dicots																					
Amaranthaceae-Chenopodiaceae	1	—	—	—	—	—	—		—	—	9	—	—	—	—	—	5	6	—	—	—
Betulaceae	—	—	2	—	6	4	—		—	—	—	—	—	4	—	—	—	—	—	—	—
Carya	—	—	—	—	—	—	—		—	—	—	—	—	4	—	—	—	—	—	—	—
Celtis	—	—	—	—	—	32	—		—	—	—	—	—	—	—	—	—	—	—	—	—
Compositae	—	—	1	—	—	—	—		—	—	—	—	—	—	—	—	—	—	—	—	—
Fagus	—	—	—	—	—	—	—		—	—	—	—	—	—	7	—	—	—	14	—	—
Platanus	—	—	1	—	—	—	—		—	—	—	—	—	—	—	—	—	—	—	—	—
Quercus	1	5	1	—	—	5	—		—	—	—	6	—	4	—	—	—	—	—	—	3
Rumex	1	—	1	—	—	—	—		—	—	—	—	—	—	—	—	—	—	—	—	—
Salix	—	—	1	—	—	—	—		—	—	—	—	—	—	—	—	—	—	—	—	—
Unknown	8	5	7	8	11	5	0		36	6	9	17	2	0	0	13	5	11	0	0	0
No. of pollen grains counted	78	19	136	12	18	56	9	0	11	16	11	18	50	21	14	8	19	18	7	14	30
Pollen frequency per sq. mm.	0.2	0.05	0.48	0.03	0.05	0.14	0.02	0.0	0.03	0.04	0.03	0.05	0.13	0.07	0.04	0.03	0.05	0.05	0.02	0.04	0.08

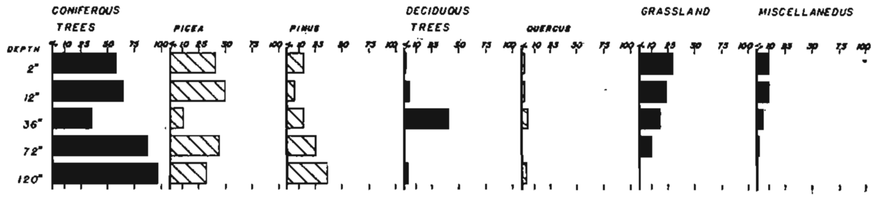

FIG. 5. — Dodge Township Peat, Union County, Series "B." Percentages of each group of fossil pollen are indicated along the top and the depth in inches is shown at the left. Figures are based on the following number of pollen grains per level: 2-inch, 78; 12-inch, 136; 30-inch, 56; 72-inch, 50; and 120-inch, 30. Ony the 12-inch level is based on a sufficient number of pollen grains to insure relative accuracy though other figures may be regarded as suggestive.

Figure 5 is a diagram of the percentages of pollen of various vegetation units found at certain levels of the "B" series from the Dodge township peat deposit. Figures showing the quantity of pollen on which these percentages are based are listed below the figure. Only one of these levels, the 12-inch, furnishes enough pollen to give a reliable guide to the composition of the vegetation. However, the other levels shown, with the exception of the 120-inch level, which is added only because it is the lowest one of the bed, all contain 50 or more grains of pollen and, although they cannot be regarded as throughly establishing a picture of the vegetation, they may be looked on at least as suggestive.

The general trend of vegetation change which these figures suggest is a slow disappearance of conifers and their replacement by grassland. The 30-inch level does not fit the picture. In this sample were found a quantity of spores resembling *Celtis* pollen, giving rise to the high percentage of pollen from deciduous trees in this level. No more pollen of this kind was found in the peat deposit.

The picture at the 12-inch level, the only one which we may regard as entirely reliable, is of a coniferous forest in which spruce was dominant. Small quantities of pine and fir were also present. Grassland forms were moderately abundant.

The percentages of the 2-inch level, based on 78 grains of pollen, showed strong increases in pine and grass pollen suggesting the beginning of a dryer period which may have led to the grassland formation as shown in the Denison peat.

Interpretation of the Aftonian in Iowa

From the evidence of the pollen preserved in peats of Aftonian age in widely separated parts of Iowa, that interglacial age must have been of long duration. Such changes of vegetation as are indicated could scarcely have been accomplished in a short period.

In western Iowa (Crawford county) it seems probable on the evidence of the pollen, that a climatic condition and vegetation considerably like the present were reached. There is no indication of a long deciduous climax at any time in the series. In southwest Iowa (Union county) the evidence for a prairie condition is less convincing, if not entirely lacking. However, it seems doubtful if the peat series here can represent the same time period as that in Crawford county. It is not likely that conifers would remain dominant here throughout the interglacial period while, only 75 miles to the northwest, a prairie vegetation flourished.

In eastern Iowa (Oelwein) much the same situation is found as in the southwestern part of the state and again it seems probable that the peat series here represents but a part of the interglacial time. While it is not absolutely impossible, on the evidence, that coniferous forests remained here throughout the Aftonian it seems more probable that a prairie vegetation was developed either preceding this peat deposit or following the cessation of the peat record.

It seems likely to the writer that the Dodge township peat in Union county represents the earliest deposit of peat in this group, that the Denison and Ricketts peat beds are next in age and separated from the Dodge township bed by a hiatus of unknown length and that the Oelwein and Thayer beds were formed during the last part of the interglacial age, although these deposits may be nearly contemporaneous with the Dodge township peat.

If the first hypothesis is true the Aftonian vegetation of Iowa was first coniferous. Conifers were directly succeeded by grassland without the development of a deciduous phase although postglacial studies in northern Iowa have shown a well developed period of deciduous tree vegetation there.[18] The coniferous period was probably of considerable length and the grassland climax was of very long duration. As the interglacial period waned, grassland was succeeded by oak in the eastern part of the state although at the same time oak played a very insignificant part in the southwestern part of the state.

Oak dominance was of short duration. Conifers quickly succeeded the oak in both peat deposits and continue dominant to the end of the

18 Lane, G. H., A Preliminary Pollen Analysis of the East McCulloch Peat Bed: Ohio Jour. Sci., Vol. XXXI, pp. 165-171, 1931.

interval except for a short time represented by peat near the top of the sections at Oelwein and Thayer, during which temporary increases of grass and oak pollen suggests that there may have been a brief amelioration of the climate near the end of the interglacial interval.

On the second hypothesis above, oak would show a larger development in eastern than in western Iowa during the coniferous-grassland transition. Other conclusions would be the same except that the record would be assumed to close soon after the interglacial age began to wane.

It is to be hoped that further discoveries of Aftonian peat may be made in other parts of Iowa so that a complete series of records from all parts of the state can be developed.

The Sangamon Interglacial Age

Near Wapello, Louisa county, Iowa, along the old highway as it rose out of the Iowa river bottom, a road cut exposed a bed of peat approximately 20 inches thick at its greatest part. On the whole the peat is quite homogeneous. It is non-fibrous throughout and somewhat laminated. The color in the upper samples to 6 inches is dark brown, in the 8-, 10-, and 12-inch levels it becomes almost black, at 14 and 16 inches it is again a dark brown and changes again to brownish-black in the lowest levels. These colors were determined in the dry condition.

This peat lies at the bottom of an eroded depression in the Illinoian gumbotil plain so it probably had its origin quite late in the Sangamon interglacial age. It is covered by 10 to 15 feet of loess deposits.[19]

Tables 7a, 7b, and 7c record the percentages of each kind of pollen found in three series of samples taken from this peat bed.

The figures represent about what one would expect in peat formed late in an interglacial interval. A great many forms are present but in small quantities, and the vegetation was predominantly coniferous.

This material contrasts with the Sangamon peat described by Voss[20] and Fuller[21] in the abundance of pollen, in the large number of genera

19 Kay, G. F., Personal Communication.

20 Voss, John, Pleistocene Forests of Central Illinois: Bot. Gaz., Vol. XCIV, pp. 808-814, 1933.
———, Forests of the Yarmouth and Sangamon Interglacial Periods in Illinois: Ecology, Vol. XX, pp. 517-528, 1939.

21 Fuller, G. D., Interglacial and Postglacial Vegetation of Illinois: Trans. Illinois State Acad. Sci., Vol. XXXII, pp. 5-15, 1939.

TABLE VIIA

Sangamon Interglacial Peat, Series "A"

Kinds of pollen	Percentages at different depths									
	2″	4″	6″	8″	10″	12″	14″	16″	18″	20″
Conifers										
Abies	1	1	1	1	1	1	1	3	7	5
Larix	3	2	1	1	4	1	1	—	—	—
Picea	13	5	24	38	47	50	15	33	16	19
Pinus	63	27	45	47	39	23	6	48	62	37
Tsuga	—	—	—	—	—	—	—	1	—	1
Monocots										
Cyperaceae	—	—	—	—	—	—	—	9	—	—
Gramineae	16	43	22	6	2	20	13	5	5	7
Dicots										
Acer	—	5	1	2	3	—	—	—	—	—
Betulaceae	—	1	1	—	—	—	52	—	—	4
Compositae	—	—	—	—	—	—	—	—	—	2
Fagus	—	—	1	—	—	—	—	—	—	—
Platanus	—	4	1	1	1	—	—	—	—	6
Quercus	2	—	4	3	1	3	3	1	7	3
Salix	—	—	—	—	—	—	—	—	—	1
Unknown	3	12	1	2	3	3	10	1	3	14
No. of pollen grains counted	103	110	160	122	128	159	173	201	134	115
Pollen frequency per sq. mm.	0.68	1.67	2.42	1.68	3.23	4.82	17.47	30.45	13.54	3.48

TABLE VIIB

Sangamon Interglacial Peat, Series "B"

Kinds of pollen	Percentages at different depths								
	2″	4″	6″	8″	10″	12″	14″	16″	18″
Conifers									
Abies	—	—	1	4	9	7	14	12	11
Larix	—	—	—	—	2	4	—	—	—
Picea	3	6	9	25	44	24	42	41	21
Pinus	25	14	21	37	29	16	20	37	62
Tsuga	—	—	—	—	2	—	—	—	—
Monocots									
Cyperaceae	—	—	—	1	—	—	—	—	—
Gramineae	17	43	43	9	5	12	5	1	—
Typha	—	1	—	—	—	—	—	—	—
Dicots									
Acer	3	—	—	3	—	—	—	—	—
Betulaceae	—	—	—	1	2	—	2	—	—
Compositae	—	—	1	—	2	—	—	—	—
Fraxinus	—	—	1	—	—	—	—	—	—
Juglans	—	—	—	—	—	1	—	—	—
Lysimachia	—	—	—	—	—	1	—	—	—
Platanus	8	2	—	1	—	1	2	—	—
Quercus	33	23	22	15	5	14	9	1	1
Unknown	11	11	3	6	2	20	6	9	6
No. of pollen grains counted	36	111	102	144	128	100	100	123	120
Pollen frequency per sq. mm.	0.26	1.68	1.55	2.88	6.46	0.99	2.16	9.32	9.19

TABLE VIIc

Sangamon Interglacial Peat, Series "C"

Kinds of pollen	Percentages at different depths					
	2″	4″	6″	8″	10″	12″
Conifers						
Abies	1	1	7	4	4	1
Larix	1	1	1	1	—	1
Picea	24	5	55	25	44	34
Pinus	37	10	21	54	42	57
Monocots						
Gramineae	28	27	12	5	7	5
Dicots						
Amaranthaceae-Chenopodiaceae	—	1	—	—	—	—
Betulaceae	—	45	1	2	—	—
Platanus	1	1	—	—	—	—
Quercus	4	5	—	5	3	5
Rumex	—	—	—	—	1	—
Unknown	4	4	3	3	0	2
No. of pollen grains counted	174	165	87	248	110	187
Pollen frequency per sq. mm.	4.49	8.33	0.24	25.05	1.25	5.31

represented, and in the large fluctuations of deciduous and grassland pollens shown in the upper levels of series "A" and "B".

A comparison of the percentages of various genera among the three series suggests that the "A" series contains both the oldest and the youngest material of the peat bed. Large numbers of the pollen of deciduous trees, especially oak, and of grasses which appeared in the upper four samples of the "B" series may be correlated with the 6- and 4-inch levels of series "A". Grassland forms showed their highest values in these levels of series "A" although oak was much less abundant here than in the "B" series. It is difficult to account for these differences since these series were collected within a few feet of each other. High counts of Betulaceae pollen appeared in the 14-inch level of the "A" and in the 4-inch level of the "C" series. If one calculates the percentages of other forms separately from the Betulaceae pollen these levels show no great differences from adjacent levels in each series.

Figure 6 is a graph of the major vegetation groups as shown in the "A" series. In the 14-inch level of this graph Betulaceae pollen has been excluded in calculating the percentages.

Coniferous dominance was practically complete except for two times represented by the 14- and 12-inch levels and the 6- and 4-inch levels. In the lower level grassland pollens were in significant numbers while in the upper one both grassland forms and deciduous tree pollen in-

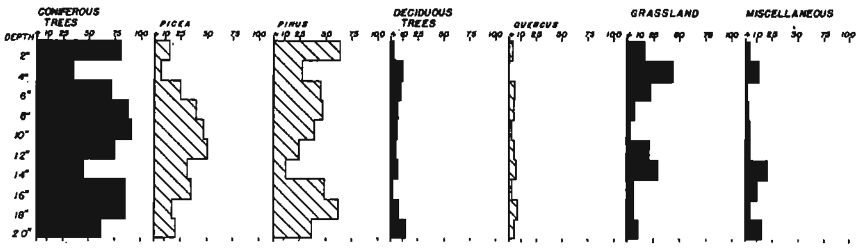

FIG. 6. — Sangamon Peat, Series "A." Percentages of each group of fossil pollen are indicated along the top and depth in inches at the left. In the 14-inch level the percentages have been recalculated, excluding Betulaceae pollen.

creased materially. If, as is suggested above, the upper four levels of series "B" may be correlated with the 6- and 4-inch levels of the "A" series then the rôle of deciduous forms at this stage may have been more important than this graph shows.

The 20-inch level, which shows slightly larger amounts of grassland and deciduous tree forms, may represent the end of a third fluctuation.

It would appear that climatic conditions toward the end of the interglacial interval fluctuated considerably. The uppermost of these peaks of grassland and deciduous tree pollen may represent the same sort of brief climatic amelioration as was noted above toward the end of the Aftonian interglacial period. The work of Jessen and Milther,[22] in which this feature appears so prominently, was on peat of the last interglacial in Europe which may be contemporaneous with the Sangamon in this country.

There is, however, no positive evidence that this peat was formed at the very end of interglacial time. The high values of grassland and oak pollen are accompanied by considerable pine and some spruce. These might be interpreted as a mixed oak-pine savannah at some earlier stage in interglacial time. However, the absence of such forms from Voss' [23] long series of materials from nearby stations in Illinois would lead one to doubt this conclusion. It seems more likely that the Iowan peat is more recent than the Illinois beds and consequently that it developed quite late in Sangamon time.

22 Jessen, K. and Milthers, V., Stratigraphical and Paleontological Studies of Interglacial Freshwater Deposits in Jutland and Northwest Germany: Danm. Geol. Unders., Ser. II, No. 48, pp. 1-379, atlas with Plates 1-40, 1928.

23 Voss, John, Pleistocene Forests of Central Illinois: Bot. Gaz., Vol. XCIV, pp. 808-814, 1933.

Summary

1. Interglacial peat materials from six widely separated locations in Iowa have been examined for fossil pollen and the percentages of different genera represented have been computed. One of the six deposits belongs to the Sangamon (last) interglacial age, the other five are Aftonian (oldest interglacial) in age.

2. The Aftonian materials seem to represent two or three separate phases of the interglacial interval. The oldest peat appears to be that from the Dodge township bed in Union county. A coniferous vegetation gradually changing to grassland is indicated. The Oelwein and Thayer peat may be nearly contemporaneous with the Dodge township peat. In that case, oak was of greater importance in eastern Iowa than in the southwestern part of the state during the transition from conifers to grassland. A grassland climax shifting toward oak and coniferous genera is recorded in the upper layers in the Denison peat. The closing part of the interglacial interval may be represented in two beds, the Oelwein and the Thayer peat. Both show dominant coniferous forms but with brief advances of oak and grass pollen shortly before the end of the peat record. The record ended with increasing coniferous forms.

3. Noteworthy in the evidence are the absence of important numbers of oak or other deciduous forms in the succession from conifers to grassland; the long dominance of grassland; the development of more oak in eastern than in western Iowa during the closing part of the ice-free time; and the appearance of a brief amelioration of climate shortly before the end of the interglacial interval.

4. The single peat bed from the Sangamon probably represents only a short time toward the end of the interglacial interval. The vegetation represented is mostly coniferous but small quantities of a number of other genera are present. Sharp fluctuations of climate are indicated. The coniferous forms were dominant except near the top of the peat where grass and oak were in majority for a short time. This brief amelioration of climatic conditions was succeeded by new increases of coniferous forms and the record ended with coniferous dominance.

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THE GEOLOGY OF ADAMS COUNTY

by

LYMAN W. WOOD

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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

IOWA

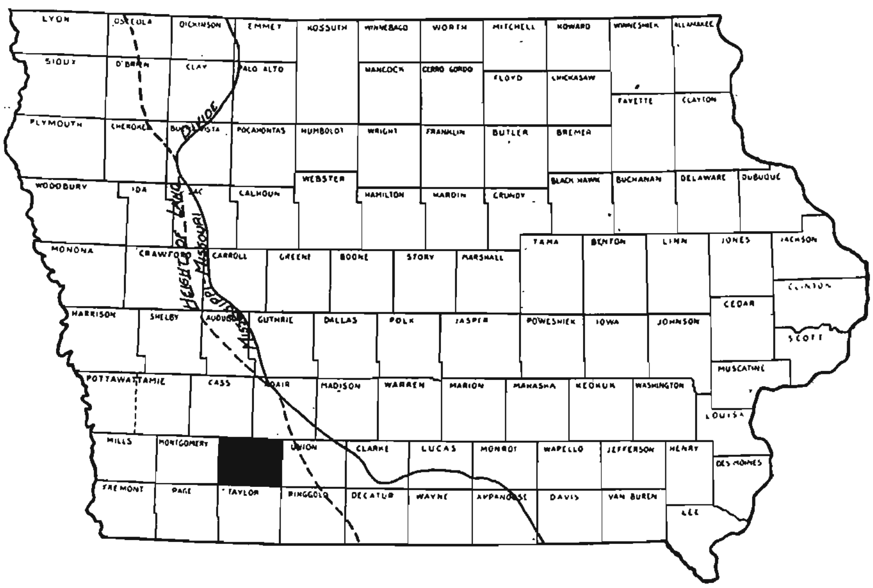

FIG. 1. — Map of Iowa showing location of Adams county with respect to the Mississippi-Missouri divide, and also with respect to the height of land, the probable earlier divide.

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

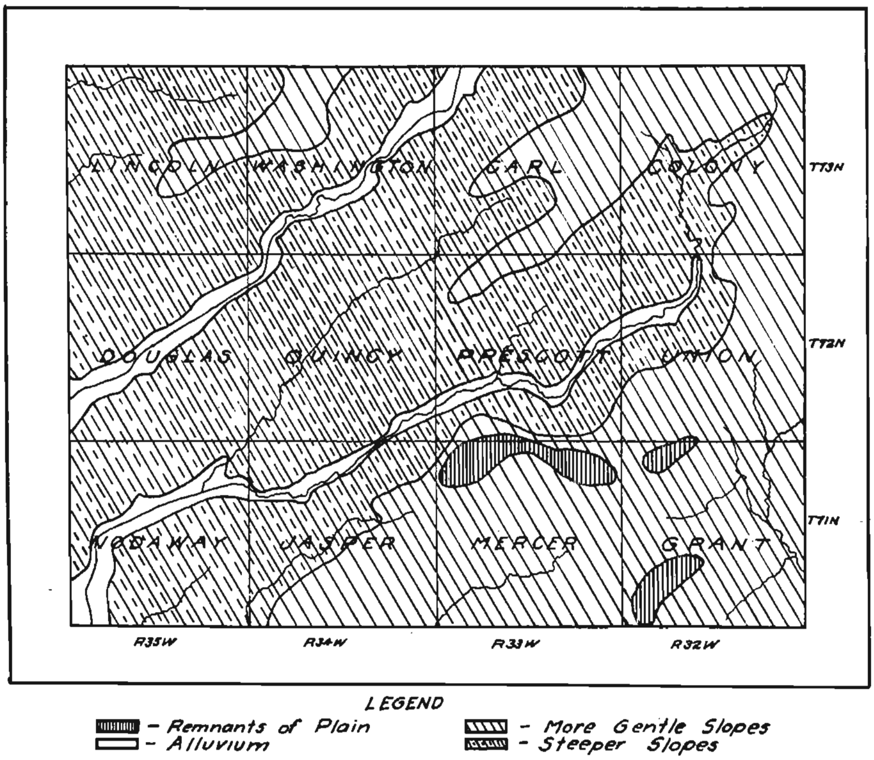

FIG. 2. — Principal topographic units of Adams county.

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-

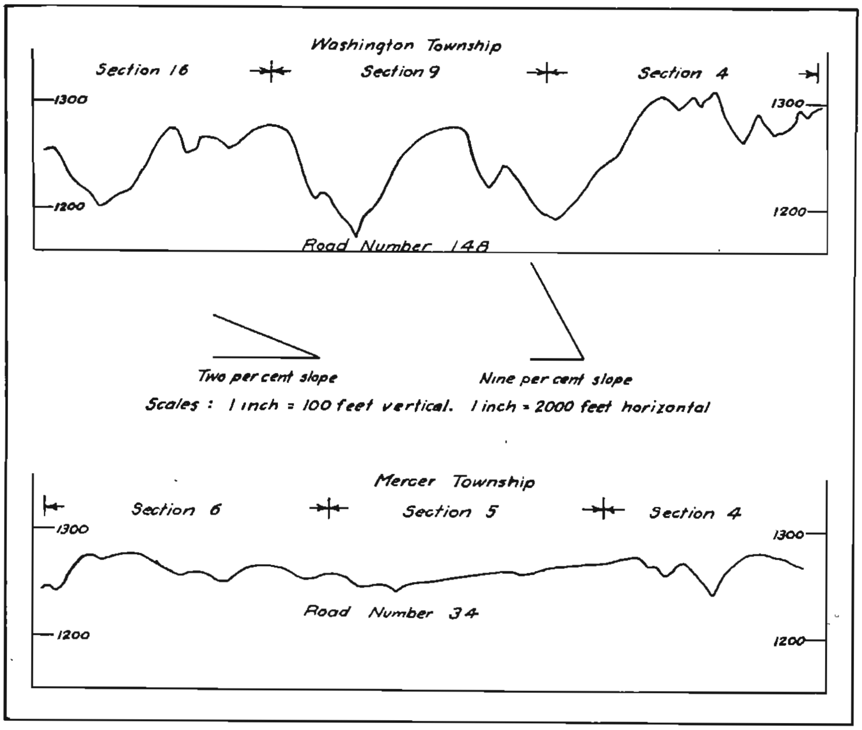

FIG. 5. — Profiles of upland slopes east and north of Corning.

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

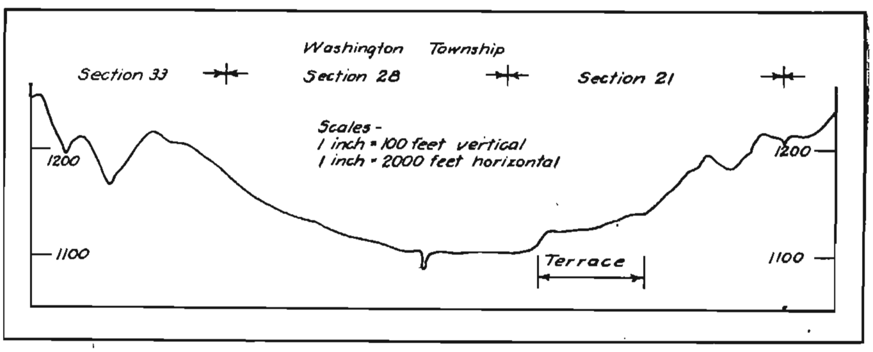

FIG. 6. — Profile across Middle Nodaway River on Road Number 148.

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:

Township	Highest Point		Lowest Point	
	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.

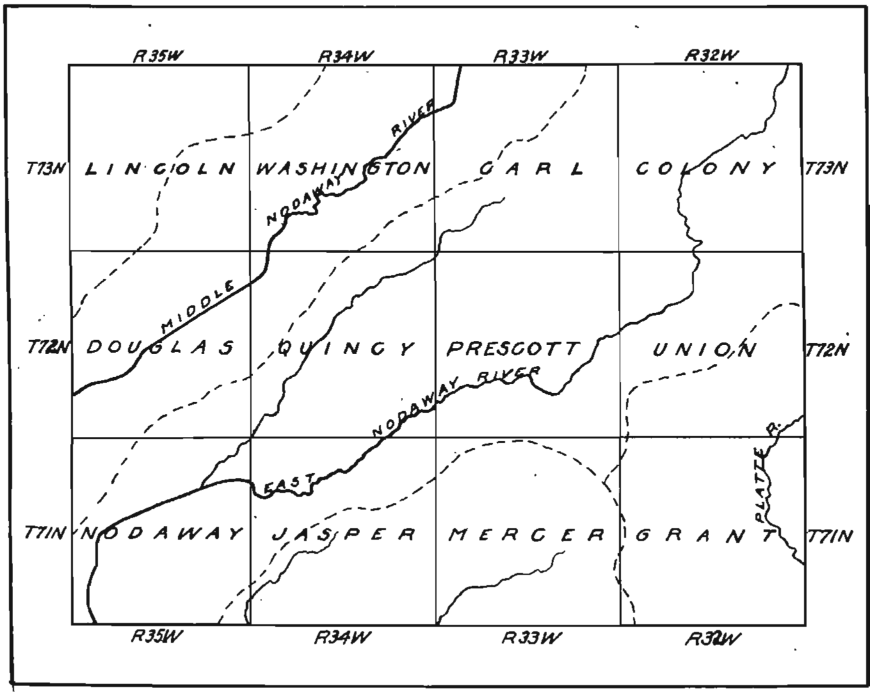

FIG. 8. — Principal streams and drainage basins of Adams county.

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

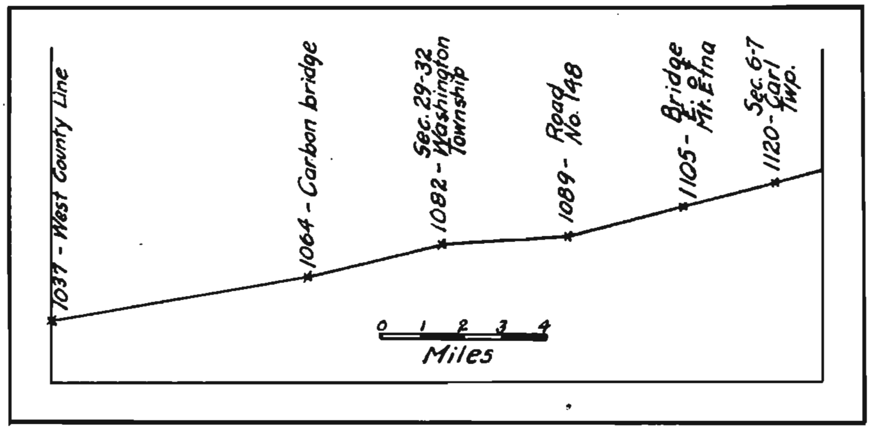

FIG. 9. — Profile of elevation of bed of Middle Nodaway River.

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 timber-clad 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.

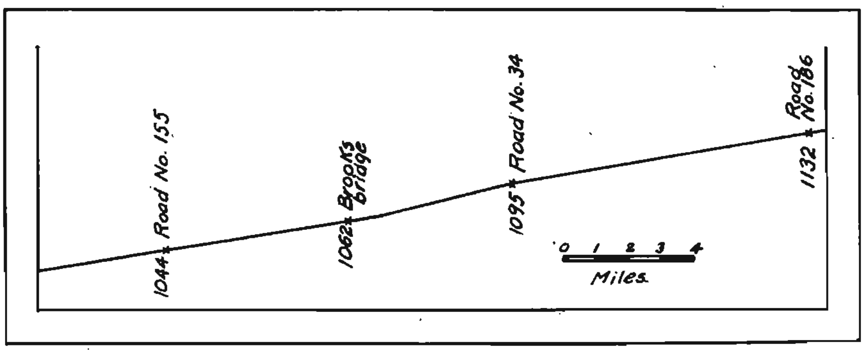

FIG. 10. — Profile of elevation of bed of East Nodaway River.

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

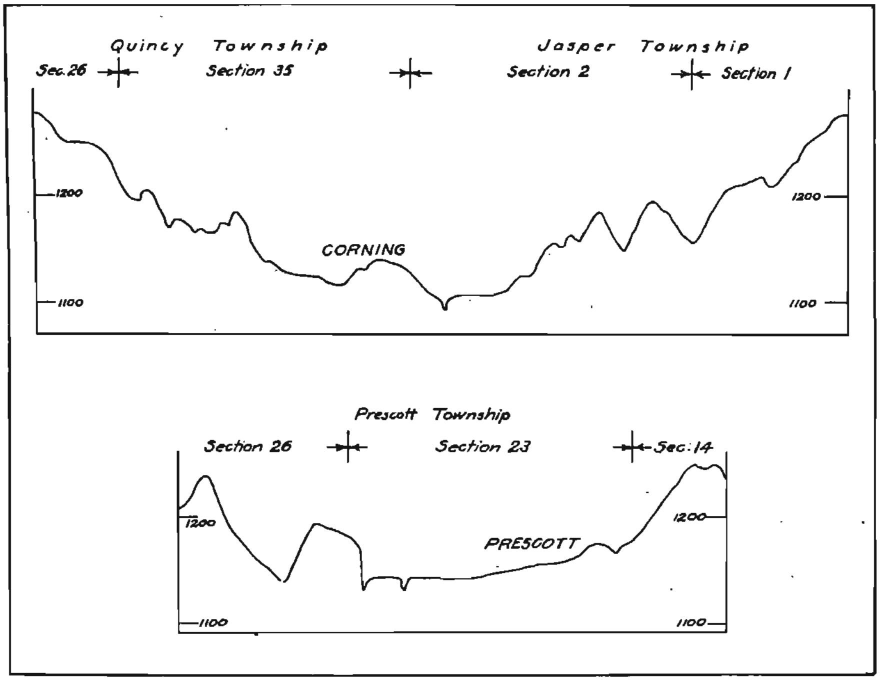

FIG. 11. — Highway profiles across East Nodaway River at Corning and Prescott, showing contrasting widths of flood plain.

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	Algonkian	Sioux
Archeozoic	Not exposed	

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	½–¾
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	2¼
4. Limestone	1¼
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

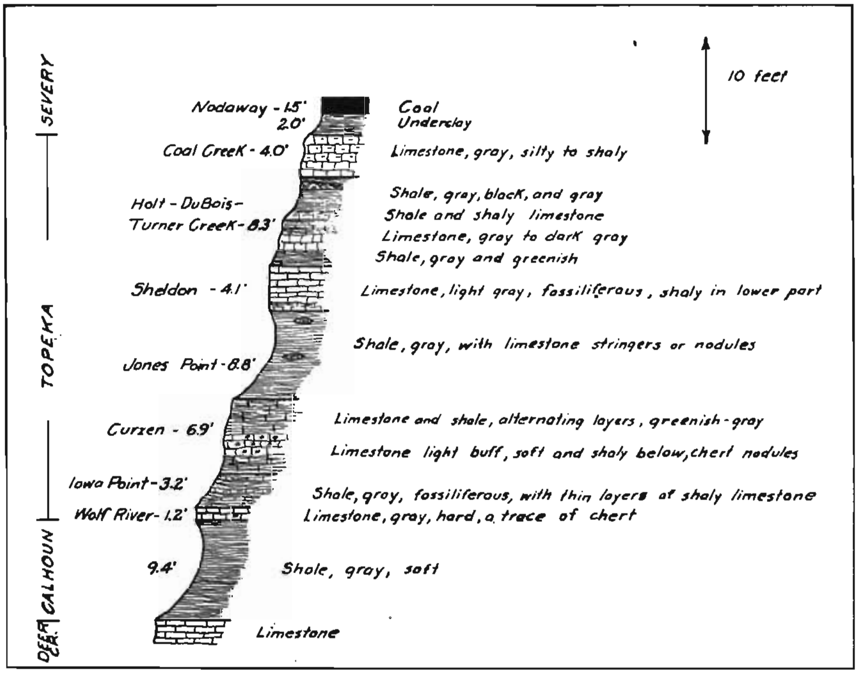

FIG. 13. — Graphic section of Deer Creek-Nodaway interval, from core drillings in sections 28 and 29, Washington township.

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.

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[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	¾
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	2¼
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

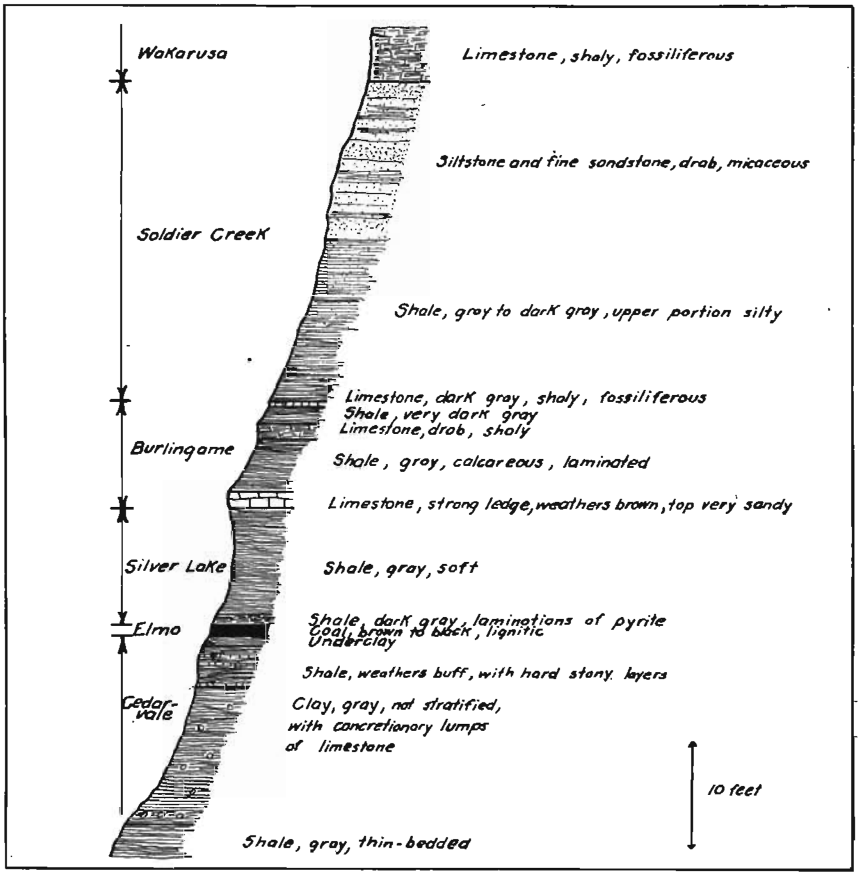

FIG. 14. — Graphic section of the Pennsylvanian in western Adams county.

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

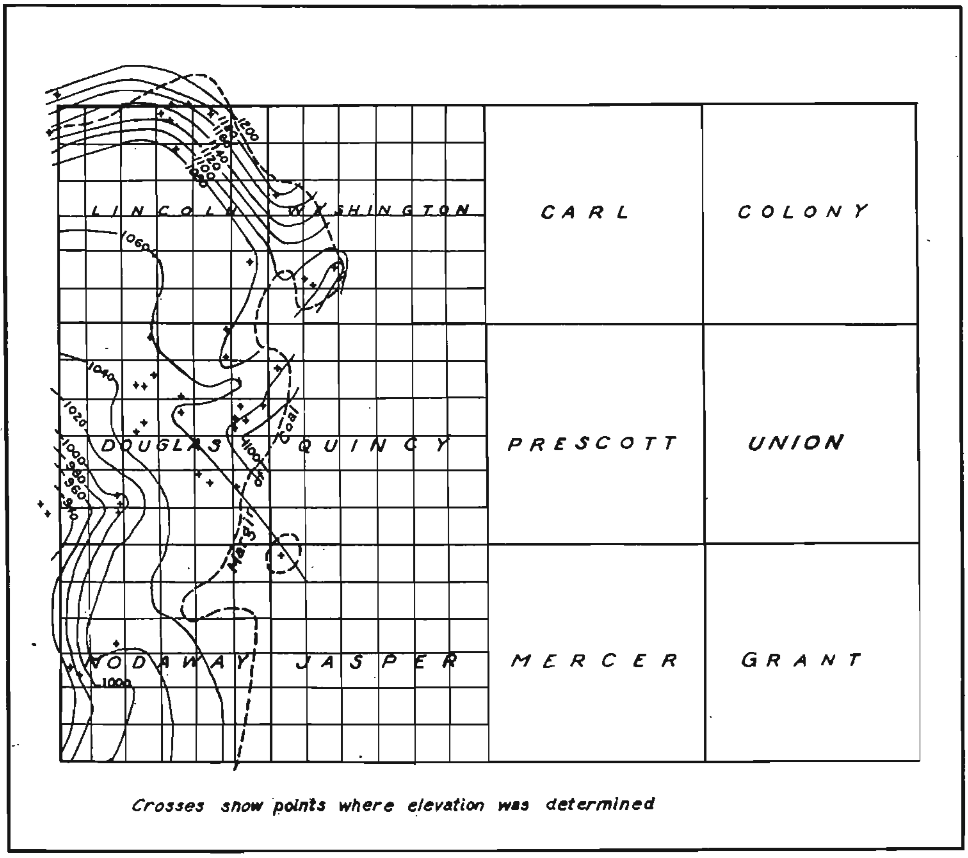

FIG. 15. — Sketch map of Adams county showing elevation of base of Nodaway coal above sea level. Contour interval 20 feet.

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

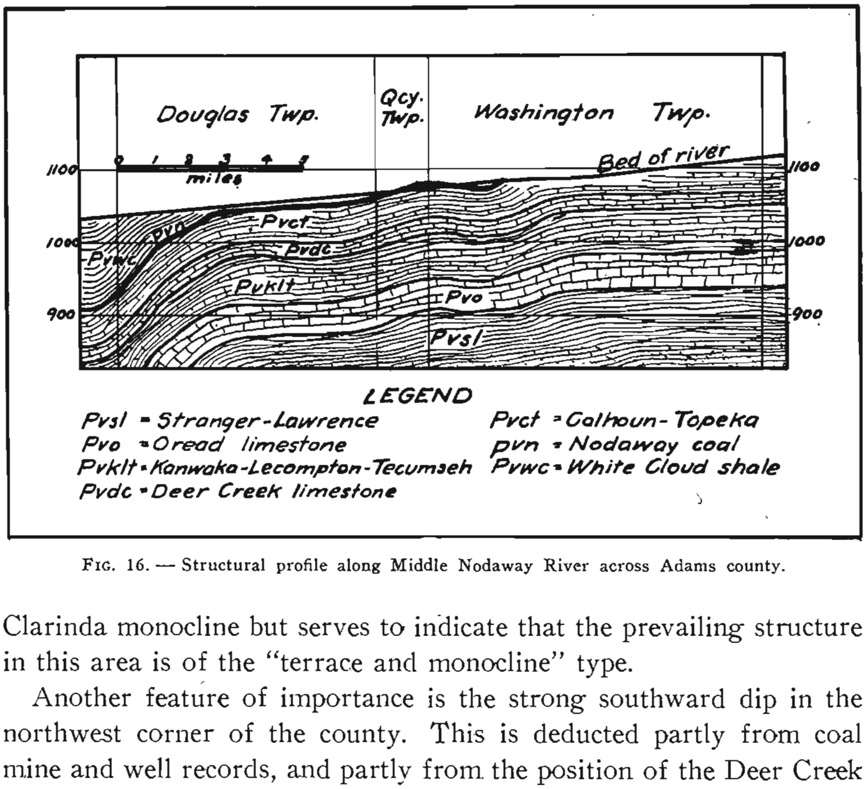

FIG. 16. — Structural profile along Middle Nodaway River across Adams county.

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

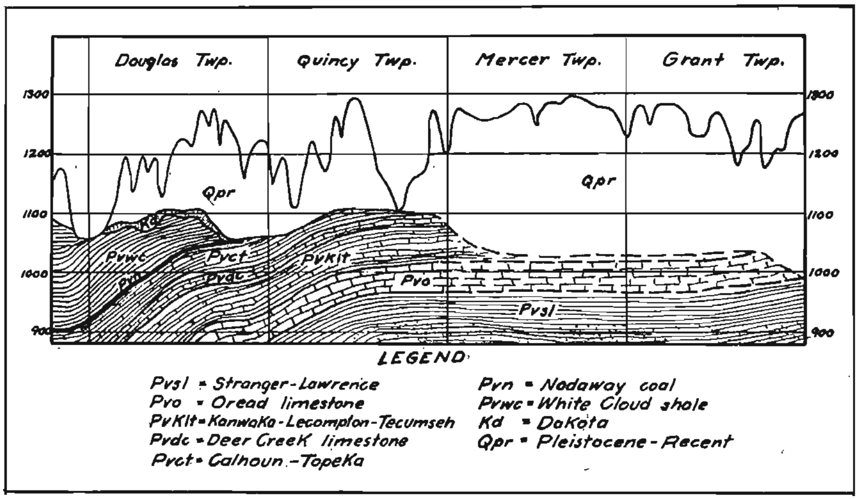

FIG. 17. — Structural profile on road No. 34 across Adams county.

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

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.[87] 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.

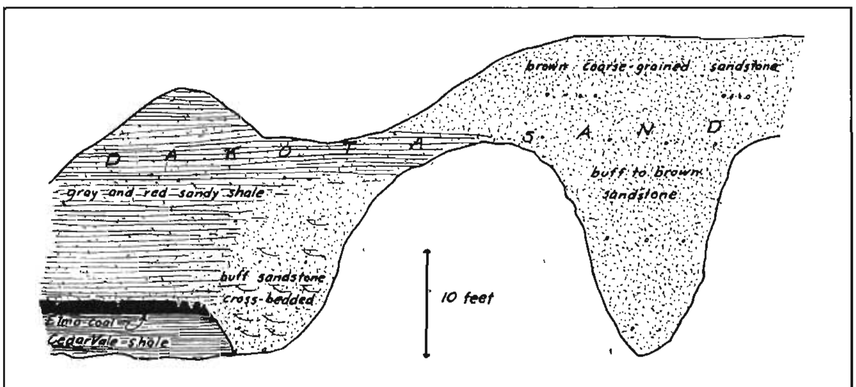

FIG. 18. — Sketch showing Cretaceous sandstones and sandy shales in contact with the Elmo and Cedar Vale formations of the Pennsylvanian north of the southeast corner of section 32, Douglas township.

[87] 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

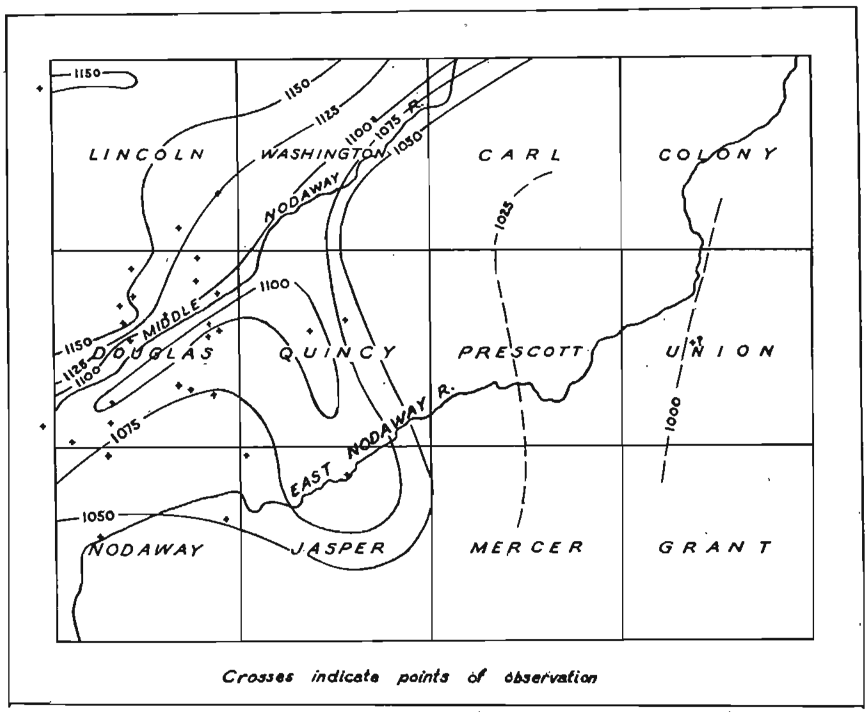

FIG. 20. — Generalized contours at 25-foot intervals on the bedrock surface.

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.

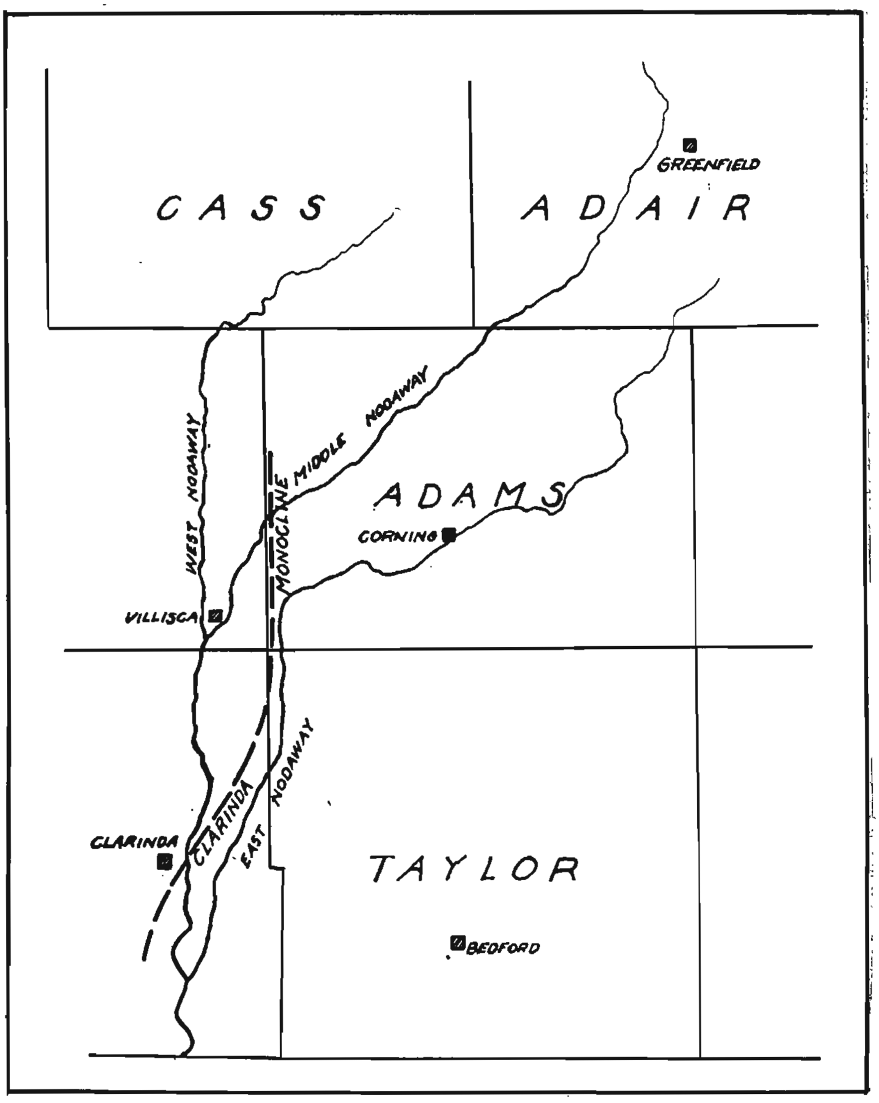

FIG. 21. — Map of Adams and parts of adjoining counties, showing parallelism between axis of Clarinda monocline and courses of Nodaway rivers.

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,

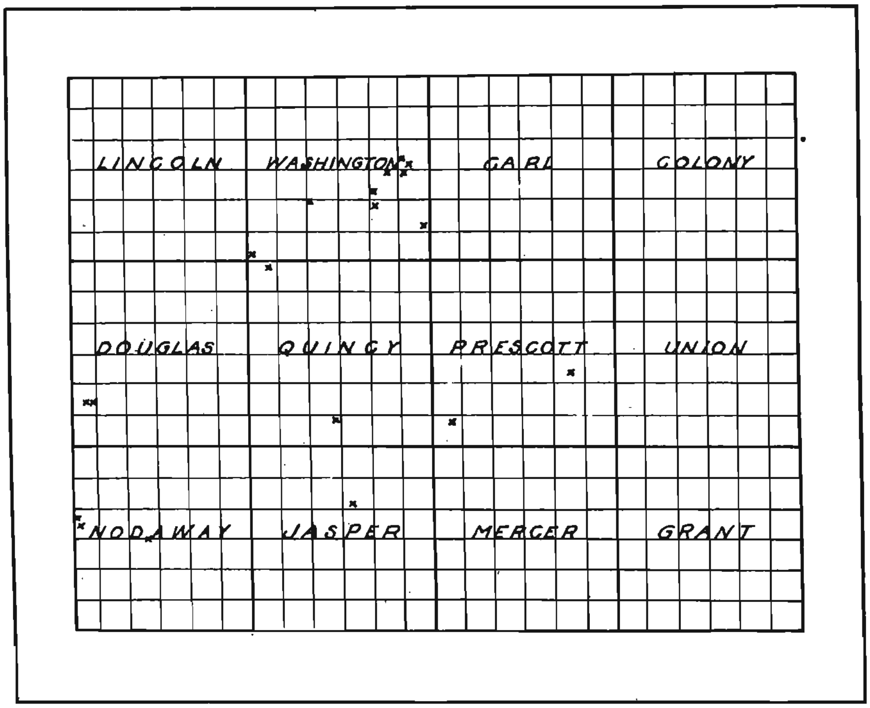

FIG. 22. — Sketch map of Adams county, showing known locations of glacial sands and gravels.

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.*

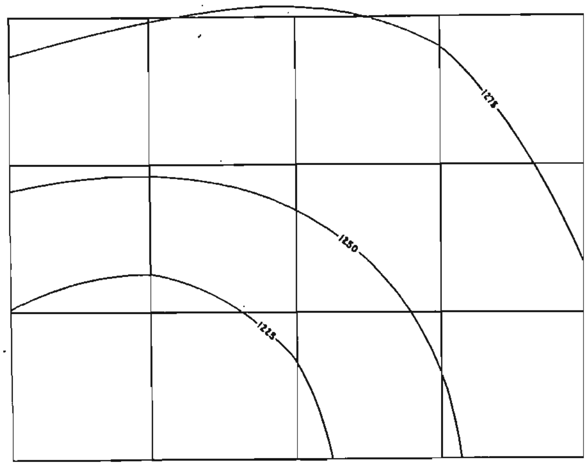

FIG. 23. — Sketch map showing approximate elevation of Kansan gumbotil plain by 25-foot contours.

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.

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[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., The 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]

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[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 bottomland 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			Material Represented	Mechanical Analyses — Percent Particles smaller than						Lower Liquid Limit	Lower Plastic Limit	Plasticity Index
	Section		Township		1.981mm	0.417mm	0.147mm	0.053mm	0.005mm	0.001mm			
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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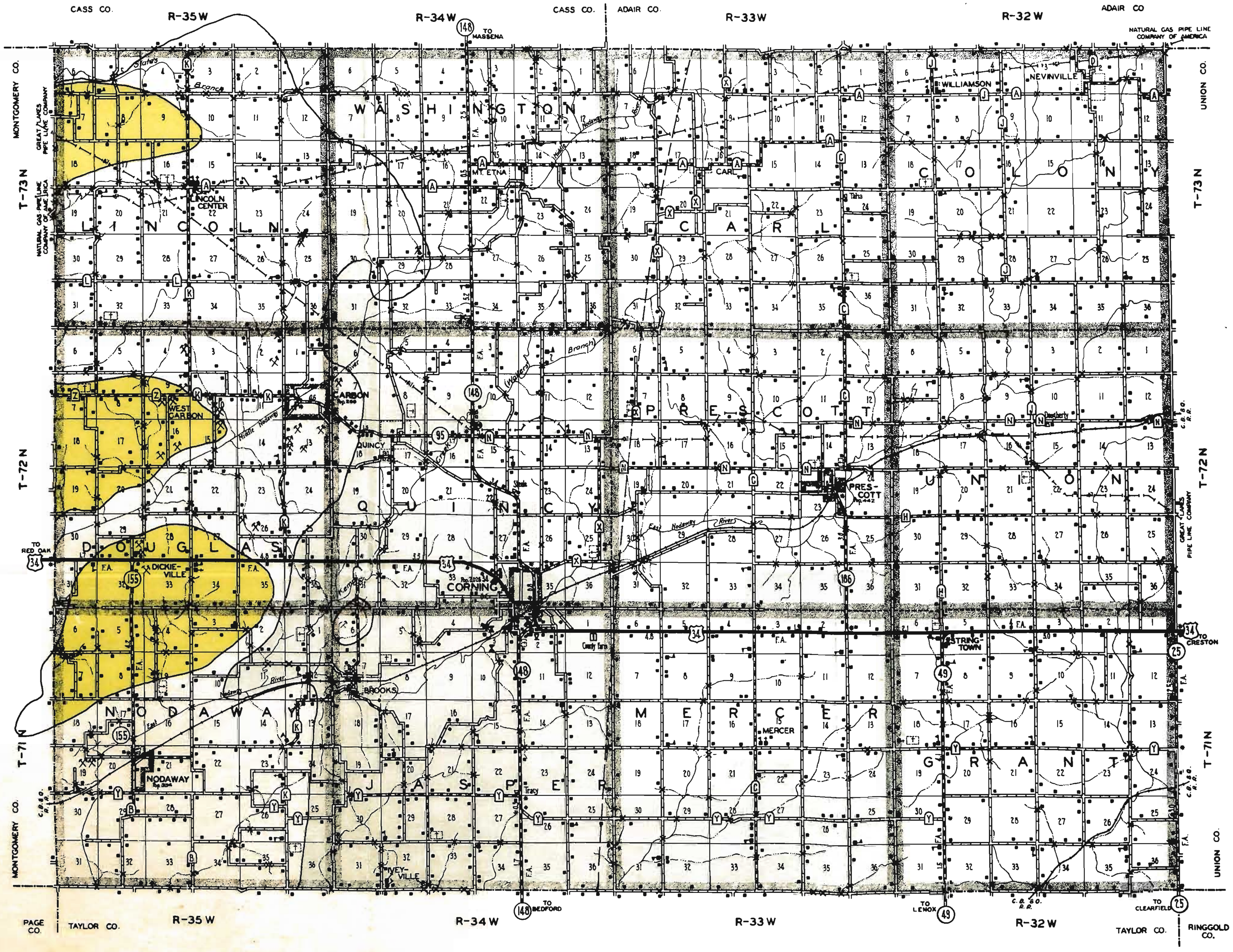

IOWA
GEOLOGICAL SURVEY
Geological Map of ADAMS COUNTY IOWA

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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MINERAL PRODUCTION IN IOWA FOR THE YEARS 1933-1938

by

H. GARLAND HERSHEY

CONTENTS

MINERAL PRODUCTION IN IOWA FOR THE YEARS 1933-1938

Foreword

This report on the mineral production of Iowa from 1933 to 1938 continues the series of statistical summaries published by the Iowa Geological Survey. It is the first such report since the statistics for 1932 were published and has been somewhat delayed because of various changes in personnel and alterations in policy of the Survey to meet increasing public demands for service and information.

The primary function of these reports is to provide in convenient form an accurate record of economic developments and trends in the mineral industries of Iowa for the information and use of the producers and the public.

The form of previous reports is followed as closely as possible in order to facilitate comparison with earlier statistics and, as in the past, the figures on the last year reported (1932) are repeated for comparative purposes. It was found necessary, however, to make certain changes in the presentation of data, which are discussed under their proper headings.

Introduction

All minerals produced in Iowa during the period 1933-1938 were of the nonmetallic type. Of these, coal was the most valuable. It had an average annual value of approximately 8.6 millions of dollars and was followed by cement which averaged about 7.1 millions of dollars for 1936-1938. These two maintained their respective ranks throughout the period of this report. Limestone, gypsum, clay products, and sand and gravel, the other leading mineral products, changed ranking positions almost yearly.

From a national viewpoint gypsum is the most important Iowa mineral produced. In 1935 approximately 14 per cent of the total production of the United States was from Iowa, which again placed her third in rank by production and value, superceded only by New

York and Michigan. Normally these three leading states yield slightly more than 50 per cent of the total domestic output.

In addition to the minerals already mentioned, Iowa produced small amounts of sandstone, peat, and stone listed as miscellaneous. There were few producers of any one of these and, to avoid revealing confidental figures, no individual statistics are presented for them.

No data are available on wool rock utilized by the one plant in the state which began operations in 1937. It is known, however, that only a small amount of raw material from Iowa is utilized.

Lists of operators in each industry except coal are included under the discussion of individual minerals. These lists are the most recent available and include operators producing in 1939, although some nonproducers are also included. They do not include all operators producing during the period of this report. No up-to-date list of coal producers was available when this report went to press.

Acknowledgments

Statistics on the production of most minerals are collected by the United States Bureau of Mines cooperating with the various state geological surveys. Each year the Bureau of Mines publishes the results of their canvasses in a Minerals Yearbook. Most of the data appearing in the report on mineral production in Iowa from 1933 to 1938 were obtained through the cooperative agreement between the Bureau of Mines and the Iowa Geological Survey and from the Minerals Yearbooks covering the period.

The canvass for clay products is made by the United States Bureau of Census and statistics for this industry appearing in the following report were furnished by the Bureau of Census.

The collection of production statistics of the bituminous-coal industry previously conducted by the Bureau of Mines was relinquished on July 1, 1937 to the National Bituminous Coal Commission which has contributed the chapter on bituminous coal to the subsequent Minerals Yearbooks. Statistics on coal for this report for 1936-1938 are taken entirely from the Minerals Yearbooks.

In addition to acknowledging the cooperation of the Federal agencies it is a pleasure to express appreciation to the various mineral producers, particularly in Iowa, for their reports which make the following statistics available.

Tabulation of production figures for this period — begun by Dr.

A. C. Tester in 1934 — was taken over in 1937 by the writer who is responsible for the statements to follow. The tables presenting sand and gravel data by counties were prepared by Mr. Walter C. Schuldt, similar tables on limestone were prepared by Mr. Maxim M. Elias, and Miss Kathryn T. Neuzil assisted in checking all figures.

General Statement

The years 1933-1938 represent a particularly interesting period in the history of mineral production in that they include the latter part of the depression which began in 1929, the recovery period from 1934 to early 1937 and a so-called recession which was believed ended in the last half of 1938.

The year 1934 was a turning point for mineral industries in Iowa. From 1929 until 1933 the total value of mineral products had decreased yearly and in 1933 was $15,154,652, the lowest since 1905. In 1934 an upswing started which resulted in increases each succeeding year including 1937. The recession began too late in 1937 to affect greatly the mineral industries in that year, but its effect was felt in 1938 when there was a decline in total value. Iowa, however, did not suffer as greatly during this period as did the United States as a whole. Conditions improved during the last half of 1938 and at the end of the year the outlook was favorable.

The quantity and value of mineral products in Iowa from 1932 to 1938 are shown in Table I. It should be noted that in 1937 and 1938 a new method of reporting the value of gypsum was instituted which makes it appear that the value dropped sharply in 1937, when as a matter of fact the value of gypsum in Iowa increased in that year (see explanation under Gypsum). This should also be remembered when comparing total state values for 1937 and 1938 with those of earlier years.

Mineral production in the United States which had shown a decrease in value each year since 1929 began an upward trend in 1933. The total value increased yearly until 1937 when it was greater than for 1928 and only slightly less than 1929. Metallics were particularly strong during the 1933-37 period and increased in value each year while the nonmetallics showed an increase each year except for the fuels in 1933 and other nonmetals in 1934. In 1938 the value of both metallics and nonmetallics dropped off sharply because of the recession. In spite of declines in production during late 1937 and early 1938,

TABLE I

Mineral Production in Iowa from 1932 to 1938

	Cement	Clay[a]	Coal	Gypsum	Limestone	Sand and gravel	Miscellaneous	Total value[b]
1932								
Unit	bbls.		tons	tons	tons			
Quantity	4,373,642		3,862,435	178,087	1,591,240[c]	5,230,562		
Value	$3,907,427	805,799	9,254,000	1,468,414	1,389,465	1,706,874	387,064[d]	18,522,625
Producers	5		212	7	53	87[e]		
1933								
Quantity	2,770,656		3,194,983	172,555	1,050,190[f]	4,343,781		
Value	$3,651,921	917,548	7,217,000	1,357,407	920,532	1,165,066	900,203[d]	15,154,652
Producers	5		242	8	60	60		
1934								
Quantity	3,340,049		3,366,992	180,271	2,276,443[c]	4,349,362[c]		
Value	$5,094,922	1,374,469	7,862,000	1,670,356	1,934,364	1,394,000[c]	1,320,509[d, h]	19,326,181
Producers	5		243[g]	8	101	45		
1935								
Quantity	3,203,301		3,650,163	230,203	1,840,080	5,732,742		
Value	$5,072,098	2,039,568	9,002,000	2,215,770	1,645,937	1,756,851	1,714,363[d, h]	21,709,817
Producers	5		263[g]	7	105	49		
1936								
Quantity	4,407,624		3,960,700[i]	344,221[j]	4,003,550	6,293,984		
Value	$6,908,225	2,774,833	9,940,000[i]	3,261,388[j]	3,397,356	2,048,282	1,762,575[d, h]	28,359,140
Producers	5		361[g]	8	130	51		
1937								
Quantity	4,598,453		3,637,054[i]	387,255[k]	4,294,310[l]	6,397,154		
Value	$7,046,021	3,301,548	9,529,000[i, m]	533,162[k]	4,276,891	2,235,103	2,163,370[d, h]	26,941,350[n, p]
Producers	5		340[g]	8	174	107[e]		
1938								
Quantity	4,759,390		3,250,000[m]	364,920	3,369,750[l]	6,994,286[c]		
Value	$7,327,048	2,913,992	8,340,000[m]	495,856	3,782,480	2,299,732[c]		25,159,058[n, p]
Producers	5		300[m]	8	85	107[e]		

a Includes products (other than pottery and refractories) and raw clay sold by producers.
b With duplications eliminated. Value of raw clay excluded 1932-1935 inclusive. Includes peat, sandstone, and miscellaneous stone.
c Revised.
d Includes ferro-alloys and pig iron, value not included in total value for state.
e Includes noncommercial producers.
f Includes sandstone.
g Not comparable with years prior to 1934.
h Includes peat.
i According to National Bituminous Coal Commission.
j Gypsum mined; value as sold (crude and calcined) comparable value for 1937 not available.
k Gypsum mined; value of crude at mine as reported by producers. Comparable value for earlier years not available.
l Includes sandstone and miscellaneous stone.
m Estimated.
n Note change in method of reporting gypsum.
p Total value for 1937-1938 not comparable with earlier years.

the mineral industries enjoyed better conditions than did business in general. Table II shows statistically the mineral production in the United States for the period of this report.

TABLE II

Mineral Production in the United States from 1932 to 1938

Year	Metallic	Nonmetallic			Grand Total
		Fuels[1]	Other	Total	
1932	$ 285,875,000	$1,743,400,000	$432,425,000	$2,175,825,000	$2,461,700,000
1933	417,065,000	1,683,400,000	454,635,000	2,138,035,000	2,555,100,000
1934	548,934,000	2,233,300,000	543,166,000	2,776,466,000	3,325,400,000
1935	733,130,000	2,330,000,000	586,870,000	2,916,870,000	3,650,000,000
1936	1,081,600,000	2,759,200,000	716,000,000	3,475,200,000	4,556,800,000
1937	1,468,200,000	3,200,500,000	744,900,000	3,945,400,000	5,413,600,000
1938[2]	891,800,000	2,804,700,000	657,500,000	3,462,200,000	4,354,000,000

1 Coal, natural gas, natural gasoline, petroleum.
2 Subject to revision.

Cement

The cement industry depends for markets directly upon construction. Concrete highway paving and building, the two principal outlets, consume more than half of the output of portland cement manufactured in an average year. The remainder is consumed by other forms of construction such as sidewalks, bridges, dams, sewage and waterworks, railway maintenance, miscellaneous jobs on farms, and river and harbor improvements.

In Iowa, cement followed the general pattern of recovery from the depression, although recovery was somewhat slower than for some other mineral products. It continued a downward trend through 1933 but in that year suggestions of the recovery to follow were in evidence. The average price per barrel at the plant increased more than 48 per cent in 1933, 15.9 additional per cent in 1934 and since then has maintained a fairly steady level. The peak price of $1.58 was reached in 1935. Shipments, after a decrease in 1933 caused in part by advanced price, increased in quantity and value each year except 1935. In 1934 and 1936 the quantity of Iowa cement shipped, represented increases of 21 per cent and 38 per cent respectively over shipments of the previous year. Production, after 1933, increased each year with the largest quantity advances in 1935 (11 per cent), 1936 (16 per cent) and 1937 (15 per cent).

The condition of the industry in Iowa for the period 1935-1938 was better than for the country as a whole. A comparison of the statistics for Iowa (Table III) and for the United States (Table IV) shows that

TABLE III

Production of Cement in Iowa from 1932 to 1938

Year	Production		Shipments				Stock at Mills Dec. 31		Annual capacity	Plants active
	Barrels	Per cent change over previous year	Barrels	Value	Average price per barrel	Per cent change in quantity over previous year	Barrels	Per cent change over previous year		
1932	4,270,739	—26	4,373,642	$3,907,427	$0.89	—23	1,311,583[a]	—7	10,293,900	5
1933	3,044,008	—29	2,770,656	3,651,921	1.32	—37	1,605,116[a]	+22		5
1934	3,180,546	+4	3,340,049	5,094,922	1.53	+21	1,445,613[a]	—10	10,006,710	5
1935	3,519,558	+11	3,203,301	5,072,098	1.58	—4	1,761,870	+22	10,066,710	5
1936	4,099,121	+16	4,407,624	6,908,225	1.57	+38	1,462,146	—17		5
1937	4,706,094	+15	4,598,453	7,046,021	1.53	+4	1,569,787	+7		5
1938	4,726,517	+0.4	4,759,390	7,327,048	1.54	+3	1,536,914	—2		5

a Revised.

TABLE IV

Production of Cement in the United States from 1932 to 1938

Year	Production		Shipments				Stock at Mills, December 31	
	Barrels	Per cent change over previous year	Barrels	Value	Average factory value per barrel	Per cent change in quantity over previous year	Barrels	Per cent change over previous year
1932	76,740,945	—39	80,843,187	$ 82,021,723	$1.01	—36	20,351,058[a]	—12
1933	63,473,189	—17	64,282,756	85,583,916	1.33	—20	19,605,323[a]	—4
1934	77,747,765	+22	75,901,279	116,921,084	1.54	+18	21,440,594[a]	+9
1935	76,741,570	—1	75,232,917	113,372,182	1.51	—1	22,949,247[a]	+7
1936	112,649,782	+47	112,849,979	170,415,302	1.51	+50	22,568,685	—2
1937	116,174,708	+3	113,804,782	168,835,208	1.48	+1	24,938,612	+11
1938	105,357,000	—9	106,324,127	153,977,226	1.45	—7	23,946,118	—4

a Revised.

Iowa productions, shipments and prices were below average for 1933 and 1934. In the years following, however, Iowa cement had a more steady advancement than cement in the United States in general. It is notable that the price was from 5 to 9 cents per barrel above the United States figures and that there was no reduction in the quantity or value of Iowa shipments, production or price in 1938 when all of these decreased for the country as a whole.

Production of cement in the United States was highly variable during the period of this report. It was far below the general level of business in 1932 and 1933, and in 1933 shipments reached the lowest level in twenty-five years, although in that year there was a marked general increase in price.

The decline in United States cement production in 1933 was caused by the sharp drop in concrete paving contract awards and the continued slump in building construction. The increases in construction contract awards, due largely to Public Works Administration activity, arrived too late in the year to prevent the decline. They are reflected, however, in the advance in shipments in 1934 in spite of the fact that residential building remained at a low level. Production and shipments fell off in 1935 and in that year two new plants were put into operation, the first new plants since 1929.

In 1936 there were increases of 47 per cent in quantity and 50 per cent in value. These advances were brought about by extensive highway building, large Federal Public Works projects and renewed activity in private construction. There was a slight increase in production and quantity shipped in 1937, but the value of shipments declined because of the 2-per cent drop in price. The average price per barrel increased almost 32 per cent in 1933, 16 per cent in 1934 and decreased 2 per cent each year in 1935, 1937 and 1938. In the last named year, production and shipments also fell off although during the last quarter of 1938 figures were above those for the same period in 1937 and the outlook appeared bright.

Manufacturers of Portland Cement in Iowa

Cerro Gordo County

Lehigh Portland Cement Co., B. L. Swett, Vice President, Young Building, Allentown, Pa. Plant at Mason City, Iowa.

Northwestern States Portland Cement Co., Peter Andersen, Secretary, First National Bank Building, Mason City, Iowa. Plant at Mason City, Iowa.

Pocahontas County

Northwestern States Portland Cement Co., First National Bank Building, Mason City, Iowa. Plant at Gilmore City, Iowa.

Polk County

Hawkeye Portland Cement Co., B. E. Manley, General Manager, Hubbell Building, Des Moines, Iowa. Plant at Des Moines, Iowa.

Pennsylvania-Dixie Cement Corp., R. A. Bechtold, Superintendent, 208 Old Colony Building, N. E. Corner 10th & Grand Avenue, Des Moines, Iowa. Plant at West Des Moines, Iowa.

Scott County

Dewey Portland Cement Co., F. E. Tyler, President, 101 West 11th Street, Kansas City, Missouri. Plant at Davenport, Iowa.

Clay

Clay, which suffered more serious declines than any other Iowa mineral product during the early part of the depression, rallied more strongly than any other product except limestone during the period 1933-1938. Total value increased over the previous year in 1933 and in each of the succeeding years except 1938. The greatest advances as shown by Table V were attained in 1934 and 1935 when they amounted to 49.8 per cent and 48.4 per cent respectively, and were never less than the 13.8 per cent gain in 1933, while the decline in 1938 amounted to only 11.7 per cent. The value in 1937 was more than four times that in 1932.

Statistics for most mineral products are collected by the Bureau of Mines cooperating with the state geological surveys. These agencies obtain data concerning the amount of clay sold either raw or prepared, but not made into wares. For clay wares the canvasses are made without the cooperation of the state surveys by the Bureau of Census, which reports clay products by class, quantity, and value. It is not known if the same producers are reached by both canvasses.

Sales of the various raw and prepared clays in Iowa followed a strong upward trend in total quantity and total value, but individually were extremely erratic during the period of this report. For example, fire clay in 1933 increased more than 730 per cent in quantity and more than 850 per cent in value, in 1934 decreased 82 per cent in

TABLE V

Value of Clay Products and Raw Clay in Iowa from 1932 to 1938

	1932	1933	1934	1935	1936	1937	1938
Clay products	$796,445	$842,726	$1,352,227	$2,006,021	$2,728,810	$3,250,677	$2,868,233
Clay, raw	9,354	74,822	22,242	33,547	46,023	50,871	45,759
Total	805,799	917,548	1,374,469	2,039,568	2,774,833	3,301,548	2,913,992

TABLE VI

Sales of Clay in Iowa from 1932 to 1938

	1932	1933	1934	1935	1936	1937	1938
Fire Clay							
Short tons	858	7,158	1,255	2,143	1,094	(a)	773
Value	$7,255	$69,169	$11,651	$20,726	$12,635	(a)	$ 9,034
Active producers	5	6	6	6	3	2	3
Miscellaneous Clay							
Short tons	2,575	2,221	1,017	1,132	3,317[b]	(a)	6,055
Value	$2,099	$ 5,653	$10,591	$12,821	$33,388	(a)	$36,725
Active producers	2	5	5	3	7	7	8
Total							
Short tons	3,433	9,379[c]	2,272	3,275	4,411	4,600	6,828
Value	$9,354	$74,822	$22,242	$33,547	$46,023	$50,871	$45,759
Active producers	6	10	10	9	10	8	10

a Withheld to avoid disclosing, exactly or approximately, data reported by individual establishments.
b Includes shale.
c Includes ground clay, modeling clay and shale.

quantity and 83 per cent in value, in 1935 increased 71 per cent in quantity and 78 per cent in value and again decreased in 1936 and 1938. Clays listed as "miscellaneous" also varied, but not as greatly as did the fire clay. The apparent discrepancy between the annual quantities and values of miscellaneous clays is due to difference in price of the various clays included under this general heading. Table VI presents the salient features of this portion of the clay industry.

Clay products after disastrous reversals, particularly in 1932, began a recovery in 1933 which resulted in a material increase in total value each year until 1938. The decline in 1938 was not serious and the total value for that year was higher than for 1936.

The production of clay products by classes in 1935 and 1936 is shown by Table VII. Hollow partition building tile leads all other

TABLE VII

Production of Clay Products in Iowa by Class, Quantity and Value, 1935-1936

	1935		1936	
	Quantity (thousands)	Value	Quantity (thousands)	Value
Common brick	30,187	$330,585	39,660	$424,066
Face brick	10,047	144,385	16,404	225,064
Vitrified brick	(a)	(a)	(a)	(a)
	Short tons		Short tons	
Hollow building tile				
Partition	130,671	762,519	177,088	1,064,123
Floor arch	16,827	119,497	29,254	203,893
Drain tile				
Vitrified	13,896	109,326	19,518	148,796
Unvitrified	22,134	161,156	24,336	182,765
Sewer pipe	21,061	295,429	31,561	423,018
Flue lining	3,457	43,169	3,376	37,711
Wall coping	405	6,229	499	8,388
	Square feet		Square feet	
Floor tile	(a)	(a)	(a)	(a)
Total		1,972,568		2,717,824

a Concealed to avoid revealing confidential information.

classes by a considerable margin and was followed in value by common brick, sewer pipe, face brick, and unvitrified drain tile in the order named. Detailed figures for clay production during 1933-1934 and 1937-1938 were not available when this report went to press.

The domestic potteries industries in the United States were relatively inactive in 1933. There was a sharp decline in sales of clay for stoneware, but recoveries in paper making and refractories manufacture reflected in clay sales for those uses. Fire clay and bentonite increased about 50 per cent. In 1934 shipments in virtually all kinds of clay began or continued to recover, and except for stoneware, continued this trend in 1935. Advances were even more marked for 1936 when production and sales of domestic kaolin broke all previous records. In 1937 china clay production and sales and ball clay shipments broke all previous records and fire clay sales were greater than for any earlier year, except 1929. Heavy clay products likewise improved further in 1937, but the recession made itself felt during the last quarter of 1937 and in early 1938 there were drastic reversals of the progress which the clay industry had made during the previous few years, although heavy clay products fell off only slightly. Building-contract awards increased substantially during the latter part of 1938 and there appeared to be every indication that clay production would again advance in 1939.

Clay Operators in Iowa

Cerro Gordo County

Lehigh Portland Cement Co., Young Building, Allentown, Pa. Mine at Mason City, Iowa.

Mason City Brick and Tile Co., 19 West State Street, Mason City, Iowa.

Dallas County

Adel Clay Products Co., Adel, Iowa. Mine at Redfield, Iowa.

Floyd County

Rockford Brick & Tile Co., Rockford, Iowa.

Keokuk County

What Cheer Clay Products Co., What Cheer, Iowa.

Mahaska County

Maria Hansel, Oskaloosa, Iowa.

Polk County

Goodwin Tile & Brick Co., Box 283, S. E. 18th & Hartford Avenue, Des Moines, Iowa.

Wapello County

Morey Clay Products Co., Ottumwa, Iowa.

Webster County

Johnston Clay Works, Inc., 214 First National Bank Building, Fort Dodge, Iowa. Clay works near Fort Dodge, Iowa.

Kalo Brick & Tile Co., 603 Snell Building, Fort Dodge, Iowa. Mine at Coalville, Iowa.

George F. Drain, Lehigh, Iowa.

TABLE VIII

Summary of the Bituminous-coal Industry in Iowa from 1932 to 1938

	Production in net tons	Value		Number of Employees			Average number of days mine operated	Average tons per man per day
		Total	Average per ton	Underground	Surface	Total		
1932	3,862,435	$9,254,000	$2.40	7,183	903	8,086	151	3.17
1933	3,194,983	7,217,000	2.26	6,591	1,104	7,695	138	3.01
1934	3,366,992	7,862,000	2.34	6,687	1,034	7,721	156	2.80
1935	3,650,163	9,002,000	2.47	6,998	1,040	8,038	162	2.80
1936	3,960,700[c]	9,940,000[cd]	2.51[cd]	7,575[c]	1,166[c]	8,741[c]	163[c]	2.78[c]
1937	3,637,054[a]	9,529,000[cd]	2.62[cd]	(f)	(f)	8,720[bc]	146[c]	2.87[c]
1938	3,250,000[ce]	8,340,000[de]	2.56[de]	(f)	(f)	(f)	(f)	(f)

a Total production including inventory change and coal unaccounted for.
b Average number of employees.
c According to National Bituminous Coal Commission.
d Estimated from various sources, includes selling expenses, and is not comparable with values of earlier years.
e Estimated.
f Not available.

Lehigh Sewer Pipe & Tile Co., Fort Dodge, Iowa. Mine at Lehigh, Iowa.

Vincent Clay Products Co., 617 State Bank Building, Fort Dodge, Iowa.

Coal

Coal is the most valuable mineral resource of Iowa on which statistics are available. Normally coal production represents over 40 per cent of the total annual mineral output of the State and because of the markets which it supplies, it is usually one of the most stable of mineral products. For the period of this report it did not react as favorably in general as did some of the other minerals in Iowa. It reached the bottom of the depression low in 1933, one year later than coal over the country as a whole, recovered in 1934, 1935 and 1936, and fell off in 1937 a year before the recession was felt in United States production. However, during the period of this report the price per ton was from $1.01 to $0.69 above the United States average.

Statistics on the general condition of the industry in Iowa may be found in Table VIII and for the United States in Table IX. The data

TABLE IX

Summary of Bituminous-coal Industry in the United States from 1932 to 1938

	Production	Value at mines	Average value per ton	Stocks[a]		Consumption (calculated)
				January 1	December 31	
1932	309,709,872	$406,677,000	$1.31	35,500,000	29,666,000	306,917,000
1933	333,630,533	445,788,000	1.34	29,666,000	32,840,000	321,748,000
1934	359,368,022	628,112,000	1.75[b]	32,840,000	34,476,000	347,043,000
1935	372,373,122	658,063,000	1.77	34,476,000	37,017,000	360,291,563
1936	439,087,903	772,794,709[c]	1.76	37,017,000	42,926,000	422,795,741
1937	445,531,449	868,786,325[c]	1.95[d]	42,926,000	47,074,000	428,496,767[e]
1938	344,630,000[f]			47,074,000	40,720,000[f]	340,735,036[f, e]

a Commercial consumers and retail yards.
b F. O. B. mine.
c Arrived at by multiplying figure for "production" by figure for "average value per ton."
d Average gross realization including selling price. Not comparable with years prior to 1937.
e Production plus imports minus exports plus or minus changes in consumers stock.
f Preliminary.

used in coal reports for all years pertain only to commercial mines with an annual output of 1,000 tons or more. No figures comparable to earlier years are available after 1935 for total value and price per ton except as noted.

In 1933 the total quantity of Iowa coal declined 667,452 net tons or about 17 per cent from the 1932 figure, the price fell 14 cents per ton to a depression low of $2.26, and the total value decreased over two millions of dollars while the number of men employed decreased 5 per cent.

Recovery began in 1934 when production, total value, price, number of men employed, and average number of days mines operated increased over the preceding year. In 1935 there were further increases in all phases of the industry which carried over through 1936 when production, value and the number of men employed were all greater than for 1932 and the ensuing years. The recession made itself felt in 1937 when there was a decrease in production, operating time, and men employed. Production and other detailed statistics by counties for 1938 were not available when this report went to press.

More detailed information on production by counties may be found in Tables X to XIV. By way of general summary of these tables, the leading counties in production and value are listed below in the order of rank.

1933 Total quantity:	Polk, Lucas, Boone, Marion, Appanoose, Dallas
Total value:	Polk, Boone, Lucas, Dallas, Appanoose, Marion
1934 Total quantity:	Lucas, Polk, Appanoose, Boone, Dallas, Monroe
Total value:	Polk, Lucas, Boone, Appanoose, Dallas, Monroe
1935 Total quantity:	Appanoose, Polk, Lucas, Boone, Dallas, Marion
Total value:	Appanoose, Polk, Boone, Lucas, Dallas, Marion
1936 Total quantity:	Appanoose, Lucas, Polk, Boone, Dallas, Marion
1937 Total quantity:	Appanoose, Marion, Polk, Lucas, Dallas, Boone

The bituminous-coal industry in the United States, a summary of which appears in Table IX, started an upswing in 1933 which carried through 1937. Total production increased about 22 millions of tons in 1933, over 26 millions in 1934, about 13 millions in 1935 and almost 67 millions in 1936, but dropped almost 101 millions of tons in 1938 according to the preliminary data for that year. The average value per ton increased from $1.31 in 1932 to $1.77 in 1935, which represents an advance of 35 per cent. The greatest annual increase in price came in 1934 when the average value reached $1.75 per ton as compared to $1.34 for 1933. For a more complete review of coal production by states for the period 1933-1937 see Tables XV-XIX.

The advance in price and improvement in the employment situation was at least partly due to National Recovery Administration activities

TABLE X

Production, Value, Men Employed, Days Operated, and Output Per Man Per Day at Bituminous-coal Mines in Iowa in 1933

County	Net Tons					Value		Number of Employees			Average number of days mines operated	Average tons per man per day
	Loaded at mines for shipment	Commercial sales by truck or wagon	Sold to local trade or used by employees or taken by locomotives at tipple	Used at mines for power and heat	Total quantity	Total	Average per ton	Underground	Surface	Total		
Adams	....	16,901	1,612	65	18,578	$ 51,000	$2.75	84	10	94	162	1.22
Appanoose	249,050	65,320	5,135	509	320,014	684,000	2.14	1,399	173	1,572	79	2.59
Boone	316,711	95,947	3,216	2,157	418,031	1,044,000	2.50	912	94	1,006	156	2.66
Dallas	212,135	76,264	12,979	1,476	302,854	709,000	2.34	491	37	528	178	3.23
Davis	....	3,350	....	60	3,410	7,000	2.05	4	11	15	74	3.09
Greene	....	45,396	....	....	45,396	115,000	2.53	58	20	78	116	5.02
Guthrie	....	9,835	....	22	9,857	36,000	3.65	76	10	86	105	1.09
Jasper	....	50,554	....	1,921	52,475	122,000	2.32	129	23	152	108	3.19
Keokuk	....	16,549	....	5	16,554	34,000	2.05	18	37	55	163	1.84
Lucas	420,466	6,148	2,077	7,582	436,273	976,000	2.24	595	58	653	177	3.78
Mahaska	1,300	53,695	2,386	814	58,195	124,000	2.13	105	62	167	144	2.41
Marion	291,417	66,705	2,634	5,668	366,424	627,000	1.71	649	198	847	116	3.74
Monroe	210,572	20,703	3,394	1,852	236,521	488,000	2.06	491	52	543	132	3.31
Page	....	30,827	1,238	....	32,065	110,000	3.43	100	10	110	172	1.69
Polk	75,891	379,929	71,742	4,845	532,407	1,215,000	2.28	894	76	970	179	3.07
Taylor	202	10,800	1,200	24	12,226	39,000	3.19	36	5	41	132	2.26
Van Buren	....	6,587	....	842	7,429	14,000	1.88	22	6	28	137	1.94
Wapello	5,407	74,998	715	1,529	82,649	185,000	2.24	175	40	215	170	2.26
Warren	16,492	155,489	280	4,066	176,327	437,000	2.48	198	105	303	159	3.65
Wayne	2,085	17,095	268	419	19,867	41,000	2.06	88	12	100	116	1.71
Webster	1,466	34,553	....	....	36,019	133,000	3.69	54	37	91	182	2.17
Other counties, Hamilton, Jefferson, and Scott	....	11,382	....	30	11,412	26,000	2.28	13	28	41	111	2.50
Total 1933	1,803,194	1,249,027	108,876	33,886	3,194,983	7,217,000	2.26	6,591	1,104	7,695	138	3.01
Total 1932	2,651,754	(1)	(1)	32,252	3,862,435	9,254,000	2.40	7,183	903	8,086	151	3.17

(1) In 1932 there were 248,225 tons reported by the operator as "trucked 10 miles or more from mine" (including 20,848 tons, a part of which went less than 10 miles, separation not possible) and 930,204 tons reported as "sales to local trade, used by employees, or taken by locomotives at tipple (including sales by truck within 10 miles of mine)." The sum of these two items in 1932, which amounted to 1,178,429 tons, is exactly comparable with the sum of columns (2) and (3) in 1933 — namely, 1,357,903 tons.

TABLE XI

Production, Value, Men Employed, Days Operated and Output Per Man Per Day at Bituminous-coal Mines in Iowa in 1934

	Net Tons					Value		Number of Employees				
County	Loaded at mines for shipment	Commercial sales by truck or wagon	Sold to local trade or used by employees or taken by locomotives at tipple	Used at mines for power and heat	Total quantity	Total	Average per ton	Underground	Surface	Total	Average number of days mines operated	Average tons per man per day
Adams	....	20,271	548	45	20,864	$ 59,000	$2.83	101	11	112	151	1.23
Appanoose	378,103	70,115	8,407	713	457,338	1,033,000	2.26	1,429	155	1,548	119	2.42
Boone	330,982	91,674	4,005	4,309	430,970	1,097,000	2.55	966	78	1,044	172	2.40
Dallas	268,274	58,858	3,995	780	331,907	820,000	2.47	539	38	577	196	2.94
Greene	....	62,345	....	286	62,631	160,000	2.55	68	24	92	136	5.00
Guthrie	....	16,468	....	55	16,523	58,000	3.51	73	11	84	153	1.29
Jasper	....	53,806	....	2,913	56,719	130,000	2.29	149	19	168	124	2.73
Keokuk	....	19,842	....	....	19,842	44,000	2.22	16	28	44	160	2.82
Lucas	485,464	10,619	1,887	8,514	506,484	1,114,000	2.20	657	42	699	196	3.70
Mahaska	27,425	61,200	110	1,422	90,157	170,000	1.89	109	69	178	145	3.49
Marion	173,415	73,824	16,391	4,864	268,494	520,000	1.94	455	184	639	148	2.85
Monroe	244,005	24,101	8,807	1,677	278,590	580,000	2.08	516	72	588	149	3.18
Page	....	37,168	1,660	31	38,859	120,000	3.09	123	9	132	173	1.70
Polk	78,488	380,441	2,191	7,646	468,766	1,144,000	2.44	909	84	993	161	2.92
Taylor	739	9,443	440	47	10,669	37,000	3.47	47	4	51	194	1.08
Van Buren	....	8,845	124	310	9,279	20,000	2.16	26	6	32	160	1.82
Wapello	1,500	66,016	427	2,184	70,127	152,000	2.17	166	31	197	152	2.35
Warren	23,254	140,374	1,029	3,790	168,447	430,000	2.55	201	102	303	169	3.30
Wayne	100	9,884	322	5	10,311	25,000	2.42	53	11	64	90	1.80
Webster	....	42,649	41	1,785	44,475	136,000	3.06	70	43	113	185	2.13
Other counties, Hamilton, Jefferson, and Scott	....	5,540	....	....	5,540	13,000	2.35	14	13	27	93	2.20
Total 1934	2,011,749	1,263,483	50,384	41,376	3,366,992	7,862,000	2.34	6,687	1,034	7,721	156	2.80
Total 1933	1,803,194	1,249,027	108,876	33,886	3,194,983	7,217,000	2.26	6,591	1,104	7,695	138	3.01

TABLE XII

Production, Value, Men Employed, Days Operated, and Output Per Man Per Day at Bituminous-coal Mines in Iowa in 1935

County	Net Tons					Value		Number of Employees			Average number of days mines operated	Average tons per man per day
	Loaded at mines for shipment	Commercial sales by truck or wagon	Sold to local trade or used by employees or taken by locomotives at tipple	Used at mines for power and heat	Total quantity	Total	Average per ton	Underground	Surface	Total		
Adams	....	23,136	....	20	23,156	$ 76,000	$3.28	128	25	153	119	1.27
Appanoose	467,738	116,034	14,343	396	598,511	1,423,000	2.38	1,596	155	1,751	142	2.41
Boone	308,770	115,107	9,665	4,573	438,115	1,180,000	2.69	947	79	1,026	183	2.33
Dallas	287,718	72,873	6,565	1,331	368,487	887,000	2.41	602	37	639	198	3.07
Davis and Jefferson	....	6,950	....	30	6,980	19,000	2.72	20	4	24	130	2.24
Greene	....	54,341	80	35	54,456	152,000	2.79	84	30	114	118	4.07
Guthrie	....	23,143	20	69	23,232	79,000	3.40	76	10	86	180	1.50
Jasper	....	43,797	989	1,188	45,974	120,000	2.61	151	20	171	98	2.74
Keokuk	....	8,324	100	....	8,424	17,000	2.02	14	15	29	135	2.14
Lucas	466,182	7,926	3,337	4,643	482,088	1,060,000	2.20	664	67	731	175	3.77
Mahaska	44,664	63,582	60	1,097	109,403	219,000	2.00	92	72	164	158	4.23
Marion	122,878	194,927	6,900	6,420	331,125	795,000	2.40	605	195	800	163	2.54
Monroe	240,313	30,270	....	2,558	273,141	580,000	2.12	526	52	578	147	3.22
Page	3,640	42,803	3,350	....	49,793	174,000	3.49	107	12	119	193	2.17
Polk	77,201	413,873	4,593	5,716	501,383	1,270,000	2.53	827	87	914	181	3.02
Van Buren	....	13,196	64	537	13,797	36,000	2.61	36	8	44	193	1.63
Wapello	2,750	78,878	475	680	82,783	226,000	2.73	203	40	243	141	2.42
Warren	36,744	120,025	790	4,400	161,959	447,000	2.76	162	78	240	161	4.19
Wayne	....	9,832	207	2	10,041	23,000	2.29	36	5	41	115	2.12
Webster	....	46,893	31	1,397	48,321	151,000	3.12	75	37	112	208	2.08
Other counties, Hamilton, Scott, and Taylor	551	16,358	2,085	....	18,994	68,000	3.58	47	12	59	207	1.55
Total 1935	2,059,149	1,502,268	53,654	35,092	3,650,163	9,002,000	2.47	6,998	1,040	8,038	162	2.80
Total 1934	2,011,749	1,263,483	50,384	41,376	3,366,992	7,862,000	2.34	6,687	1,034	7,721	156	2.80

TABLE XIII

Production, Men Employed, Days Operated and Output Per Man Per Day at Bituminous-coal Mines in Iowa in 1936

County	Net Tons					Number of Employees			Average number of days mines operated	Average tons per man per day
	Loaded at mines for shipment	Commercial sales by truck or wagon	Sold to local trade or used by employees or taken by locomotives at tipple	Used at mines for power and heat	Total quantity	Underground	Surface	Total		
Adams	....	30,299	....	38	30,337	181	24	205	128	1.16
Appanoose	483,876	158,059	14,689	3,312	659,936	1,762	196	1,958	138	2.44
Boone	297,451	142,030	1,646	3,822	444,949	960	84	1,044	182	2.34
Dallas	298,356	93,398	5,756	1,407	398,917	632	47	679	184	3.19
Davis and Jefferson	....	21,525	27	10	21,562	26	17	43	168	2.98
Greene	....	54,996	62	220	55,278	71	26	97	137	4.17
Guthrie	....	29,887	....	39	29,926	118	10	128	155	1.51
Jasper	....	57,789	200	2,547	60,536	175	26	201	112	2.70
Keokuk	....	8,244	....	25	8,269	10	17	27	100	3.07
Lucas	531,748	20,190	4,248	4,541	560,727	676	66	742	189	4.00
Mahaska	60,163	91,209	76	1,026	152,474	167	122	289	138	3.83
Marion	103,533	241,919	15,364	5,897	366,713	583	189	772	174	2.72
Monroe	177,529	62,577	3,369	2,482	245,957	424	47	471	168	3.11
Page	....	40,990	5,112	37	46,139	108	9	117	193	2.04
Polk	93,068	428,035	4,174	5,792	531,069	937	106	1,043	178	2.86
Taylor	1,910	13,124	595	6	15,635	56	6	62	191	1.32
Van Buren	....	13,354	54	612	14,020	44	11	55	162	1.57
Wapello	2,400	97,445	512	2,239	102,596	267	48	315	146	2.24
Warren	21,672	109,475	448	4,332	135,927	193	69	262	154	3.37
Wayne	....	28,884	334	425	29,643	113	16	129	148	1.55
Webster	....	49,477	43	570	50,090	72	30	102	212	2.32
Total 1936	2,071,706	1,792,906	56,709	39,379	3,960,700	7,575	1,166	8,741	163	2.78
Total 1935	2,059,149	1,502,268	53,654	35,092	3,650,163	6,998	1,040	8,038	162	2.80

TABLE XIV

Production, Men Employed, Days Operated, and Output Per Man Per Day at Bituminous-coal Mines in Iowa in 1937

County	Net Tons					Average number of employees	Average number of days mines operated	Average tons per man per day
	Loaded at mines for shipment	Truck deliveries including local sales	Used by mine employees[2]	Mine fuel	Total production including inventory change and coal unaccounted for [1]			
Adams	....	28,250	....	20	28,270	180	151	1.04
Appanoose	442,498	156,388	3,871	175	602,846	1,925	131	2.39
Boone	236,592	97,507	7,918	1,913	343,930	987	142	2.45
Dallas	286,228	96,098	7,394	1,720	393,047	703	182	3.08
Greene	....	40,392	....	230	40,622	84	102	4.30
Guthrie	....	22,552	....	18	22,570	101	156	1.43
Jasper	....	42,271	100	1,698	44,069	158	91	3.06
Keokuk	....	10,181	....	25	10,206	26	94	4.18
Lucas	404,974	14,602	7,576	4,766	431,918	825	133	3.94
Mahaska	91,009	136,007	1,435	1,731	230,297	282	174	4.71
Marion	72,743	392,961	2,892	2,113	470,955	916	156	3.29
Monroe	108,069	72,588	7,172	1,681	189,352	387	156	3.13
Page	....	39,563	....	25	39,588	143	162	1.71
Polk	65,162	360,988	4,175	5,232	435,557	1,039	153	2.74
Van Buren	64	18,121	....	40	18,225	52	169	2.08
Wapello	12,275	120,397	100	1,627	134,414	353	140	2.73
Warren	11,189	91,473	1,711	2,668	107,019	270	116	3.41
Wayne	....	22,530	400	30	22,960	104	150	1.47
Webster	....	36,468	....	190	36,658	91	164	2.45
Other counties (Davis, Jefferson and Taylor)	370	33,668	493	20	34,551	94	163	2.25
Total Iowa, 1937	1,731,173	1,833,005	45,237	25,922 (2)	3,637,054	8,720	146	2.87
Total Iowa, 1936	2,071,706	1,792,906	56,709	39,379	3,960,700	8,741	163	2.78

1 The total production differs from the sum of the items shown by the amount of the changes in inventory and of tonnage not accounted for in the distribution analysis.

2 Other sales to local trade or used by employees or taken by locomotives at tipple.

which began in 1933, carried through 1934, but on May 22, 1935 was invalidated in the courts. The price structure of coal suffered for a time, but was aided by the Guffey Act passed on August 20, 1935 and the subsequent appointment of the National Bituminous Coal Commission.

After passing the Bituminous Coal Act of 1937, Congress discontinued the appropriation for collection of bituminous coal statistics by the Bureau of Mines, since such work would thereafter center in the Bituminous Coal Commission.

The Commission changed the method of reporting "value per ton" by including selling expense, an item which was not included in the old method used by the Bureau of Mines in calculating this value. A comparison of the two series is possible for 1936. In that year the average value per ton, on the basis used by the Bureau of Mines was $1.76, while the average gross realization, as collected by the Coal Commission, was $1.83. Comparable figures are not available for later years.

In Tables XV to XIX presenting the summaries of coal production, value, men employed, days operated, and output per man per day by states, the average tons per man per day is based upon (1) the "reported" number of man-shifts where the operator keeps a record thereof; otherwise upon (2) the "calculated" number of man-shifts obtained by multiplying the average number of men employed underground and on the surface at each mine by the number of days worked by the mine and tipple, respectively.

TABLE XV

Summary of Coal Produced, Value, Men Employed, Days Operated, and Output Per Man Per Day, by States, in 1933. (Exclusive of Product of Truck and Wagon Mines Producing Less Than One Thousand Tons)

State	Total quantity	Total value	Average per ton	Number of employees	Average number of days mines operated	Average tons per man per day
Alabama	8,759,989	$ 13,758,000	$1.57	18,237	148	3.26
Alaska	96,467	481,000	4.99	100	199	4.86
Arizona	10,345	52,000	5.03	23	268	1.68
Arkansas	882,924	2,348,000	2.66	3,671	94	2.57
California, Idaho and Oregon	7,492	27,000	3.60	58	79	1.65
Colorado	5,229,767	11,350,000	2.17	7,908	148	4.46
Georgia	41,382	77,000	1.86	93	234	1.90
Illinois	37,413,145	54,578,000	1.46	44,145	141	6.00
Indiana	13,761,052	17,567,000	1.28	11,199	163	7.52
Iowa	3,194,983	7,217,000	2.26	7,695	138	3.01
Kansas	2,217,622	3,881,000	1.75	3,809	140	4.15
Kentucky	36,099,729	40,748,000	1.13	43,717	170	4.87
Maryland	1,530,748	2,134,000	1.39	2,880	172	3.09
Michigan	406,584	1,171,000	2.88	1,186	130	2.63
Missouri	3,432,212	6,175,000	1.80	5,690	150	4.02
Montana	2,152,207	3,309,000	1.54	1,324	166	9.80
New Mexico	1,226,236	3,071,000	2.50	2,340	168	3.12
North Carolina	2,014	7,000	3.48	10	175	1.15
North Dakota	1,782,272	2,248,000	1.26	1,301	173	7.93
Ohio	19,588,763	23,549,000	1.20	25,442	169	4.55
Oklahoma	1,238,244	2,616,000	2.11	2,974	128	3.26
Pennsylvania, bituminous	79,295,944	108,418,000	1.37	115,453	162	4.24
South Dakota	59,375	104,000	1.75	147	100	4.04
Tennessee	3,774,761	5,255,000	1.39	7,051	161	3.33
Texas	821,878	833,000	1.01	803	162	6.32
Utah	2,674,986	5,109,000	1.91	2,906	176	5.23
Virginia	8,178,642	10,029,000	1.23	9,761	184	4.55
Washington	1,394,068	3,916,000	2.81	2,555	168	3.25
West Virginia	94,343,535	107,124,000	1.14	92,472	196	5.20
Wyoming	4,013,167	8,636,000	2.15	3,753	170	6.29
Total, 1933	333,630,533	445,788,000	1.34	418,703	167	4.78
Total, 1932	309,709,872	406,677,000	1.31	406,380	146	5.22

TABLE XVI

Summary of Coal Produced, Value, Men Employed, Days Operated, and Output Per Man Per Day, by States, in 1934. (Exclusive of Product of Truck and Wagon Mines Producing Less Than One Thousand Tons)

State	Total quantity	Total value	Average per ton	Number of employees	Average number of days mines operated	Average tons per man per day
Alabama	9,142,117	$18,838,000	$2.06	18,851	185	2.62
Alaska	107,508	451,000	4.20	93	217	5.33
Arkansas	856,432	2,564,000	2.99	3,415	102	2.46
Oklahoma	1,208,289	2,846,000	2.36	3,225	124	3.02
Colorado	5,210,933	12,309,000	2.36	8,094	158	4.08
Illinois	41,272,384	64,238,000	1.56	46,067	160	5.62
Indiana	14,793,643	21,838,000	1.48	11,173	171	7.75
Iowa	3,366,992	7,862,000	2.34	7,721	156	2.80
Kansas	2,508,254	4,619,000	1.84	3,744	151	4.45
Missouri	3,352,283	6,278,000	1.87	5,540	141	4.29
Kentucky	38,525,235	60,548,000	1.57	49,509	180	4.33
Maryland	1,627,112	3,089,000	1.90	2,976	176	3.12
Michigan	621,741	1,940,000	3.12	1,556	157	2.54
Montana	2,565,702	3,997,000	1.56	1,590	166	9.73
New Mexico	1,259,323	3,402,000	2.70	2,342	164	3.29
North Dakota	1,753,888	2,363,000	1.35	1,518	174	6.65
South Dakota	42,407	76,000	1.79	91	152	3.07
Ohio	20,690,564	34,774,000	1.68	29,247	167	4.23
Pennsylvania	89,825,875	165,371,000	1.84	126,079	179	3.98
Tennessee	4,135,790	7,514,000	1.82	7,308	185	3.05
Georgia	32,716	80,000	2.45	113	185	1.56
North Carolina	3,140	9,000	2.87	18	221	.79
Texas	759,289	1,145,000	1.51	805	178	5.30
Utah	2,406,183	4,746,000	1.97	2,807	171	5.00
Virginia	9,376,681	16,375,000	1.75	12,207	200	3.84
Washington	1,382,991	4,002,000	2.89	2,161	193	3.32
West Virginia	98,134,393	167,104,000	1.70	105,906	196	4.73
Wyoming	4,367,961	9,591,000	2.20	3,760	188	6.17
Other States	38,196	143,000	3.74	95	189	2.13
Total, 1934	359,368,022	628,112,000	1.75	458,011	178	4.40
Total, 1933	333,630,533	445,788,000	1.34	418,703	167	4.78

TABLE XVII

Summary of Coal Produced, Value, Men Employed, Days Operated, and Output Per Man Per Day, by States, in 1935. (Exclusive of Product of Truck and Wagon Mines Producing Less Than One Thousand Tons)

State	Total quantity	Total value	Average per ton	Total number of employees	Average number of days mines operated	Average tons per man per day
Alabama	8,504,510	$ 18,251,000	$2.15	18,906	161	2.79
Alaska	119,425	502,000	4.20	95	249	5.05
Arizona, California, Idaho, and Oregon	24,844	95,000	3.82	103	140	1.72
Arkansas	1,133,279	3,448,000	3.04	3,743	123	2.47
Colorado	5,910,511	13,675,000	2.31	8,153	177	4.08
Georgia and North Carolina	22,734	58,000	2.55	109	160	1.30
Illinois	44,525,469	69,516,000	1.56	43,748	171	5.97
Indiana	15,754,214	23,722,000	1.51	11,347	176	7.91
Iowa	3,650,163	9,002,000	2.47	8,038	162	2.80
Kansas	2,686,164	4,943,000	1.84	3,896	173	4.00
Kentucky	40,760,939	65,956,000	1.62	52,339	182	4.28
Maryland	1,678,059	3,266,000	1.95	2,962	179	3.17
Michigan	628,384	2,017,000	3.21	1,467	158	2.70
Missouri	3,645,996	6,924,000	1.90	5,710	159	4.02
Montana	2,758,906	4,146,000	1.50	1,571	189	9.30
New Mexico	1,388,877	3,681,000	2.65	2,355	185	3.19
North Dakota	1,955,510	2,395,000	1.22	1,365	188	7.61
Ohio	21,153,151	35,111,000	1.66	29,524	162	4.44
Oklahoma	1,229,398	2,879,000	2.34	3,151	122	3.19
Pennsylvania	91,404,670	172,170,000	1.88	124,109	180	4.10
South Dakota	13,243	21,000	1.59	55	98	2.46
Tennessee	4,137,802	7,435,000	1.80	7,531	181	3.04
Texas	757,529	654,000	.86	792	177	5.42
Utah	2,946,918	6,091,000	2.07	2,752	188	5.70
Virginia	9,667,018	17,128,000	1.77	13,043	189	3.92
Washington	1,559,206	4,686,000	3.01	2,258	192	3.60
West Virginia	99,179,061	169,164,000	1.71	109,315	192	4.74
Wyoming	5,177,142	11,127,000	2.15	3,966	217	6.00
Total, 1935	372,373,122	658,063,000	1.77	462,403	179	4.50
Total, 1934	359,368,022	628,383,000	1.75	458,011	178	4.40

TABLE XVIII

Summary of Coal Produced. Men Employed, Days Operated, and Output Per Man Per Day, by States, in 1936. (Exclusive of Product of Truck and Wagon Mines Producing Less Than One Thousand Tons)

State	Total quantity	Total number of employees	Average number of days mines operated	Average tons per man per day
Alabama	12,229,287	20,491	206	2.90
Alaska	136,593	111	245	5.02
Arizona, Idaho, and Oregon	15,364	53	202	1.43
Arkansas	1,622,787	4,123	152	2.58
Colorado	6,811,802	8,802	191	4.06
Georgia	24,288	94	207	1.25
Illinois	50,926,599	44,347	175	6.55
Indiana	17,822,536	11,801	178	8.48
Iowa	3,960,700	8,741	163	2.78
Kansas	2,944,028	3,755	163	4.80
Kentucky	47,521,950	54,089	202	4.34
Maryland	1,703,589	2,916	186	3.14
Michigan	626,145	1,400	164	2.73
Missouri	3,984,999	5,654	171	4.13
Montana [1]	2,988,524	1,459	195	10.53
New Mexico	1,596,775	2,392	202	3.30
North Dakota [1]	2,215,335	1,408	192	8.20
Ohio	24,110,078	29,853	183	4.42
Oklahoma	1,540,303	3,153	155	3.15
Pennsylvania	109,887,470	127,211	205	4.22
South Dakota [1]	41,331	50	231	3.58
Tennessee	5,108,195	7,982	203	3.16
Texas [1]	842,624	810	192	5.42
Utah	3,246,565	3,057	186	5.70
Virginia	11,661,636	14,882	196	4.00
Washington	1,812,104	2,625	200	3.46
West Virginia	117,925,706	111,468	216	4.89
Wyoming	5,780,590	4,477	215	6.00
Total, 1936	439,087,903	477,204	199	4.62
Total, 1935	372,373,122	462,403	179	4.50

1 Includes figures on lignite compiled by Bureau of Mines.

TABLE XIX

Summary of Coal Produced, Men Employed, Days Operated, and Output Per Man Per Day, by States, in 1937. (Exclusive of Product of Truck and Wagon Mines Producing Less Than One Thousand Tons)

State	Total quantity	Average number of employees	Average number of days mines operated	Average tons per man per day
Alabama	11,760,221	22,613	200	2.74
Alaska	128,608	123	207	5.16
Arkansas	1,465,468	4,253	136	2.61
Colorado	5,338,492	9,432	181	4.21
Illinois	42,824,674	42,449	168	7.25
Indiana	15,546,298	11,238	174	9.10
Iowa	1,731,173	8,720	146	2.87
Kansas	2,520,166	3,574	173	4.68
Kentucky	45,216,686	55,596	192	4.41
Maryland	1,283,125	2,525	189	3.25
Michigan	180,969	1,343	145	2.88
Missouri	2,950,424	6,436	152	4.18
Montana [1]	2,767,758	1,503	186	10.62
New Mexico	1,552,612	2,608	208	3.17
North Dakota [1]	1,577,216	1,475	181	8.41
Ohio	20,792,181	30,294	185	4.49
Oklahoma	1,411,648	3,147	142	3.58
Pennsylvania	96,758,008	133,897	199	4.16
South Dakota [1]	26,444	47	165	6.05
Tennessee	4,812,564	8,465	195	3.17
Texas[1]	861,793	819	199	5.59
Utah	3,500,403	3,417	189	5.88
Virginia	13,017,015	16,494	200	4.18
Washington	1,445,024	2,882	204	3.40
West Virginia	114,227,504	113,643	209	5.00
Wyoming	5,530,230	4,743	204	6.11
Other States [2]	10,871	128	165	1.15
Total, 1937	399,237,575	491,864	193	4.69
Total, 1936	439,087,903	477,204	199	4.62

[1] Includes figures on lignite from Bureau of Mines; "Loaded at mines for shipment," as published by Bureau of Mines, included under "all-rail"; "commercial sales by truck or wagon" and "other sales to local trade, etc.," as published by Bureau of Mines, included under "truck deliveries including local sales."

[2] Arizona, California, Georgia, Idaho, and Oregon.

Gypsum

Gypsum depends for markets almost entirely upon building construction and particularly residential building. It is natural, therefore, that when building construction activities dropped off after 1929 one result was a decline in production and value of gypsum.

Most of the calcined gypsum produced is used to make building materials such as plasters, wallboards, partition tile, and insulating materials, and smaller quantities are sold to manufacturing companies for special purposes. Uncalcined or raw gypsum is used chiefly by the cement industry as a retarder, although land plaster and other outlets are important at times.

Raw or crude gypsum is not and has never been a high-priced product and in recent years there has been a tendency among the producers of raw gypsum to manufacture and attempt to increase the markets for gypsum products rather than to increase sales of the crude material.

Nationally, Iowa ranks third in the value and production of gypsum and is outranked only by New York and Michigan in the order named. The entire industry in the State has been centered in the immediate vicinity of Fort Dodge, Webster county since 1934. Prior to that time a minor percentage of the total production was obtained from Appanoose county.

Gypsum followed the general trend of mineral production in Iowa, but was somewhat above the average during the period of this report. The tonnage of crude gypsum mined dropped off in 1933 but increased each year since then except during 1938. The largest increase came in 1936 when it amounted to approximately 50 per cent over 1935 and was greater than any year since the beginning of the depression.

Sales of uncalcined gypsum decreased in tonnage and total value in 1933 and in 1935, recovered in 1934 and increased greatly in 1936, the last year on which data were collected. The value and tonnage of "calcined gypsum sold" fell off in 1933 but showed increases in 1934, 1935 and 1936.

Table XX shows production figures for Iowa for the period 1932-1938. A revised method of canvassing the gypsum industry was begun in 1937 by the Bureau of Mines at the request of the producing companies. By this revision no data were collected by states after 1936 on gypsum "sold calcined" and "sold uncalcined". This has a bearing

TABLE XX

Production of Gypsum in Iowa from 1932 to 1938

Year	Active mines	Crude gypsum mined		Sold uncalcined		Sold calcined		Total value
		Short tons	Value	Short tons	Value	Short tons	Value	
1932	7	178,087		63,931	$ 91,267	105,788	$1,377,147	$1,468,414
1933	8	172,555		58,863	75,083	104,371	1,282,324	1,357,407
1934	8	180,271		63,510	97,626	115,282	1,572,730	1,670,356
1935	7	230,203	$233,926	54,150	74,914	151,366	2,109,010	2,215,770[a]
1936	8	344,221	352,834	97,511	146,233	217,088	3,115,155	3,261,388
1937	8	387,255	533,162	(b)	(b)	(b)	(b)	(b)
1938	8	364,920	495,856	(b)	(b)	(b)	(b)	(b)

a Revised.
b Data not collected.

on "total value" recorded in the tables including gypsum in Iowa, in that the value of crude gypsum is substituted for total value of the calcined and uncalcined products. The total value of crude is much less than the combined value of calcined and uncalcined gypsum, and in Table I this makes it appear that total values in 1937 and 1938 were far below average, whereas these two years were actually well above the average of the period of this report. Other changes affect the figures for the United States "total value" and "calcined gypsum products sold".

The drastic decrease in production of gypsum in the United States which began in 1930 continued until 1933 and the amount produced in 1933 was less than in any year since 1905. The price dropped an additional 6 per cent in 1933, but late in that year the market started an upswing. In 1934 the total production increased 15 per cent, but was still below the general recovery level because of the lag of residential building. Increases in production of both raw and calcined gypsum continued through 1935, and in 1936 the crude product increased an additional 42 per cent and the sales of gypsum products increased 29 per cent over 1935. The advance was due principally to increase in privately financed building construction. Further increases continued through the early months of 1937 and the total value of uncalcined and calcined gypsum for 1937 exceeded that for 1936, but production fell off during the last half of the year. Activity continued to be slower through much of 1938 but in the last quarter improvement was definitely under way.

Table XXI shows production of gypsum in the United States for the period of this report.

During 1937 products derived from byproduct gypsum (first util-

TABLE XXI

Production of Gypsum in the United States from 1932 to 1938

Year	No. of active establishments[a]	Crude gypsum mined		Sold or Used by Producers				
				Uncalcined		Calcined		
		Short tons	Value	Short tons	Value	Short tons	Value	Total value
1932	57	1,416,274		444,816	$ 929,567	890,495	$11,976,719	$12,906,286
1933	61	1,335,192		420,935	806,325	821,738	11,121,153	11,927,478
1934	64	1,536,170		512,317	970,828	902,539	12,791,149	13,761,977
1935	57	1,903,880		520,594	1,089,979	1,233,816	17,820,369	18,860,348
1936	59	2,712,510		752,625	1,458,123	1,730,687	24,764,254	26,222,377
1937	58	3,058,166	$4,782,503	860,825[b]	1,920,706[b]	2,643,075[b]	36,879,814[b]	38,800,520[b]
1938	56	2,684,205	4,271,674	756,565[b]	1,681,371[b]	2,556,296[b]	34,574,937[b]	36,256,308[b]

a Each mine, plant or combination mine plant is counted as one establishment; beginning in 1937 plants utilizing by-product gypsum are included.

b Includes gypsum products made from domestic, imported, and by-product crude gypsum sold or used in the United States.

ized about 1925) comprised an appreciable part of the total sales value, and the process for a new product, hydraulic gypsum was patented. In 1938 two new processing plants were opened, one in Georgia and one in Florida.

Gypsum Producers in Iowa

Webster County

Cardiff Gypsum Co., 903 Central Avenue, Fort Dodge, Iowa. Mine and mill at Gypsum, Iowa.

Certain-teed Products Corporation, Att: E. H. Laney, Assistant Auditor, 100 E. 42nd Street, New York, New York. Mill and mine at Fort Dodge.

A. R. Eno, Fort Dodge, Iowa.

Fort Dodge Plaster Co., J. M. Norton, Manager, 1420 Seventh Avenue, North, Fort Dodge, Iowa. Mine at Fort Dodge.

Hawkeye Gypsum Products Co., John E. Gustin, Manager, Fort Dodge, Iowa. Mine at Fort Dodge.

Johnston Clay Works, Inc., 214 First National Bank Building, Fort Dodge, Iowa. Mine at Fort Dodge.

National Gypsum Co., F. E. Davis, Treasurer, 192 Deleware Avenue, Buffalo, New York. Mill and mine at Fort Dodge.

United States Gypsum Co., 300 West Adams Street, Chicago, Illinois. Mill and mine at Fort Dodge.

Wasem Plaster Co., H. W. Wasem, President, Warden Building, Fort Dodge, Iowa. Mill and mine at Fort Dodge.

Limestone

Limestone is utilized chiefly for road metal and concrete and these uses generally govern the trends of production. Important secondary uses in Iowa are for agricultural purposes and riprap, and during the past few years an increasing amount has been consumed by sugar factories.

The limestone industry had a remarkable history in Iowa during the period 1933-1938. The low of 1933 was well above the average of total production from 1895 to 1925. In 1934 all previous records were broken and although there was a decline in 1935, that year was sixth in rank for the years after 1895. All records were again broken in 1936 when total quantity and total value more than doubled the figures of the previous year. The peak was reached in 1937 when the total quantity produced was 4,272,670 tons valued at $4,261,184 which was more than four times greater than for 1933. Production declined in 1938, but exceeded that of any earlier year except 1937 and the average price per ton was higher than for any year during the period of this report.

Production of limestone for road metal and concrete after a drop in 1933, rallied strongly in 1934 and decreased slightly in 1935. In 1936 there was an increase of more than 100 per cent. Records in total tonnage and value were established in 1937, and in 1938 the advance in prices permitted only a slight decline in value in spite of a sharp drop in quantity produced.

Limestone used for agriculture followed approximately the same trends as that used for road metal and concrete. Riprap had a similar history although the variations in productions and values were more spectacular. Building stone, rubble and flux varied greatly; building stone showed exceptionally high production in 1937, while rubble production was considerably above average in 1933.

It is significant that the number of producers in Iowa increased steadily from 60 in 1933 to 174 in 1937. and that the noncommercial operators and production became proportionally larger each year. The drop in the number of producers in 1938 was due to the increased activity of W. P. A., considered as one operator, which reported an output of 1,739,625 tons valued at $2,392,875, representing 52 per cent of total production and 64 per cent of total value for the year.

Statistics of limestone production in Iowa may be found in Table XXII and more detailed data by counties in Tables XXIV to XXIX. In the latter tables it was necessary to combine counties in order to avoid revealing confidential information.

TABLE XXII

Production of Limestone in Iowa from 1932 to 1938

	Building stone [a]	Rubble	Flux	Rip rap	Road metal and concrete	Railroad ballast	Agri-culture	Other limestone	Total
1932									
Short tons	1,672	2,329[b]		23,686	1,475,718[c]		67,663	20,167	1,591,235
Value	$1,929	3,088[b]		19,069	1,283,713[c]		50,983	30,683	1,389,465
Producers	4	2	1	9	47[c]	1	24	4	53[j]
1933									
Short tons	4,270	11,620	3,476	9,690	861,550	46,640	63,610	30,440[d]	1,031,290[k]
Value	$4,402	9,484	3,889	8,830	781,750	21,485	44,649	34,703[d]	909,192
Producers	3	3	2	9	51	5	27	4	60[j]
1934									
Short tons		1,870		67,220	2,035,900[c]		143,386	22,560[e]	2,276,440[k]
Value		$1,752		48,285	1,734,123[c]		96,164	49,086[e]	1,934,364
Producers	2	3	2	14	95	2	24	7[e]	101[j]
1935									
Short tons	4,070	1,790		53,220	1,642,080[c]		104,080	33,840[f]	1,840,080[k]
Value	$3,685	1,623		44,267	1,447,993[c]		82,107	67,763[f]	1,645,937
Producers	3	4	2	12	103[c]	1	20	7[f]	105[j]
1936									
Short tons		1,916	11,457	120,230	3,521,170	107,122	222,700	18,950[g]	4,003,550[k]
Value		$1,887	12,070	139,774	2,943,060	48,233	197,688	54,543[g]	3,397,356
Producers	4	3	2	11	118	3	27	7[g]	130[j]
1937									
Short tons	13,830		16,790	260,290	3,621,540	39,690	304,690	8,870[h]	4,272,670
Value	$12,570		17,279	193,392	3,662,185	20,881	301,845	41,298[h]	4,261,184
Producers	4	1	3	31	173	4	58	6[h]	174[j]
1938									
Short tons	2,410			182,180	2,853,890[c]		236,300	34,000[i]	3,323,750
Value	$1,935			113,089	3,313,323[c]		207,883	78,013[i]	3,742,580
Producers	4	3	2	18	69	2	46	17[i]	85[j]

a Chiefly rough construction.
b Includes flux.
c Includes railroad ballast.
d Includes that sold to sugar factories.
e Includes building stone, curbing and flux.
f Includes curbing, flux.
g Includes building stone, curbing and that sold to sugar factories.
h Includes curbing and rubble.
i Includes curbing, rubble and flux.
j From U. S. Mineral Yearbooks, includes some non-operating plants.
k Revised.

In the United States as a whole, as in Iowa, the most important uses of limestone are for road metal and concrete. Following in the order of importance are uses for fluxing, argriculture, railroad ballast and riprap. Their relative importance and other details of production in the United States may be found in Table XXIII in which limestone utilized for cement manufacture is not included. The table shows that total production and total value of limestone decreased in 1933, increased in 1934, decreased slightly in 1935, increased materially in 1936 and 1937 and again decreased in 1938.

In 1933 the value of limestone for all uses increased over the nation except for concrete and road metal which fell off about 6.4 millions of dollars, but in 1934 the values for all uses increased; that for road metal and concrete advanced approximately 8.5 millions of dollars. All values again increased in 1935 except for road metal and concrete, riprap and railroad ballast. In 1936 decreases occured only in limestone used for building stone and rubble, and these decreases were easily offset by increases in other fields which brought about an advance of approximately 60 per cent in total value of all limestone produced. Further increase in 1937 in all items except rubble, riprap and railroad ballast resulted in the largest total production and total value for the period of this report. As in other mineral industries production of limestone in the United States fell off in 1938 except that used for road metal and concrete, rubble, and riprap.

TABLE XXIII

Production of Limestone in the United States from 1932 to 1938

	Building stone [a]	Rubble	Flux	Rip rap	Concrete and road metal	Railroad ballast	Agri-culture	Total [b]
1932								
Short tons	50,580	84,570	3,945,170	1,448,040	32,612,550	2,450,970	909,470	46,913,520
Value	$ 77,872	84,308	2,902,847	1,421,024	28,650,198	1,748,412	1,229,107	48,015,748
1933								
Short tons	78,790	79,060	7,982,560	1,566,560	25,820,640	2,786,050	994,540	45,922,280
Value	$108,100	94,046	5,510,445	1,767,541	22,239,698	1,896,308	1,239,724	44,499,311
1934								
Short tons	156,000	190,080	9,230,880	2,490,760	33,209,910	3,614,430	1,612,380	57,501,510
Value	$179,000	179,791	6,297,579	2,668,215	30,749,136	2,549,091	1,788,142	53,790,846
1935								
Short tons	293,050	185,790	12,191,660	1,982,250	30,151,790	3,623,500	2,140,370	57,492,760
Value	$310,878	276,569	7,902,717	1,890,625	26,354,559	2,525,949	2,656,728	50,668,765
1936								
Short tons	156,970	204,700	17,724,880	2,205,700	49,751,570	5,101,580	3,907,710	87,735,740
Value	$272,164	181,415	11,576,156	3,275,193	46,058,424	3,632,649	4,512,703	81,559,984
1937								
Short tons	191,660	107,550	21,311,250	2,769,640	51,108,620	5,033,180	5,004,930	94,577,270
Value	$380,324	136,028	14,685,215	2,891,936	49,547,350	3,588,974	6,454,695	90,901,877
1938								
Short tons	166,260	155,370	9,692,130	2,590,770	54,357,130	3,187,770	4,367,410	81,679,690
Value	$316,772	194,621	6,933,621	3,107,511	52,387,376	2,210,881	5,637,485	82,286,555

a Rough construction except as noted.
b Including rough architectural, finished building stone, curbing, flagging, paving, stone used in sugar factories, glass factories and paper mills and other uses.

TABLE XXIV

Production of Limestone in Iowa in 1933

Counties	Number of producers [a]	Road metal, concrete, railroad ballast		Other uses [b]		Total	
		Short tons	Value	Short tons	Value	Short tons	Value
Allamakee (1), Clayton (1), Delaware (2)	4	45,771	$ 33,054	(c)	(c)	45,771	$ 33,054
Black Hawk (3), Bremer (1), Cerro Gordo (1), Floyd (1)	6	62,787	84,462	22,965	$32,708	85,752	117,170
Buchanan (1), Johnson (2), Linn (5)	8	122,875	115,742	7,600	6,807	130,475	122,549
Dubuque (3), Jackson (2), Jones (5)	10	164,815	166,179	30,542	22,900	195,357	189,079
Cedar (1), Clinton (4)	5	63,620	64,275	(c)	(c)	63,620	64,275
Scott (3), Louisa (1)	4	135,020	96,552	17,514	12,696	152,534	109,248
Davis (2), Keokuk (1), Lee (3), Mahaska (1), Van Buren (2), Wapello (1), Wayne (1)	11	128,277	106,425	(c)	(c)	128,277	106,425
Grundy (1), Hardin (1), Madison (3), Marshall (2), Tama (1)	8	161,488	125,313	24,909	17,189	186,397	142,502
Fremont (1), Montgomery (1), Woodbury (2)	4	43,099	24,890	(c)	(c)	43,099	24,890
Total, 1933	60	927,752	$816,892	103,530	$92,300	1,031,290[d]	$ 909,192
Total, 1932	54	1,491,861	1,295,039	89,005	83,583	1,591,235	1,389,465

a Commercial and noncommercial.
b Other uses includes: Agricultural, sugar factories, building stone, rubble, riprap, flux, poultry grit.
c Included under road metal, concrete and railroad ballast for purposes of concealment.
d Adjusted.

TABLE XXV

Production of Limestone in Iowa in 1934

Counties	Number of producers [a]	Building stone, curbing, rubble, riprap		Road metal, concrete, railroad ballast		Other uses [b]		Total	
		Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value
Bremer (2), Buchanan (2), Chickasaw (2), Fayette (1), Howard (1), Winneshiek (2)	10			128,369	$119,597	801	$ 760	129,170	$120,357
Butler (2), Cerro Gordo (3), Floyd (1), Mitchell (1)	7			53,703	45,574			53,703	45,574
Worth (2)	2			135,146	135,146			135,146	135,146
Clayton (3), Dubuque (4)	7	20,430	$15,566	295,292	253,600	28,727	20,920	344,449	290,086
Benton (2), Blackhawk (2), Grundy (1), Hardin (1), Tama (1)	7			125,428	76,162	20,606	40,275	146,034	116,437
Delaware (4)	4			68,878	51,928	2,000	1,000	70,878	52,928
Johnson (2), Linn (5)	7			182,467	185,497	42,158	34,249	224,625	219,746
Cedar (1), Jones (5), Muscatine (2), Scott (3)	11	20,810	14,952	314,729	190,989	36,808	26,598	372,347	232,539
Clinton (6), Jackson (5)	11	(c)	(c)	109,610	97,047	1,700	1,490	111,310	98,537
Henry (1), Keokuk (2), Washington (1)	4			79,219	76,964			79,219	76,964
Lee (2), Van Buren (2)	4			92,103	89,785	(c)	(c)	92,103	89,785
Davis (1), Jefferson (1), Wapello (1)	3			112,803	99,548			112,803	99,548
Appanoose (2), Lucas (1), Mahaska (2)	5			92,227	83,221			92,227	83,221
Madison (4), Marshall (4)	8	3,009	2,941	148,237	117,373	31,169	18,959	182,415	139,273
Clarke (2), Decatur (3), Wayne (1)	6			64,814	55,023			64,814	55,023
Adams (1), Fremont (1), Montgomery (2), Pottawattamie (1)	5			65,200	79,200			65,200	79,200
Total, 1934	101	44,249	$33,459	2,068,225	$1,756,654	163,969	$144,251	2,276,440[d]	$1,934,364
Total, 1933	60			927,752	816,892	103,530	92,300	1,031,290[d]	909,192

a Commercial and noncommercial.
b Includes limestone for agriculture, flux, and other uses.
c Included in road metal, concrete and railroad ballast column for purpose of concealment.
d Adjusted.

TABLE XXVI

Production of Limestone in Iowa in 1935

Counties	Number of producers [a]	Building stone, curbing, rubble, riprap		Road metal, concrete, railroad ballast		Other uses [b]		Total	
		Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value
Allamakee (3), Clayton (6), Dubuque (5)	14	16,824	$14,411	353,371	$284,765	28,299	$27,397	398,494	$326,573
Chickasaw (1), Fayette (3), Floyd (1), Mitchell (1), Winneshiek (4)	10			126,410	122,904			126,410	122,904
Black Hawk (4), Bremer (2), Buchanan (2), Delaware (3)	11			148,827	134,136	3,846	3,541	152,673	137,677
Cerro Gordo (1), Franklin (1), Hardin (1), Marshall (3)	6			63,557	56,196	29,835	57,905	93,392	114,101
Benton (1), Butler (2), Grundy (1), Tama (2)	6			54,316	45,297			54,316	45,297
Jackson (2), Johnson (3), Jones (5), Linn (7)	17	20,474	14,804	134,214	123,143	29,270	22,619	183,958	160,566
Cedar (1), Clinton (1), Louisa (1), Muscatine (2), Scott (3)	8	20,809	16,988	124,903	94,264	32,610	25,024	178,322	136,276
Des Moines (1), Henry (1), Keokuk (2), Washington (1)	5			112,830	109,356			112,830	109,356
Jefferson (1), Mahaska (2), Wapello (1)	4			102,786	100,764			102,786	100,764
Appanoose (1), Davis (1), Lee (3), Van Buren (3)	8			131,870	121,888	(c)	(c)	131,870	121,888
Clarke (1), Decatur (2), Madison (4), Wayne (2)	9	(c)	(c)	179,959	149,026	9,623	7,263	189,582	156,289
Adair (2), Cass (1), Pottawattamie (1)	4			83,792	82,599			83,792	82,599
Fremont (2), Montgomery (1)	3			31,647	31,647			31,647	31,647
Total, 1935	105	58,107	$46,203	1,648,482	$1,455,985	133,483	$143,749	1,840,080[d]	$1,645,937
Total, 1934	101	44,249	33,459	2,068,225	1,756,654	163,969	144,251	2,276,440[d]	1,934,364

a Commercial and noncommercial.
b Includes limestone for agriculture, flux, sugar factories, and other uses.
c Included in road metal, concrete and railroad ballast column for purpose of concealment.
d Adjusted.

TABLE XXVII

Production of Limestone in Iowa in 1936

Counties	Number of producers [a]	Building stone, curbing, rubble, riprap		Road metal, concrete, railroad ballast		Other uses [b]		Total	
		Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value
Allamakee (6), Bremer (1), Chickasaw (1), Fayette (3), Howard (1), Mitchell (1), Winneshiek (1)	14			451,074	$360,146	6,982	$6,982	458,056	$367,128
Butler (1), Floyd (1), Grundy (1), Worth (1)	4			66,382	41,457			66,382	41,457
Cerro Gordo (2), Hardin (1), Marshall (3)	6	(c)	(c)	330,460	244,812	48,452	84,234	378,912	329,046
Benton (2), Black Hawk (6), Buchanan (4)	12			212,190	175,691	17,321	13,464	229,511	189,155
Clayton (6), Delaware (3), Linn (5)	14	9,635	$ 9,024	281,521	241,942	9,295	9,091	300,451	260,057
Clinton (2), Dubuque (4), Jackson (1), Jones (6)	13	12,464	10,554	245,211	214,415	45,787	35,659	303,462	260,628
Iowa (1), Keokuk (2), Poweshiek (2), Tama (2)	7			269,913	235,303			269,913	235,303
Henry (2), Johnson (3), Lee (1), Van Buren (4), Washington (2)	12			468,133	364,303	(c)	(c)	468,133	364,303
Cedar (2), Des Moines (3), Louisa (1), Muscatine (1), Scott (4)	11	89,222	110,394	408,013	318,443	80,957	74,794	578,192	503,631
Davis (1), Jefferson (2), Mahaska (1), Wapello (1)	5			267,824	237,634			267,824	237,634
Lucas (1), Marion (2), Warren (1)	4			39,516	37,819	5,364	5,364	44,880	43,183
Appanoose (1), Monroe (1), Wayne (1)	3			92,400	108,500			92,400	108,500
Clarke (1), Decatur (3), Madison (5)	9	(c)	(c)	283,698	227,693	15,868	12,603	299,566	240,296
Adair (1), Cass (1), Guthrie (1)	3			33,134	26,393	500	500	33,634	26,893
Ringgold (1), Taylor (1), Union (1)	3			29,734	27,993			29,734	27,993
Adams (2), Montgomery (1), Page (2)	5			42,909	38,349			42,909	38,349
Fremont (2), Mills (2), Pottawattamie (1)	5			139,577	123,800			139,577	123,800
Total, 1936	130	111,321	$129,972	3,661,689	$3,024,693	230,526	$242.691	4,003,550[d]	$3,397,356
Total, 1935	105	58,107	46,203	1,648.482	1,455,985	133.483	143.749	1,840,080[d]	1,645,937

[a] Commercial and noncommercial.
[b] Includes limestone for agriculture, flux, sugar factories, and other uses.
[c] Included in road metal, concrete and railroad ballast column for purpose of concealment.
[d] Adjusted.

TABLE XXVIII

Production of Limestone in Iowa in 1937

Counties	Number of producers[a]	Building stone, curbing, rubble, riprap		Road metal, concrete, railroad ballast		Other uses[b]		Total	
		Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value
Allamakee (5), Clayton (6), Dubuque (4)	15	188,701	$127,792	295,702	$295,906	12,322	$12,422	496,725	$436,120
Chickasaw (1), Howard (1), Winneshiek (3)	5			88,206	102,175	5,072	3,297	93,278	105,472
Cerro Gordo (1), Hardin (3), Mitchell (3)	7	130	15	50,065	47,456	29,114	65,317	79,309	112,788
Kossuth (1), Palo Alto (1)	2	1,750	938					1,750	938
Bremer (3), Butler (2), Fayette (4), Floyd (4)	13			187,690	176,621	12,586	13,087	200,276	189,708
Black Hawk (5), Grundy (2), Marshall (5)	12	(c)	(c)	321,667	325,776	18,159	14,532	339,826	340,308
Benton (3), Buchanan (2), Delaware (2), Linn (7)	14	98	75	353,372	306,994	51,956	51,419	405,426	358,488
Cedar (3), Johnson (4), Jones (6)	13	14,744	12,349	268,985	249,124	26,577	19,632	310,306	281,105
Clinton (2), Jackson (4), Muscatine (5), Scott (4)	15	58,683	58,253	303,763	269,208	89,878	91,101	452,324	418,562
Des Moines (4), Henry (2), Lee (2), Louisa (1), Van Buren (3), Washington (3)	15	4,760	3,161	451,071	474,244	273	245	456,104	477,650
Jefferson (3), Keokuk (3)	6	3,112	1,756	178,982	196,745	1,630	1,467	183,724	199,968
Mahaska (4), Poweshiek (1), Tama (1)	6	500	500	225,230	241,973	1,000	850	226,730	243,323
Appanoose (3), Davis (2), Wapello (3)	8			215,121	232,195	991	754	216,112	232,949
Lucas (2), Monroe (2), Wayne (1)	5			184,155	188,950			184,155	188,950
Clarke (2), Decatur (4), Madison (7), Marion (2), Warren (1)	16	(c)	(c)	283,942	254,751	86,175	96,345	370,117	351,096
Adair (2), Dallas (1), Guthrie (1)	4			31,335	37,300	1,000	1,250	32,335	38,550
Adams (3), Ringgold (1), Union (2)	6	420	225	104,670	133,183	360	300	105,450	133,708
Montgomery (3), Page (1), Taylor (1)	5	840	450	11,039	24,213			11,879	24,663
Fremont (2), Mills (2), Pottawattamie (2)	6			105,681	125,338			105,681	125,338
Undistributed (noncommercial)	1			1,150	1,500			1,150	1,500
Total, 1937	174	273,734[d]	$205,514	3,661,826	$3,683,652	337,110[d]	$372,018	4,272,670[d]	$4,261,184
Total, 1936	130	111,321	129,972	3,661,689	3,024,693	230,526	242,691	4,003,550[d]	3,397,356

a Commercial and noncommercial.
b Includes limestone for agriculture, flux, sugar factories, and other uses.
c Included in road metal, concrete and railroad ballast column for purpose of concealment.
d Adjusted.

TABLE XXIX

Production of Limestone in Iowa in 1938

Counties	Number of producers [a]	Building stone, curbing, rubble, riprap		Road metal, concrete, railroad ballast		Other uses [b]		Total	
		Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value
Allamakee (2), Clayton (4), Dubuque (2), Jackson (3)	11	75,026	$39,516	73,818	$57,971	14,328	$13,612	163,172	$111,099
Cerro Gordo (1), Floyd (2), Howard (2), Mitchell (1)	6	(c)	(c)	31,834	22,152	18,165	31,537	49,999	53,689
Black Hawk (3), Bremer (2), Butler (1), Fayette (2)	8	750	1,000	91,893	67,812	13,075	11,465	105,718	80,277
Delaware (1), Jones (6)	7	6,851	5,579	119,080	80,771	22,969	16,177	148,900	102,527
Clinton (3), Muscatine (3), Scott (2)	8	41,297	30,588	179,112	136,798	88,867	70,260	309,276	237,646
Johnson (2), Linn (5), Washington (1)	8	4,785	3,742	151,844	145,842	13,312	13,012	169,941	162,596
Hardin (2), Marion (1), Marshall (2), Story (1)	6			92,920	82,288	36,396	86,616	129,316	168,904
Des Moines (1), Lee (1), Louisa (1), Van Buren (5)	8	(c)	(c)	106,068	85,751	29,767	24,925	135,835	110,676
Keokuk (1), Mahaska (1), Wapello (1)	3			77,284	69,044			77,284	69,044
Appanoose (1), Lucas (2), Warren (1)	4	300	225	42,240	51,940	7,000	7,000	49,540	59,165
Decatur (1), Guthrie (2), Harrison (1), Madison (2), Ringgold (2)	8	(c)	(c)	140,255	94,976	11,891	10,320	152,146	105,146
Adams (1), Fremont (1), Montgomery (1)	3			23,250	20,000	1,715	2,373	24,965	22,373
Undistributed (noncommercial)	5	54,370	32,750	1,726,343	2,400,674	26,945	25,864	1,807,652	2,459,280
Total, 1938	85	183,379	113,400	2,855,941	3,316,019	284,430	313,161	3,323,750	3,742,580
Total, 1937	174	273,734[d]	205,514	3,661,826	3,683,652	337,110[d]	372,018	4,272,670[d]	4,261,184

a Commercial and noncommercial.
b Includes limestone for agriculture, flux, sugar factories, and other uses.
c Included in road metal, concrete and railroad ballast column for purpose of concealment.
d Adjusted.

Limestone Operators in Iowa

Noncommercial

Adair County

Adair County Highway Department, County Engineer, Greenfield, Iowa.

Adams County

Adams County Highway Department, Corning, Iowa.

City of Corning, Highway Department, Corning, Iowa.

Allamakee County

Allamakee County Highway Department, Waukon, Iowa.

Appanoose County

Appanoose County Highway Department, County Engineer, Centerville, Iowa.

C. C. C. Camp 14, Drakesville, Iowa.

Benton County

Benton County Highway Department, Vinton, Iowa.

Blackhawk County

Blackhawk County Highway Department, Waterloo, Iowa.

City of Cedar Falls, Cedar Falls, Iowa.

City of Waterloo, Waterloo, Iowa.

Bremer County

Bremer County Highway Department, Waverly, Iowa.

Buchanan County

Buchanan County, County Engineer, Independence, Iowa.

Butler County

Butler County, County Engineer, Allison, Iowa.

Cass County

Cass County Highway Department, Atlantic, Iowa.

Cedar County

Cedar County Highway Department, Tipton, Iowa.

Cerro Gordo County

Cerro Gordo County Highway Department, Mason City, Iowa.

Chickasaw County

Chickasaw County, County Engineer, New Hampton, Iowa.

Clarke County

Clarke County, County Engineer, Osceola, Iowa.

Clayton County

Clayton County, County Engineer, Elkader, Iowa.

Clinton County
Clinton County Highway Department, Clinton, Iowa.

Davis County
Davis County Highway Department, Bloomfield, Iowa.

Decatur County
Decatur County Highway Department, Leon, Iowa.
Soil Conservation Committee, Grand River, Iowa.

Delaware County
Delaware County, County Engineer, Manchester, Iowa.

Des Moines County
City of Burlington, Burlington, Iowa.
Des Moines County, County Engineer, Burlington, Iowa.

Dubuque County
Dubuque County Highway Department, County Engineer, Dubuque, Iowa.

Fayette County
Fayette County Highway Department, West Union, Iowa.

Floyd County
Floyd County Highway Department, Charles City, Iowa.

Franklin County
Franklin County, County Engineer, Hamilton, Iowa.

Fremont County
Fremont County, County Engineer, Sidney, Iowa.
Fremont County Soil Association, Farragut, Iowa.

Grundy County
Grundy County Highway Department, Grundy Center, Iowa.

Guthrie County
County Agricultural Agent, Guthrie, Iowa.

Henry County
Henry County, County Engineer, Mt. Pleasant, Iowa.
Supervisor W. P. A., Mt. Pleasant, Iowa.

Howard County
Howard County, County Engineer, Cresco, Iowa.

Humboldt County
City of Humboldt Highway Department, Humboldt, Iowa.

Jackson County
Jackson County Highway Department, Maquoketa, Iowa.

Jefferson County

Jefferson County Highway Department, County Engineer, Fairfield, Iowa.

Johnson County

Johnson County Highway Department, County Engineer, Iowa City, Iowa.

Jones County

Jones County, County Engineer, Anamosa, Iowa.

Men's Reformatory, Anamosa, Iowa.

Keokuk County

Keokuk County, County Engineer, Sigourney, Iowa.

Lee County

Lee County Highway Department, Fort Madison, Iowa.

Linn County

City of Cedar Rapids Street Department, Cedar Rapids, Iowa.

Linn County, County Engineer, Cedar Rapids, Iowa.

Louisa County

Louisa County, County Engineer, Wapello, Iowa.

Lucas County

Lucas County, County Engineer, Chariton, Iowa.

Lucas County Farm Bureau, County Board of Supervisors, Chariton, Iowa.

Madison County

Madison County Highway Department, Winterset, Iowa.

Mahaska County

Mahaska County, County Engineer, Oskaloosa, Iowa.

Marion County

Soil Conservation Service, Knoxville, Iowa.

Marshall County

Marshall County, County Engineer, Marshalltown, Iowa.

Mills County

Mills County, County Engineer, Glenwood, Iowa.

Mitchell County

Mitchell County, County Highway Engineer, Osage, Iowa.

Monroe County

Monroe County, County Engineer, Albia, Iowa.

Montgomery County

Montgomery County Highway Department, Red Oak, Iowa.

U. S. Department of Agriculture, Soil Conservation Association, C. C. C., Red Oak, Iowa.

Muscatine County

Muscatine County Highway Department, Muscatine, Iowa.

Works Progress Administration, Supervisor, Conesville, Iowa.

Page County

Soil Conservation Service, Experiment Station, Box 341, Clarinda, Iowa.

Pottawattamie County

Pottawattamie County Highway Department, Council Bluffs, Iowa.

Poweshiek County

Poweshiek County Highway Department, Montezuma, Iowa.

Ringgold County

Ringgold County, County Enginer, Mt. Ayr, Iowa.

Scott County

Scott County Highway Department, Davenport, Iowa.

Tama County

Tama County Highway Department, Toledo, Iowa.

Taylor County

Taylor County Highway Department, Bedford, Iowa.

Union County

Union County, Board of County Supervisors, Creston, Iowa.

Van Buren County

Farm Bureau Soils Committee, Keosauqua, Iowa.

Van Buren County Highway Department, Keosauqua, Iowa.

Wapello County

Wapello County Highway Department, Ottumwa, Iowa.

Warren County

Warren County Highway Department, Indianola, Iowa.

Washington County

Washington County Highway Department, Washington, Iowa.

Wayne County

Wayne County Highway Department, Corydon, Iowa.

Winneshiek County

Winneshiek County Highway Department, Decorah, Iowa.

Worth County

Worth County Highway Department, Northwood, Iowa.

State of Iowa

Property & Epuipment Division, Ames, Iowa.

Administrator, Iowa Works Progress Administration, Royal Union Life Building, Des Moines, Iowa.

Limestone Operators in Iowa

Commercial

Allamakee County

Halvorson Bros., Rochester, Minnesota. Quarry at Lansing.

Roverud Bros., Spring Grove, Minnesota. Pool Hill Quarry at New Albin.

E. C. Schroeder, McGregor, Iowa. Martin Manton Quarry at Harpers Ferry.

Hess Bros., Lansing, Iowa. Johnson Quarry.

Edward Anderson, Lansing, Iowa.

Appanoose County

Centerville Limestone Co., Centerville, Iowa.

Dixon Construction Co., Centerville, Iowa.

Benton County

Say Raymond, Garrison, Iowa.

Black Hawk County

A. C. Newton, LaPorte, Iowa.

Concrete Materials Co., Box 790, Cedar Rapids, Iowa. Portable Plants.

Gill & Mullen, LaPorte City, Iowa.

R. G. Holm, Waterloo, Iowa.

Harold E. Pint, Raymond, Iowa.

Frank Frost, Jesup, Iowa.

Bremer County

Joseph Alcock, New Hampton, Iowa. Fredrika Quarry, Fredrika, Iowa.

Schield Bros., Waverly, Iowa. Colburn Quarry.

Buchanan County

Lewis V. T. Francis, Fairbank, Iowa. Quarry at Jesup.

Butler County

R. W. Phillips, Rockwell, Iowa. Portables.

Carroll County

Emery Construction Co., Coon Rapids, Iowa.

Cedar County

Donald P. Thomson, Mt. Vernon, Iowa. Quarry at Mechanicsville.

Cerro Gordo County

N. W. States Portland Cement Co., Mason City, Iowa.

Stoddard Stone Products Co., 500 14th Street, N. E., Mason City, Iowa.

Clarke County

W. C. Busick, Osceola, Iowa.

Willis Busick, Osceola, Iowa.

Clayton County

Eberhard Construction Co., Guttenberg, Iowa.

H. L. Leas, Monona, Iowa.

E. C. Schroeder, McGregor, Iowa.

Clinton County

Harry Belby, Charlotte, Iowa.

C. T. Hanrahan, Charlotte, Iowa.

Adolf Thiessen, Charlotte, Iowa.

George T. Smith, 715 Sixth Avenue, South, Clinton, Iowa. Nagel's Quarry at Lyons.

Decatur County

Sargent Bros., Inc., 411 E. Grand Avenue, Des Moines, Iowa. Quarry at Decatur.

Des Moines County

Henry Roscum, Burlington, Iowa.

Dubuque County

Dubuque Stone Products Co., 2900 Rhomberg Avenue, Dubuque, Iowa.

John Rider Wallis, Dubuque, Iowa. Horseshoe Bluff Quarries.

M. F. Simon, Farley, Iowa.

Fayette County

L. H. Stranahan, Fayette, Iowa.

Floyd County

Clyde Stevens, Floyd, Iowa. Knowlton Quarry.

E. J. Wilcox and Sons, Floyd, Iowa.

Fremont County

Hartsell & Evans, Thurman, Iowa.

Guthrie County

Boyd Crandall, Guthrie Center, Iowa.

Fred B. Owen, Guthrie Center, Iowa. Quarry at Redfield.

Hardin County

Pearce Limestone Corp., Gifford, Iowa.

Iowa Limestone Co., 907 Bankers Trust Building, Des Moines, Iowa. Quarry at Alden.

M. B. Musgrave, Woodbine, Iowa.

Henry County

Hamill Limestone Co., Lockridge, Iowa.

Paul Niemann, West Union, Iowa.

Iowa County

E. D. Wahl, Victor, Iowa.

Jackson County

C. C. Putnam, Hager City, Wisconsin. Riching & Keeney Quarry.

H. C. Roberts, Maquoketa, Iowa.

Hurst Stone Co., R. R. No. 3, Maquoketa, Iowa.

Johnson County

River Products Co., 20-21 Schneider Building, Iowa City, Iowa. Quarry at Coralville.

Jones County

Myron Baker Contractor, Independence, Iowa. Portable crushers all over Iowa.

Charles W. Zimmer, Anamosa, Iowa. Quarry in Cass township.

Columbia Quarry, G. J. Albright, 612 C Avenue, N. W., Cedar Rapids, Iowa. Columbia Quarry, Stone City.

Merle Ballou, Olin, Iowa.

Willis Johnson, Stone City, Iowa.

Fall Brothers, Olin, Iowa.

H. Dearborn Sons, Stone City, Iowa. Stone City Quarry.

Malcolm Vernon, Olin, Iowa.

Theodore Patnode, Stone City, Iowa.

Lee County

McManus Quarries Co., Inc., 112 Masonic Building, Keokuk, Iowa.

Driscoll & Hayes, Farmington, Iowa. Quarry at Belfast.

Fred Osborne, Denmark, Iowa.

Keokuk Quarry & Construction Co., 1325 Main Street, Keokuk, Iowa.

Oral France, Martinsburg, Iowa. Quarry at Ollie, Iowa.

Linn County

Larimer & Shafer, Inc., E. Moore, Recorder, First Avenue and Second Street, Cedar Rapids, Iowa.

Art Lanning, Alburnett, Iowa. Lafayette Quarry.

J. G. Vernon, Marion, Iowa.

Lanning & Fulkerson, Marion, Iowa.
G. W. Gaines, Lisbon, Iowa.
Dewees & Whitney, Marion, Iowa.
Dewees & Smith, R. F. D. No. 1, Springville, Iowa.
I. H. Whitman, Lisbon, Iowa.
John Vernon, Springville, Iowa.
Dan Thompson, Mt. Vernon, Iowa.
A. R. Gaines, Mt. Vernon, Iowa.

Madison County

Hawkeye Portland Cement Co., 802 Hubbell Building, Des Moines, Iowa. Quarry at Earlham.
Sargent Bros., Inc., 411 E. Grand Avenue, Des Moines, Iowa. Quarry at Winterset.
Winterset Limestone Co., Winterset, Iowa.
Madison County Limestone Co., Winterset, Iowa.

Mahaska County

John P. Abramson Construction Co., Des Moines, Iowa.

Marion County

Pella Limestone Co., Knoxville, Iowa. Quarry at Pella.
A. K. Verrifs, Pella, Iowa.
E. Groenendyke, Tracy, Iowa.

Marshall County

Chicago & N. W. Ry. Co., Quarry at Marshalltown, Iowa.
LeGrand Limestone Co., 105 W. Madison Street, Chicago, Illinois. Quarry at Lake View, Iowa.

Mitchell County

Falk & Litzelman, Osage, Iowa. Quarry at Rudolph Nitardy at St. Ansgar. Quarry of Gaylord Snyder at Osage, Iowa.
Kollman Bros., Osage, Iowa. Quarry at New Haven.
H. L. Wilson Estate, Osage, Iowa. Osage Stone Quarry.

Montgomery County

Albert Mulvenna, Red Oak, Iowa.

Muscatine County

C. C. Putnam, Hager City, Wisconsin. Schroder Quarry at Montpelier or Princeton.
Otto Wendling, 1549 Washington Street, Muscatine, Iowa. Quarry at Moscow.

Pocahontas County
N. W. States Portland Cement Co., Gilmore Portland Cement Corp., Mason City, Iowa.
Pottawattamie County
Kelley Construction Co., 532 46th Street, Des Moines, Iowa. Quarry at Macedonia.
Ringgold County
Harco Construction Co., Mount Ayr, Iowa. Watterson Quarry.
Scott County
Dewey Portland Cement Co., 409 Scarrett Building, Kansas City, Missouri.
Falk & Litzelman, Osage, Iowa. Quarry at Bettendorf.
Linwood Stone Products Co., 928 Davenport Bank Building., Davenport, Iowa. Quarry at Linwood.
Story County
Maudlin Construction Co., Box 134, Webster City, Iowa.
Nelson & Malone, Nevada, Iowa.
Ray Cook, Nevada, Iowa. Quarry at Ames.
Tama County
B. L. Anderson, Toledo, Iowa.
Lake Park Holding Corp., Gladbrook, Iowa.
Van Buren County
Roberts Willits, Bonaparte, Iowa. Mud Creek Quarry.
Douds Quarries, Inc., Douds, Iowa.
Washington County
J. C. Smay, Nevada, Iowa. Grace Hill Quarry.
Webster County
Fort Dodge Lime Stone Co., Fort Dodge, Iowa.
Winneshiek County
Decorah Stone Products Co., Decorah, Iowa.
Cremer Construction Co., Decorah, Iowa.
T. D. Jeglum, Decorah, Iowa.

Sand and Gravel

Principal uses of sand and gravel in Iowa are for paving and roads, and for structural purposes. The chief secondary use is for railroad ballast. Normally the total value of gravel is approximately four times that of sand. Table XXX summarizes the outstanding features of this industry in Iowa from 1933 to 1938, and reports by counties may

TABLE XXX

Summary of Sand and Gravel Production in Iowa from 1932 to 1938

	Molding sand	Structural sand	Paving and road sand	Cutting, grinding, polishing, and blast sand	Engine sand	Filter sand	Railroad ballast sand	Other uses	Total sand	Structural gravel	Paving and road gravel	Railroad ballast gravel	Other gravel	Total gravel	Grand total sand and gravel
1932															
Short tons	(a)	288,719	827,883	6,111	22,277	(a)	45,054	14,124	1,204,168	289,349	3,422,195	308,059	6,791	4,026,394	5,230,562
Value	(a)	$118,866	204,192	8,315	10,449	(a)	14,933	11,896	368,651	219,651	1,063,008	52,806	2,758	1,338,223	1,706,874
1933															
Short tons	(a)	228,170b	420,607b	(a)	26,896	1,336	(a)	59,703	136,712	156,520	3,233,422	208,842	8,285	3,607,069	4,343,781
Value	(a)	$115,182b	117,451b	(a)	12,735	4,302	(a)	32,278	281,948	126,591	703,859	45,260	7,408	883,118	1,165,066
1934															
Short tons	(a)	369,720	459,031	(a)	25,143	1,951	17,318	48,795	921,958	266,272	3,011,978	(c)	148,654	3,426,904	4,349,362
Value	(a)	$169,441	151,145	(a)	9,716	6,122	3,944	35,516	375,884	216,733	776,670	(c)	25,513	1,017,916	1,394,000
1935															
Short tons	(a)	368,416	463,189	(a)	27,234	(a)	15,249	116,375	990,463	278,041	4,238,618	(c)	(c)	4,742,270	5,732,742
Value	(a)	$176,530	132,652	(a)	11,425	(a)	4,538	88,518	413,663	223,840	1,041,962	(c)	(c)	1,343,188	1,756,851
1936															
Short tons	(a)	545,410	511,852	(a)	25,956	(a)	4,705	82,428	1,170,351	423,669	4,258,146	436,639	5,179	5,123,633	6,293,984
Value	(a)	$263,076	207,704	(a)	11,287	(a)	2,506	67,141	551,714	337,561	1,086,483	56,531	15,993	1,496,568	2,048,282
1937															
Short tons	(a)	562,244	629,155	(a)	40,232	(a)	(a)	110,173	1,341,804	570,874	4,347,826	(d)	136,650	5,055,350	6,397,154
Value	(a)	$324,733	266,745	(a)	19,815	(a)	(a)	91,502	702,795	414,162	1,091,044	(d)	27,102	1,532,308	2,235,103
1938															
Short tons	(a)	415,613	623,569	10,095	37,885	(a)	18,594	45,476	1,151,232	812,465	4,818,859	152,600	59,090	5,373,761	6,994,286e
Value	(a)	$236,557	279,629	9,759	20,282	(a)	11,308	41,452	598,987	356,426	1,275,485	31,062	37,722	1,637,684	2,299,732

(a) Included under others.
(b) Includes noncommercial.
(c) Included under total.
(d) Included under others.
(e) Revised.

be found in Tables XXXII to XLIII. In the latter tables it was found necessary to combine counties to avoid revealing confidential data.

Total quantity and total value of all sand and gravel produced in the state, after a decrease in 1933, increased in each of the ensuing years including 1938. The greatest advance in value came in 1935 when the total was $363,051 greater than in 1934 while the largest increase in quantity was attained in 1936 when the figures for 1935 were exceeded by 1,383,880 tons.

The 1938 figures of 6,994,286 ton valued at $2,299,682 represent the greatest quantity and the highest total annual value of production in the history of the sand and gravel industry in Iowa.

Paving and road gravel after a decrease in 1933 advanced in total value each year including 1938 and sand for the same use had a similar history except for a decrease in value in 1935. Sand and gravel used for structural purposes decreased in 1933 in tonnage and total value, but increased each year thereafter until 1937, and in 1938 gravel production for this use broke all previous records.

In the United States the grand total of sand and gravel production and value dropped in 1933, increased each year from 1934 to 1937 inclusive and decreased slightly in 1938 as shown by Table XXXI.

The 1933 decreases of commercial sand and gravel amounted to 22 per cent in quantity and 17 per cent in value from 1932. Commercial increases in 1934 amounted to 13.9 per cent in quantity and 6.7 per cent in value while the increases in 1935 were of somewhat smaller magnitude. The greatest increase in production was attained in 1936 when there were apparent advances of 39 per cent in tonnage and 43 per cent in value. The factors responsible for this upward trend were greater activity in building and highway construction and the resulting demand for commercial sand and gravel. Increases of 6 per cent in quantity and 8 per cent in value were effective in 1937 while in 1938 commercial production dropped 16 per cent and total quantity of sand and gravel "sold or used" dropped 4 per cent.

An important feature of the sand gravel industry in 1938 was the further tendency toward increasing use of noncommercial operations for supplies of aggregates. It is reported that the domestic output of plants operated by states, counties, municipalities and other Government agencies was 17 per cent higher in 1938 than in 1937 and represented 42 per cent of the total tonnage produced.

TABLE XXXI

Sand and Gravel Industry in the United States from 1932 to 1938

	Glass sand	Molding sand	Building sand	Paving sand	Grinding, polishing, and blast sand	Fire or furnace sand	Engine sand	Filter sand	Railroad ballast	Other sand	Total sand	Building gravel	Paving gravel	Railroad ballast	Other gravel	Total gravel	Grand total sand and gravel
1932																	
Short tons	1,370,255	1,118,146	14,745,267	19,399,117	419,691	36,698	1,151,011	68,035		4,486,655	42,794,875	14,065,070	56,533,460	6,644,483		77,243,022	120,037,897
Value	$2,266,564	1,051,702	7,604,983	8,635,934	638,556	54,371	688,563	92,751		1,463,650	22,497,074	9,803,629	23,397,380	1,823,993		35,025,002	57,522,076
1933																	
Short tons	1,781,423	1,718,251	13,187,431	12,876,139	572,735	106,133	1,051,695	24,387		1,842,652	33,160,846	12,584,953	56,581,914	5,427,636		74,594,503	107,755,349
Value	$3,011,023	1,558,738	6,580,311	6,295,569	739,222	121,149	623,285	52,186		695,189	19,676,672	8,338,524	22,992,172	2,065,542		33,396,238	53,072,910
1934																	
Short tons	1,923,614	2,167,731	14,869,511	15,917,663	571,191	137,000	1,211,033	35,750	607,380	959,217	38,400,090	14,899,930	56,133,881	6,422,166	755,622	78,211,599	116,611,689
Value	$3,326,538	2,169,254	8,342,007	8,165,589	1,039,614	169,424	795,648	85,567	166,918	620,512	24,881,071	10,276,219	23,812,375	1,873,563	403,945	36,366,102	61,247,173
1935																	
Short tons	2,125,761	2,980,879	16,540,324	13,484,723	816,540	172,847	1,389,877	49,301	997,499	1,875,808	40,433,559	15,641,576	54,929,553	7,546,489	5,372,746	83,490,364	123,923,923
Value	$3,735,343	2,915,173	8,819,712	6,900,996	1,198,653	204,477	881,910	93,470	256,922	860,557	25,867,222	10,332,709	21,639,090	2,143,275	1,995,083	36,110,157	61,977,879
1936																	
Short tons	2,394,710	4,210,017	28,533,156	20,025,606	934,059	183,667	1,576,432	126,248	300,102	815,714	35,926,994	18,768,415	32,031,124	3,169,961	411,258	54,380,758	90,307,752
Value	$4,050,749	4,072,387	15,378,912	8,684,096	1,306,871	201,099	990,816	72,381	1,177,843	1,195,523	60,303,394	27,102,886	78,461,576	11,723,535	738,423	118,026,420	178,329,814
1937																	
Short tons	2,799,230	4,953,873	27,590,739	22,099,777	1,067,178	258,287	1,802,869	99.383	1,418,316	1,295,419	63,385,071	27,838,317	85,267,855	12,318,575	850,605	126,275,352	189,660,423
Value	$4,746,629	5,239,435	15,405,031	10,644,979	1,440,736	268,355	1,092,171	182,414	334,585	1,058,162	40,412,497	19,526,213	33,201,326	3,757,068	575,893	57,060,500	97,472,997
1938																	
Short tons	2,109,462	2,319,902	25,097,184	23,378,707	502,328	108,093	1,378,450	93,711	786,435	1,399,556	57,113,828	26,314,759	88,660,248	8,194,244	1,037,154	124,206,405	181,320,233
Value	$3,601,734	2,651,779	13,779,047	10,762,421	754,805	124,343	786,639	137,283	212,935	1,124,739	33,935,725	15,737,827	33,579,665	2,255,355	414,275	51,987,122	85,922,847

TABLE XXXII

Total Production of Sand and Gravel in Iowa in 1933 — Sand

Counties	Producers	Structural sand		Paving sand		Other sand[a]		Total sand	
		Tons	Value	Tons	Value	Tons	Value	Tons	Value
Appanoose (1), Mahaska (1), Wapello (1)	3	24,756	$ 13,310	22,849	$ 8,085	1,886	$ 581	49,491	$21,976
Black Hawk (4), Clayton (2)	6	9,910	7,305	14,352	4,147	(b)	(b)	24,262	11,452
Boone (1), Emmet (1), Humboldt (1), Webster (3)	6	16,163	6,870	60,910	22,824	(c)	(c)	77,073	29,694
Harrison (1), Plymouth (1), Sioux (3)	5	42,013	16,726	46,695	10,504			88,708	27,230
Butler (3), Cerro Gordo (2)	5	23,223	11,271	66,560	20,925	3,500	1,725	93,283	33,921
Cherokee (2), Crawford (1), Sac (3)	6	(d)	(d)	17,727	7,930	43,755	14,660	61,482	22,590
Clay (2), Lyon (1)	3	(b)	(b)	17,623	8,585	(b)	(b)	17,623	8,585
Clinton (2), Dubuque (2), Jackson (1)	5	14,578	6,392	14,502	2,454	(b)	(b)	29,080	8,846
Johnson (1), Linn (2)	3	13,108	10,652	4,572	2,051	(b)	(b)	17,680	12,703
Lee (1), Des Moines (3)	4	1,241	1,130	5,932	1,793	(c)	(c)	7,173	2,923
Marion (1), Story (1), Tama (1)	3	5,124	3,045	(c)	(c)	(c)	(c)	5,124	3,045
Muscatine (4), Scott (1)	5	8,885	4,930	28,703	10,657	28,757	29,050	66,345	44,637
Polk (6)	6	59,401	32,080	39,644	12,218	2,640	1,156	101,685	45,454
Total commercial, 1933	60	218,402	113,711	340,069	112,173	80,538	47,172	639,009	273,056
Total noncommercial, 1933		1,154	907	96,550	6,985			97,704	7,892
Grand Total, 1933		219,556	114,618	436,619	119,158	80,538	47,172	736,713	280,948
Grand Total, 1932	78	233,734	114,525	805,467	198,891			1,039,201	313,316

a Includes molding, blast, engine, filter, and railroad ballast sand.
b Included with paving sand.
c Included with structural sand.
d Included with other sand.

TABLE XXXIII

Total Production of Sand and Gravel in Iowa in 1933 — Gravel

Counties	Producers	Structural gravel		Paving and other gravel [a]		Total sand and gravel		Total quantity washed	
		Tons	Value	Tons	Value	Tons	Value	Tons	Value
Appanoose (1), Mahaska (1), Wapello (1)	3	(b)	(b)	27,388	$29,035	76,879	$51,011	76,689	$50,941
Black Hawk (4), Clayton (2)	6	(b)	(b)	12,373	16,058	36,635	28,510	36,414	28,393
Boone (1), Emmet (1), Humboldt (1), Webster (1)	4	8,344	7,909	99,053	72,439	184,470	110,042	161,299	107,440
Harrison (1), Plymouth (1), Sioux (1)	3	11,351	10,102	25,063	22,206	125,122	59,538	115,575	57,638
Butler (3), Cerro Gordo (2)	5	15,417	15,417	54,316	43,453	163,016	92,791	162,016	92,391
Cherokee (2), Crawford (1), Sac (3), Woodbury (0)	6	10,909	11,477	77,524	31,812	149,915	65,879	72,342	41,689
Clay (2), Lyon (1)	3	(b)	(b)	19,195	20,083	36,818	28,668	36,818	28,668
Clinton (2), Dubuque (2), Jackson (1)	5	19,439	8,673	27,184	7,937	75,703	25,456	49,010	21,257
Johnson (1), Linn (2), State (1)	4	3,411	3,893	105,096	39,140	126,187	55,736	126,184	55,736
Lee (1), Des Moines (3)	4	(b)	(b)	4,285	4,430	11,458	7,353	9,035	6,458
Marion (1), Story (1), Tama (1), Wright (1)	4	(b)	(b)	13,142	5,259	18,266	8,304	11,142	7,679
Muscatine (4), Scott (1)	5	38,372	26,812	32,469	22,245	137,186	93,694	137,186	93,694
Polk (6)	6	27,256	30,048	50,672	34,848	179,613	110,350	179,613	110,350
Total commercial, 1933	61	134,499	115,331	547,760	348,945	1,321,268	737,332	1,173,323	702,334
Total noncommercial,[c] 1933		11,040	2,455	2,913,769	417,387	3,022,513	427,734	50,045	27,113
Grand Total, 1933		145,539	117,786	3,461,529	766,332	4,343,781	1,165,066	1,223,368	729,447
Grand Total, 1932		346,588	228,878	3,844,733	1,164,780	5,230,562	1,706,874	2,465,145	1,047,524

a Including railroad ballast gravel.
b Included with paving and other gravel.
c Includes railroad ballast gravel.

TABLE XXXIV

Total Production of Sand and Gravel in Iowa in 1934— Sand

Counties	Producers	Structural sand		Paving sand		Other sand[a]		Total sand	
		Tons	Value	Tons	Value	Tons	Value	Tons	Value
Appanoose (1), Lee (1), Des Moines (1), State (0)	3	5,908	$2,574	5,356	$2,302	(b)	(b)	11,264	$4,876
Black Hawk (3), Butler (2)	5	8,758	3,755	30,701	15,746	7,340	$4,468	46,799	23,969
Boone (1), Emmet (1), Humboldt (1), Webster (1)	4	23,297	11,759	22,049	7,680	(c)	(c)	45,346	19,439
Clayton (2), Dubuque (2), Jackson (1)	5	69,655	24,728	34,773	8,446	18,873	10,497	123,301	43,671
Clinton (2), Scott (1)	3	25,428	13,615	14,259	4,785	(c)	(c)	39,687	18,400
Linn (1), Mahaska (1), Tama (1)	3	26,241	17,510	10,960	4,675	(c)	(c)	37,201	22,185
Lyon (2), Clay (1), Sioux (2)	5	44,349	12,231	79,267	29,500	(b)	(b)	123,616	41,731
Muscatine (3)	3	41,455	21,579	42,005	21,799	32,903	30,377	116,363	73,755
Polk (6)	6	64,471	26,441	50,249	14,072	9,496	4,629	124,216	45,142
Sac (3), Cherokee (1), Plymouth (1)	5	20,480	7,367	45,085	20,352	2,060	964	67,625	28,683
Wapello (1), Cerro Gordo (2)	3	41,409	24,104	25,617	10,300	3,261	1,264	70,287	35,668
Total commercial, 1934	45	371,451	165,663	360,321	139,657	73,933	52,199	805,705	357,519
Total noncommercial,[d] 1934		11,565	5,742	102,579	12,698	2,109	125	116,253	18,565
Grand Total, 1934		383,016	171,405	462,900	152,355	76,042	52,324	921,958	376,084
Grand Total, 1933		219,556	114,618	436,619	119,158	80,538	47,172	736,713	280,948

a Includes molding, blast, engine, filter, and railroad ballast sand.
b Included with structural sand.
c Included with paving sand.
d Includes railroad ballast sand.

TABLE XXXV

Total Production of Sand and Gravel in Iowa in 1934 — Gravel

Counties	Producers	Structural gravel		Paving and other gravel		Total sand and gravel		Total quantity washed	
		Tons	Value	Tons	Value	Tons	Value	Tons	Value
Appanoose (0), Lee (1), Des Moines (1), State (2)	4	8,841	$ 6,221	133,150	$ 28,600	153,255	$39,697	98,695	$ 33,597
Black Hawk (3), Butler (1)	4	9,754	7,806	12,086	11,951	68,639	43,726	67,764	43,376
Boone (1), Emmet (1), Humboldt (1), Webster (2)	5	11,764	11,640	31,786	24,001	88,896	55,080	83,284	54,486
Clayton (2), Dubuque (2), Jackson (1)	5	53,777	43,119	40,864	26,843	217,942	113,633	165,827	104,037
Clinton (2), Scott (1)	3	47,178	25,688	(a)	(a)	86,865	44,088	82,093	43,577
Linn (0), Mahaska (1), Tama (1), Van Buren (1)	3	(b)	(b)	29,164	20,356	65,365	42,541	57,465	41,341
Lyon (2), Clay (1), Sioux (2)	5	26,132	20,576	68,694	56,600	218,442	118,907	207,621	117,560
Muscatine (4)	4	16,965	13,894	41,740	34,545	175,068	122,194	175,068	122,194
Polk (6)	6	37,574	47,494	69,840	44,845	231,630	137,481	231,630	137,481
Sac (3), Cherokee (1), Plymouth (1)	5	33,532	23,969	82,120	46,463	183,277	99,115	179,899	98,115
Wapello (1), Cerro Gordo (2)	3	16,604	18,306	15,022	15,397	101,913	69,371	101,913	69,371
Wright (1), Buena Vista (1), Harrison (2), Mitchell (1), O'Brien (1)	6	4,178	1,595	39,260	8,345	43,438	9,940	2,380	1,340
Total commercial, 1934	49	266,299	220,308	563,726	317,946	1,635,730	895,773	1,453,639	866,475
Total noncommercial[c], 1934		15,918	4,443	2,581,461	475,219	2,713,632	498,227	141,520	61,991
Grand Total, 1934		282,217	224,751	3,145,187	793,165	4,349,362	1,394,000	1,595,159	928,466
Grand Total, 1933		145,539	117,878	3,461,529	766,332	4,343,781	1,165,066	1,223,368	729,447

a Included with structural gravel.
b Included with paving gravel.
c Includes railroad ballast gravel.

TABLE XXXVI

Total Production of Sand and Gravel in Iowa in 1935—Sand

Counties	Producers	Structural sand		Paving sand		Other sand[a]		Total sand	
		Tons	Value	Tons	Value	Tons	Value	Tons	Value
Black Hawk (4), Linn (1)	5	58,779	$38,215	(b)	(b)	(b)	(b)	58,779	$ 38,215
Cherokee (1), Clay (1), Emmet (1)	3	18,488	8,045	40,131	$ 14,734	(b)	(b)	58,619	22,779
Clayton (1), Dubuque (2), Jackson (1), Clinton (1)	5	48,412	21,211	74,766	42,685	(c)	(c)	123,178	63,896
Des Moines (1), Mahaska (1), Wapello (1), Lee (2)	5	52,145	27,209	28,165	10,608	(b)	(b)	79,310	37,817
Humboldt (1), Webster (1), Boone (1), Wright (0)	3	35,873	17,288	(b)	(b)			35,873	17,288
Lyon (2), Sioux (2)	4	45,200	13,100	76,516	26,455	(b)	(b)	121,716	39,555
Mitchell (0), Butler (1), Tama (1), Cerro Gordo (2)	4	46,656	23,946	23,650	11,200	(c)	(c)	70,306	35,146
Muscatine (3), Scott (1)	4	33,151	16,659	29,392	12,688	61,724	50,052	124,267	79,399
Polk (5)	5	66,584	31,544	49,886	18,374	(c)	(c)	116,470	49,918
Sac (3), Harrison (0), State (0)	3	6,625	1,746	16,625	4,723	(c)	(c)	23,250	6,469
Total commercial, 1935	41	410,913	198,963	339,131	141,467	61,724	50,052	811,768	390,482
Total noncommercial, 1935		11,400	1,440	167,295	21,740			178,695	23,180
Grand Total, 1935		422,313	200,403	506,426	163,207	61,724	50,052	990,463	413,662
Grand Total, 1934		383,016	171,405	462,900	152,355	76,042	52,324	921,958	376,084

a Includes molding, cutting and grinding, engine, filter, and railroad ballast sand.
b Included under structural sand.
c Included under paving sand.

TABLE XXXVII

Total Production of Sand and Gravel in Iowa in 1935 — Gravel

Counties	Producers	Structural gravel [a]		Paving and other gravel		Total sand and gravel		Total quantity washed	
		Tons	Value	Tons	Value	Tons	Value	Tons	Value
Black Hawk (4), Linn (0)	4	10,277	$10,945	(b)	(b)	60,056	$49,160	51,556	$34,436
Cherokee (1), Clay (1), Emmet (1)	3	(c)	(c)	66,745	56,638	125,364	79,417	125,364	79,417
Clayton (0), Dubuque (2), Jackson (1), Clinton (1)	4	110,346	57,540	(b)	(b)	233,524	121,436	2,335,240	1,214,360
Des Moines (1), Mahaska (1), Wapello (1), Lee (0)	3	(c)	(c)	33,902	33,667	113,212	71,484	106,852	69,254
Humboldt (1), Webster (1), Boone (1), Wright (1)	4	11,724	8,134	31,913	24,994	79,510	50,416	73,680	49,802
Lyon (2), Sioux (2)	4	25,800	20,720	70,595	55,105	218,111	115,380	205,111	112,240
Mitchell (2), Butler (1), Tama (1), Cerro Gordo (2)	6	24,793	25,160	140,356	47,329	235,455	107,635	223,180	105,565
Muscatine (3), Scott (0)	3	(c)	(c)	133,430	93,019	257,697	172,418	215,358	150,778
Polk (5)	5	50,720	59,967	59,120	45,041	226,310	154,926	226,310	154,925
Sac (3), Harrison (1), State (3)	7	19,197	6,569	455,635	149,699	498,082	162.737	339,182	136,237
Total commercial, 1935	43	252,857	189,035	991,696	505,492	2,056,321	1,085,009	3,901,833	2,107,014
Total noncommercial,[d] 1935		1,260	425	3,496,466	648,237	3,676,421	671,842	63,324	24,896
Grand Total, 1935		254,117	189,460	4,488,162	1,153,729	5,732,742	1,756,851	3,965,157	2,131,906
Grand Total, 1934		282,217	224,751	3,145,187	793,165	4,349,362	1,394,000	1.595,159	928,466

a Structural gravel includes some paving gravel and paving gravel includes some structural gravel.
b Included under structural gravel.
c Included under paving gravel.
d Includes railroad ballast gravel.

TABLE XXXVIII

Total Production of Sand and Gravel in Iowa in 1936 — Sand

Counties	Producers	Structural sand		Paving sand		Other sand[a]		Total sand	
		Tons	Value	Tons	Value	Tons	Value	Tons	Value
Black Hawk (4), Linn (1)	5	31,296	$ 19,821	13,551	$ 5,873	16,269	$ 8,962	61,116	$ 34,656
Boone (1), Dallas (0), Polk (4)	5	86,539	50,633	56,918	19,252	(c)	(c)	143,457	69,885
Cerro Gordo (2), Wright (0), Humboldt (1), Webster (0)	3	63,347	34,864	81,859	40,503	(c)	(c)	145,206	75,367
Clayton (1), Dubuque (2), Clinton (1), Jackson (2)	6	30,568	12,734	66,210	38,753	(c)	(c)	96,778	51,487
Emmet (1), O'Brien (0), Clay (1), Cherokee (1)	3	114,325	44,340	(b)	(b)	(b)	(b)	114,325	44,340
Lyon (2), Sioux (1), State (1)	4	(c)	(c)	118,312	56,100			118,312	56,100
Mahaska (1), Wapello (1), Lee (2)	4	48,090	29,763	47,943	19,922	(c)	(c)	96,033	49,685
Mitchell (0), Butler (2), Tama (1)	3	17,252	11,926	(b)	(b)			17,252	11,926
Sac (2), Harrison (1)	3	63,615	20,286	(b)	(b)	(b)	(b)	63,615	20,286
Scott (1), Muscatine (3), Des Moines (1)	5	119,933	53,665	69,536	26,395	46,635	40,325	236,104	120,385
Total commercial, 1936	41	574,965	278,032	454,329	206,798	62,904	49,287	1,092,198	534,117
Total noncommercial, 1936		7,988	2,113	70,165	15,484			78,153	17,597
Grand Total, 1936		582,953	280,145	524,494	222,282	62,904	49,287	1,170,351	551,714
Grand Total, 1935		422,313	200,403	506,426	163,207	61,724	50,052	990,463	413,662

[a] Includes molding, cutting and grinding, engine, filter, and railroad ballast sand.
[b] Included under structural sand.
[c] Included under paving sand.

TABLE XXXIX

Total Production of Sand and Gravel in Iowa in 1936 — Gravel

Counties	Producers	Structural gravel [a]		Paving and other gravel		Total sand and gravel		Total quantity washed	
		Tons	Value	Tons	Value	Tons	Value	Tons	Value
Black Hawk (4), Linn (0)	4	16,175	$18,710	(b)	(b)	77,291	$53,366	77,291	$17,366
Boone (1), Dallas (1), Polk (4)	6	62,867	77,192	189,313	79,281	395,637	226,358	395,637	226,358
Cerro Gordo (2), Wright (2), Humboldt (1), Webster (3)	8	37,952	53,611	114,356	97,702	297,514	226,680	261,820	222,893
Clayton (0), Dubuque (2), Jackson (1), Clinton (2)	5	101,782	53,734	(b)	(b)	198,560	105,221	198,560	105,221
Emmet (1), O'Brien (1), Clay (1), Cherokee (1)	4	(c)	(c)	169,867	136,068	284,192	180,408	256,303	178,409
Lyon (1), Sioux (1), State (2)	4	(c)	(c)	395,714	109,364	514,026	165,464	232,826	144,114
Mahaska (1), Wapello (1), Lee (2)	4	38,143	41,195	(b)	(b)	134,176	90,880	134,176	90,880
Mitchell (1), Butler (1), Tama (1)	3	(c)	(c)	16,798	14,128	34,050	26,054	30,930	24,512
Sac (2), Harrison (2)	4	(c)	(c)	325,521	139,888	389,136	160,174	386,896	160,014
Scott (0), Muscatine (3), Des Moines (1)	4	(c)	(c)	177,623	134,817	413,727	255,202	395,926	322,322
Total commercial, 1936	46	256,919	244,442	1,389,192	711,248	2,738,309	1,489,807	2,370,365	1,492,089
Total noncommercial,[d] 1936		32,906	5,460	3,444,616	535,418	3,555,675	558,475	77,697	29,372
Grand Total, 1936		289,825	249,902	4,833,808	1,246,666	6,293,984	2,048,282	2,448,062	1,521,461
Grand Total, 1935		254,117	189,460	4,488,162	1,153,729	5,732,742	1,756,851	3,965,157	2,131,906

a Structural gravel includes some paving gravel and paving gravel includes some structural gravel.
b Included under structural gravel.
c Included under paving gravel.
d Includes railroad ballast gravel.

TABLE XL

Total Production of Sand and Gravel in Iowa in 1937 — Sand

Counties	Producers	Structural sand		Paving sand		Other sand[a]		Total sand	
		Tons	Value	Tons	Value	Tons	Value	Tons	Value
Black Hawk (5), Winneshiek (1), Clayton (2)	8	48,504	$ 33,270	(b)	(b)	74,403	$ 51,409	122,907	$ 84,679
Cerro Gordo (2), Mitchell (0), Butler (2)	4	50,392	36,871	49,309	34,601	(c)	(c)	99,701	71,472
Crawford (0), Sac (2), Carroll (1), Harrison (0)	3	73,738	30,986	(b)	(b)			73,738	30,986
Dallas (0), Polk (3), State (1)	4	102,862	46,830	65,377	30,774	(c)	(c)	168,239	77,604
Dubuque (2), Jackson (1), Clinton (2)	5	33,405	22,332	55,910	17,427	(c)	(c)	89,315	39,759
Emmet (1), Cherokee (2), Buena Vista (1)	4	32,393	13,976	97,578	34,663	(c)	(c)	129,971	48,639
Humboldt (1), Wright (0), Webster (0), Boone (2)	3	78,111	38,575	(b)	(b)	(b)	(b)	78,111	38,575
Lee (2), Mahaska (1), Wapello (1)	4	54,674	32,733	40,526	20,273	(b)	(b)	95,200	53,006
Lyon (3), Sioux (1), O'Brien (0)	4	191,727	71,254	(b)	(b)	(b)	(b)	191,727	71,254
Muscatine (3), Des Moines (1), Scott (1)	5	81,327	72,614	79,012	35,418	(b)	(b)	160,339	108,032
Tama (2), Linn (1), Johnson (1)	4	62,900	55,727	36,061	14,742	(b)	(b)	98,961	70,469
Total commercial, 1937	48	810,033	455,168	423,773	187,898	74,403	51,409	1,308,209	694,475
Total noncommercial, 1937	7	20,204	2,419	13,391	5,901			33,595	8,320
Grand Total, 1937	55	830,237	457,587	437,164	193,799	74,403	51,409	1,341,804	702,795
Grand Total, 1936		582,953	280,145	524,494	222,282	62,904	49,287	1,170,351	551,714

a Includes molding, cutting and grinding, engine, filter, and railroad ballast sand.
b Included under structural sand.
c Included under paving sand.

TABLE XLI

Total Production of Sand and Gravel in Iowa in 1937 — Gravel

Counties	Producers	Structural gravel[a]		Paving and other gravel		Total sand and gravel		Total quantity washed	
		Tons	Value	Tons	Value	Tons	Value	Tons	Value
Black Hawk (4), Winneshiek (0), Clayton (0)	4	19,515	$ 22,402	(b)	(b)	142,422	$ 107,081	139,203	$105,150
Cerro Gordo (2), Mitchell (1), Butler (1)	4	(c)	(c)	97,161	81,082	196,862	152,554	193,610	152,178
Crawford (1), Sac (2), Carroll (0), Harrison (4)	7	55,752	57,771	116,000	35,312	245,490	124,069	165,312	111,589
Dallas (1), Polk (3), State (2)	6	54,817	59,401	578,220	180,504	801,276	317,509	521,276	297,509
Dubuque (1), Jackson (1), Clinton (2)	4	102,843	79,272	(b)	(b)	192,158	119,031	184,038	117,001
Emmet (1), Cherokee (2), Buena Vista (1)	4	24,208	20,963	131,242	109,657	285,421	179,259	276,207	175,709
Humboldt (1), Wright (1), Webster (1), Boone (2)	5	18,363	17,747	76,568	55,399	173,042	111,721	140,937	109,064
Lee (1), Mahaska (1), Wapello (1)	3	34,404	35,069	(b)	(b)	129,604	88,075	129,604	88,075
Lyon (3), Sioux (1), O'Brien (1)	5	108,120	52,564	103,489	89,322	403,336	213,140	336,336	205,015
Muscatine (3), Des Moines (1), Scott (1)	5	(c)	(c)	197,914	127,674	358,253	235,706	313,453	229,306
Tama (2), Linn (1), Johnson (1)	4	22,984	20,182	25,277	28,132	147,222	118,783	147,222	118,783
Total commercial, 1937	51	441,006	365,371	1,325,871	707,082	3,075,086	1,766,928	2,547,198	1,709,379
Total noncommercial[d], 1937	40	80,425	9,696	3,208,048	450,159	3,322,068	468,175	6,667	4,659
Grand Total, 1937	91	521,431	375,067	4,533,919	1,157,241	6,397,154	2,235,103	2,553,865	1,714,038
Grand Total, 1936		289,825	249,902	4,833,808	1,246,666	6,293,984	2,048,282	2,448,062	2,131,906

[a] Structural gravel includes some paving gravel and paving gravel includes some structural gravel.
[b] Included under structural gravel.
[c] Included under paving gravel.
[d] Includes railroad ballast gravel.

TABLE XLII

Total Production of Sand and Gravel in Iowa in 1938 — Sand

Counties	Producers	Structural sand		Paving sand		Other sand[a]		Total sand	
		Tons	Value	Tons	Value	Tons	Value	Tons	Value
Buena Vista (1), Sac (3), Harrison (1)	5	36,283	$ 21,499	112,332	$ 44,280			148,615	$ 65,779
Butler (2), Black Hawk (3)	5	(c)	(c)	55,171	31,697	(c)	(c)	55,171	31,697
Cerro Gordo (2), Humboldt (1), Wright (0)	3	71,099	46,351	40,408	18,021	2,386	1,281	113,893	65,653
Clinton (2), Jackson (1)	3	(c)	(c)	47,626	33,435			47,626	33,435
Dallas (0), Polk (5), Adams (1)	6	91,651	46,140	124,694	49,356	(c)	(c)	216,345	95,496
Emmet (1), O'Brien (0), Cherokee (2)	3	(c)	(c)	66,214	30,599	(c)	(c)	66,214	30,599
Grundy (1), Marshall (0), Tama (1), Linn (1)	3	44,548	31,519	(b)	(b)	(b)	(b)	44,548	31,519
Lee (2), Des Moines (1)	3	20,402	11,184	(b)	(b)	(b)	(b)	20,402	11,184
Lyon (3), Sioux (1)	4	(c)	(c)	77,962	40,703	(c)	(c)	77,962	40,703
Marion (0), Mahaska (1), Wapello (1), Johnson (1)	3	(c)	(c)	111,440	71,461	(c)	(c)	111,440	71,461
Mitchell (0), Winneshiek (1), Clayton (1), Dubuque (2)	4	(c)	(c)	45,234	30,846	(c)	(c)	45,234	30,846
Muscatine (3), Scott (2)	5	42,690	21,914	135,283	63,892	(c)	(c)	177,973	85,806
Webster (0), Hamilton (0), Boone (1)	1	(d)	(d)						
Total commercial, 1938	48	306,673	178,607	816,364	414,290	2,386	1,281	1,125,423	594,178
Total noncommercial[e], 1938	4	17,588	2,289	1,400	500	4,459	371	23,447	3,160
Grand Total, 1938	52	324,261	180,896	817,764	414,790	6,845	1,652	1,148,870	597,338
Grand Total, 1937	55	830,237	457,587	437,164	193,799	74,403	51,409	1,341,804	702,795

a Includes molding, cutting and grinding, engine, filter, and railroad ballast sand.
b Included under structural sand.
c Included under paving sand.
d Included under paving and other gravel.
e Includes railroad ballast sand.

TABLE XLIII

Total Production of Sand and Gravel in Iowa in 1938 — Gravel

Counties	Producers	Structural gravel [a]		Paving and other gravel		Total sand and gravel		Total quantity washed	
		Tons	Value	Tons	Value	Tons	Value	Tons	Value
Buena Vista (1), Sac (3), Harrison (2)	6	61,486	$48,037	119,317	$90,618	329,418	$204,434	329,098	$204,184
Butler (1), Black Hawk (2)	3	(c)	(c)	15,515	18,927	70,686	50,624	63,903	47,954
Cerro Gordo (2), Humboldt (2), Wright (3)	7	34,559	41,664	80,303	48,504	228,755	155,821	191,886	152,010
Clinton (2), Jackson (1)	3	(c)	(c)	84,982	44,173	132,608	77,608	132,608	77,608
Dallas (1), Polk (4), Adams (1)	6	69,353	56,242	682,910	189,526	968,608	341,264	595,508	313,714
Emmet (1), O'Brien (1), Cherokee (2)	4	(c)	(c)	107,379	64,280	173,593	94,879	149,793	93,179
Grundy (1), Marshall (1), Tama (1), Linn (1)	4	62,252	22,082	(b)	(b)	106,800	53,601	54,042	43,731
Lee (2), Des Moines (1)	3	9,740	9,065	(b)	(b)	30,142	20,249	30,142	20,249
Lyon (3), Sioux (1)	4	(c)	(c)	104,648	78,986	182,610	119,689	182,610	119,689
Marion (1), Mahaska (1), Wapello (1), Johnson (1)	4	74,359	62,828	(b)	(b)	185,799	134,289	185,799	134,289
Mitchell (1), Winneshiek (1), Clayton (0), Dubuque (1)	3	(c)	(c)	25,277	7,687	70,511	38,533	103,707	79,452
Muscatine (3), Scott (1)	4	(c)	(c)	187,778	131,959	365,751	217,765	365,751	217,765
Webster (1), Hamilton (1), Boone (2)	4	(c)	(c)	18,345	9,350	18,345	9,350	10,501	8,790
Total commercial, 1938	55	311,749	239,918	1,426,454	684,010	2,863,626	1,518,106	2,395,348	1,512,614
Total noncommercial [d], 1938	42	1,731,401	520,195	2,375,812	258,271	4,130,660	781,626	70,516	37,002
Grand Total, 1938	97	2,043,150	760,113	3,802,266	942,281	6,994,286	2,299,732	2,465,864	1,549,616
Grand Total, 1937	91	521,431	375,067	4,533,919	1,157,241	6,397,154	2,235,103	2,553,865	1,714,038

a Structural gravel includes some paving gravel and paving gravel includes some structural gravel.
b Included under structural gravel.
c Included under paving gravel.
d Includes railroad ballast gravel.

Sand and Gravel Producers in Iowa

Adams County

Maudlin Construction Co., 629 Ohio Street, Webster City, Iowa.
Robert E. Devereux, Route 3, Corning, Iowa.

Allamakee County

Northeastern Iowa Sand and Gravel Co., Harpers Ferry, Iowa.

Blackhawk County

Jay B. Bagenstos, LaPorte City, Iowa.
Concrete Materials Corp., 504 Lafayette Building, Waterloo, Iowa.
Martin Hanson & Son, 1901 Commercial Street, Waterloo, Iowa.
Waterloo Dredging Co., 85 W. Mullen, Waterloo, Iowa.
Waterloo Sand and Gravel Co., C. H. Werner, 335 Sheridan Road, Waterloo, Iowa.

Boone County

Munson & Sons, Boone, Iowa.
Fraser Sand Company, c/o Otis Lumber Co., Boone, Iowa. Quarry at Fraser.
Markey River Sand Co., R. B. Markey, Boone, Iowa.

Buchanan County

Myron Baker, 1102 Fifth Avenue, N. E., Independence, Iowa.

Buena Vista County

LeGrand Limestone Co., 105 W. Madison Street, Chicago, Illinois, Quarry at Sioux Rapids.
L. L. Walton, Linn Grove, Iowa.

Butler County

Chas. Willeke & Sons, Aplington, Iowa.
Waverly Gravel & Tile Co., Shell Rock, Iowa.

Carroll County

Matt Lappe, Carroll, Iowa.

Cerro Gordo County

Clear Lake Sand & Gravel Co., Clear Lake, Iowa.
Ideal Sand & Gravel Co., Mason City, Iowa.

Cherokee County

Harris & Loucks Gravel Co., Cherokee, Iowa.
Northwestern Gravel Co., Lake View, Iowa.
Shea Sand & Gravel Co., Cherokee, Iowa.

Clayton County

The Korite Corporation, 329 N. Milwaukee Street, Milwaukee, Wisconsin.

Langworthy Silica Co., 705 Federal Bank Building, Dubuque, Iowa.

Clinton County

Camanche Sand & Gravel Co., Box 854, Davenport, Iowa.

Schneider Sand & Gravel Co., Clinton, Iowa.

Crawford County

James Ballantine, Arion, Iowa.

Hannah Carlson, Kiron, Iowa.

Rogers Bros., Dunlap, Iowa.

Dallas County

Kaser Construction Co., Adel, Iowa.

Des Moines County

R. J. Dietlien, Burlington, Iowa.

Kelley Sand & Materials Co., Mark E. Smith, Secretary-Treasurer, Burlington, Iowa.

Dubuque County

Lillie Coal Co., 510 Garfield Avenue, Dubuque, Iowa.

Molo Sand & Gravel Co., 135 W. Fifth Street, Dubuque, Iowa.

Emmett County

Concrete Materials Corp., Lafayette Building, Waterloo, Iowa.

Fayette County

Clermont Brick & Sand Co., Clermont, Iowa.

Grundy County

Ben Ankes, Wellsburg, Iowa.

Guthrie County

Ada Johnson, Guthrie Center, Iowa.

Hamilton County

James B. Weaver, National Bank & Trust Co., Des Moines, Iowa.

Hardin County

Iowa Falls Sand & Gravel Co., Iowa Falls, Iowa.

Harrison County

M. B. Musgrave, Woodbine, Iowa.

John Schumacher, Bancroft, Iowa.

Humboldt County

Concrete Materials Corporation, Waterloo, Iowa.

J. H. Tanck, Renwick, Iowa.

Jackson County

Bellevue Sand & Gravel Co., Att: A. C. Schneider, Bellevue, Iowa.

Johnson County

Central Sand & Gravel Co., Iowa City, Iowa.

Hawkeye Material Co., Box 104, Iowa City, Iowa.

W. Stock, River Junction, Iowa.

Lee County

Joseph Jaeger, Fort Madison, Iowa.

Keokuk Sand Co., Foot of Bank Street, Keokuk, Iowa.

Linn County

Kings Crown Plaster Co., 98 First Avenue, W., Cedar Rapids, Iowa.

Lyon County

L. G. Everist, Inc., 2100 E. Fourth Street, Sioux City, Iowa. Pit at Klondike.

LeGrand Limestone Co., 105 W. Madison Street, Chicago, Illinois. Quarry at Rock Rapids.

Miller Sand & Gravel Co., Box 101, Doon, Iowa.

Mahaska County

Concrete Materials Corp., Eddyville, Iowa.

Marion County

Harvey Sand & Gravel Co., Harvey, Iowa.

Wilson Sand & Gravel Co., Harvey, Iowa. Pit at Tracy.

Marshall County

Empire Sand & Material Co., Lock Box 467, Marshalltown, Iowa. Pit at Keller.

LeGrand Limestone Co., Chicago, Illinois.

Sam Wright, New Providence, Iowa. Pit at Zearing.

Mitchell County

Falk & Litzelman, St. Ansgar, Iowa. Pit at Osage.

Irvin C. Wheeler, McIntire, Iowa.

Muscatine County

Automatic Gravel Products Co., Box 34, Muscatine, Iowa.

Hahn Brothers Sand and Gravel Co., 207 W. Front Street, Muscatine, Iowa.

Northern Gravel Co., Muscatine, Iowa.

Plymouth County

Albert A. Wenzel, Kingsley, Iowa.

Polk County

Builders Cooperative Sand Co., S. E. 3rd & Jackson Avenue, Des Moines, Iowa.

Capital City Cooperative Sand & Gravel Co., Box 864, Des Moines, Iowa.

The Des Moines Sand & Fuel Coop. Ass'n., Box 1334, Des Moines, Iowa.

Flint Crushed Gravel Co., 907 Bankers Trust Building, Des Moines, Iowa. Pit at West Des Moines.

N. Leon Harris, R. R. No. 4, Des Moines, Iowa.

Keefner Sand & Gravel Co., 822 W. Ninth Street, Des Moines, Iowa.

Sac County

Wm. Brauer, R. F. D. No. 1, Lake View, Iowa.

Lake View Concrete Tile Co., Lake View, Iowa.

Northwestern Gravel Co., Lake View, Iowa.

LeGrand Limestone Co., 105 W. Madison Street, Chicago, Illinois. Quarry at Lake View.

W. H. Schnirring, Sac City, Iowa.

Mrs. W. H. Townsend, Sac City, Iowa.

Scott County

Builders Sand & Gravel Co., 104 Western Avenue, Davenport, Iowa.

Sioux County

L. G. Everist, Inc., 2100 Fourth Street, Sioux City, Iowa.

Hawarden Gravel Co., Hawarden, Iowa.

Story County

R. E. Carr Sand & Gravel Co., E. 16th Street, Ames, Iowa.

Roy Templeton, Ames, Iowa.

Tama County

Flint Crushed Gravel Co., 907 Bankers Trust Building, Des Moines, Iowa.

Van Buren County

J. C. Edvenson, Fort Dodge, Iowa. Pit at Stratford.

Wapello County

Ottumwa Sand Co., Ottumwa, Iowa.

Webster County

James Casey, Lehigh, Iowa.

Johnston Clay Works, Inc., Fort Dodge, Iowa.

Earl Richardson, Stratford, Iowa.
James B. Weaver, National Bank & Trust Co., Des Moines, Iowa.
Welch Bros., Fort Dodge, Iowa.

Winneshiek County

Decorah Concrete Products Co., 906 South Mill Street, Decorah, Iowa.

Wright County

Luick Gravel Co., Belmond, Iowa.
A. A. McCurry, Renwick, Iowa.
Mrs. Etta Middleton, Eagle Grove, Iowa.

Miscellaneous Stone Producers in Iowa

Commercial

Harrison County

M. O. Weaver, Inc., 539 Fifth Street, Des Moines, Iowa.

Noncommercial

Marshall County

City of Des Moines Highway Department, Des Moines, Iowa.

Peat Producers in Iowa

Noncommercial

Story County

Iowa State Highway Commission, John M. Hall, Roadside Improvement Engineer, Ames, Iowa.

Commercial

Worth County

Colby Pioneer Peat Co., Inc., Hanlontown, Iowa.

Sandstone Producers in Iowa

Commercial

Lucas County

W. T. Kelly, Des Moines, Iowa.

Noncommercial

Marion County

Marion County Highway Department, Knoxville, Iowa.

Lime Producers in Iowa

Marion County

A. K. Verrifs, Pella, Iowa.

A SUMMARY OF MINERAL PRODUCTION IN IOWA 1895-1938

by

H. GARLAND HERSHEY

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A SUMMARY OF MINERAL PRODUCTION IN IOWA 1895-1938

Foreword

The purpose of this report is to present in condensed form the trends in the development of the minerals industries in Iowa from 1895 to 1938. The Iowa Geological Survey and the United States Bureau of Mines publish reports on annual mineral production which provide detailed economic reviews for individual years. It is not their purpose, however, to summarize statistics of all preceding years and it is difficult, therefore, to obtain a composite picture of the development of production quantities and values over long periods. A summary of mineral productions in Iowa is needed for the 43-year period 1895-1938 and the following report was assembled to fulfill that need.

In preparing the report the aim was to outline only the outstanding features of the development of production of leading individual minerals and of the minerals industries as a whole. It was felt that this could be accomplished best by the use of diagrams and tables. These make up a large portion of the report and the discussion is intentionally short.

The leading mineral commodities produced in the state during the period were coal, clay and clay products, cement, gypsum, lime and limestone, and sand and gravel. Normally they made up more than 99 per cent of the total annual state mineral production. Of less importance were lead and zinc, sandstone, iron, mineral waters, mineral paint, sand lime brick, potash, natural gas and peat. Summaries of only the leading products are presented although the total yearly productions include the minor products.

Certain policies followed in the annual reports are also followed here. The production of sandstone, which is normally small, is included with lime and limestone. Raw clay is excluded from total yearly productions but is included in the figures for clay and clay products. The data presented for cement are based on the quantity and value of cement shipped from the mills.

The figures for quantity and value of production appearing in the tables were taken almost entirely from mineral reports of the Iowa Geological Survey, although a few were obtained from publications of the United States Bureau of Mines and the United States Geological Survey. These data were collected originally under a cooperative agreement between the State Survey and the two Federal agencies mentioned, except the data for clay, whch were furnished by the United States Bureau of the Census after collection by that agency without state cooperation.

The published reports of the various agencies do not always agree because of differences in the methods of interpreting and presenting data submitted by producers. Furthermore, in many cases published original figures have been corrected or revised in later publications of the same agency. These discrepancies are usually of small magnitude and where they occur, the most recent figures of the Iowa Geological Survey have been used in this report.

The work of assembling the report was begun by the Iowa State Planning Board under the immediate supervision of R. H. Matson and later of O. H. Baldwin. When the existence of the Planning Board was terminated in 1939 the project was incomplete. At that time the columnar diagram for total mineral production had been completed to 1935, the tables had been prepared up to include 1936, the plate showing the geology and distribution of mineral production had been completed and the columnar diagrams for individual minerals had been outlined. The Planning Board, therefore, is responsible for the plan of the report and for a considerable part of its preparation. The Iowa Geological Survey has brought up to date and checked all tables and diagrams and has prepared the accompaning discussion.

Major Geological Systems of Iowa

Rocks of ten major geologic subdivisions occur at the surface in Iowa. In the order of decreasing age they are: Pre-Cambrian, Cambrian, Ordovician, Silurian, Devonian, Mississippian, Pennsylvanian, Permian(?), Cretaceous, and Pleistocene (including Recent). Materials composing the Pleistocene are almost entirely unconsolidated, all others are considered to be consolidated.

Pleistocene deposits cover much of the surface of the state. They consist of glacial and interglacial clays, silts, loess, sands and gravels. Much of the sand and gravel was deposited by water associated with the glaciers. Glacial sand and gravel is the chief source of supply for the sand and gravel industry. The clays, which are chiefly glacial, have been sparingly used for the manufacture of clay products, but normally they are not suitable for this purpose. The loess has been somewhat more widely used for clay product manufacture.

The generalized geologic map (Plate I, figure D) shows the distribution of the consolidated rocks in Iowa which occur at the surface or which immediately underlie the glacial drift and other younger deposits. The best exposures of consolidated rocks occur in the northeast corner of the state, in the Mississippi River and Missouri River valleys and in the valleys of major tributary streams. Elsewhere they are masked by overlying Pleistocene deposits except for occasional exposures on the uplands.

Outcrops of pre-Cambrian rocks are limited in Iowa to the extreme northwestern corner of the state. The only formation exposed is a quartzite which has been utilized to a limited extent in the past for crushed stone and building material.

Cambrian rocks, composed primarily of sandstones with minor amounts of limestone, dolomite and shale, are limited in exposure area to northeastern Iowa. The sandstones and limestones have been used for building purposes and for crushed stone.

Formations of the Ordovician system are exposed only in the northeastern part of Iowa. They are made up of shales, limestones, dolomites, and sandstones, all of which have been developed commercially.

The outcrop area of the Silurian system is limited to east-central Iowa. It is composed essentially of dolomites which are used for building and crushed stone.

Rocks of the Devonian also form a band of outcrop in the eastern and north-central portions of the state. The formations are chiefly limestones, shales and dolomites. The limestones are used for crushed rock and by four of the six cement plants in the state; the shales furnish raw materials for clay products and cement manufacture.

Mississippian rocks, composed essentially of limestones and shales, form a band of outcrop from the southeastern corner to the north-central portion of the state. The limestones are utilized for crushed stone, the shales for making clay products. A minor amount of gypsum has been mined from the Mississippian.

The Pennsylvanian system of rocks, often referred to as the "Coal Measures," is made up chiefly of shales, limestones, sandstones, coals, and underclays. It has a larger outcrop area (Plate I, figure D) and contributes more materials to the mineral industries than any other system in the state. From the Pennsylvanian comes all of the coal mined in Iowa, large volumes of shale for clay products and cement, and limestone for cement and crushed stone.

Rocks of the Permian (?) system, made up of red and green shales and gypsum, are restricted in Iowa to a small area in the vicinity of Fort Dodge which is too small to show on the accompanying map. Most of the gypsum extracted in the state has been obtained from the Permian (?).

Cretaceous deposits, composed of shales, loosely consolidated sandstones and conglomerates and a minor amount of limestone, occur in northwestern Iowa and in scattered areas in the southwestern portion of the state. They are exploited chiefly for shales used in the making of clay products and for road-making materials derived from the sandstones and conglomerates.

Geographical Distribution of Mineral Production

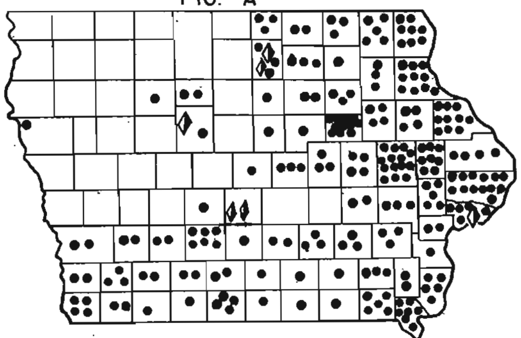
The geographical distribution of the various mineral products may be seen from Plate I, figures A, B and C. These maps show that the eastern and central portions of the state lead in the number of producers and that there are comparatively few producers in the western portion, particularly in the extreme northwest.

All of the cement produced in Iowa is manufactured in six large plants (Plate I, figure A). Two are located in Cerro Gordo county, two in Polk county and one each in Scott and Pocahontas counties. Raw materials are obtained chiefly from the immediate vicinity of the plants; those for the plants in Polk county are derived from Pennsylvanian rocks, all others come from the Devonian.

Clay, including shale, has been produced for commercial purposes from many geological horizons from almost all portions of the state, but utilization has been most concentrated in the central, north-central and southeastern areas. The distribution of operators for 1920 and for 1936 is shown by Plate I, figure C.

Coal is extracted chiefly from the central and southern portion of the state, where Pennsylvanian rocks are at or near the surface. An idea of the distribution of production can be obtained from Plate I, figure B which shows that in 1935 there were 262 operators in 23

FIG. A

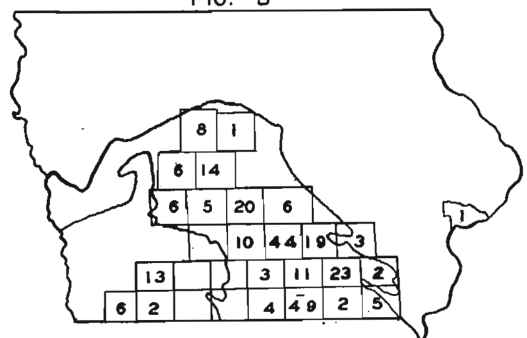


GEOGRAPHIC DISTRIBUTION OF:

● LIME & LIMESTONE PRODUCERS FOR 1936, PEAK YEAR.

◊ CEMENT PRODUCERS FOR 1936.

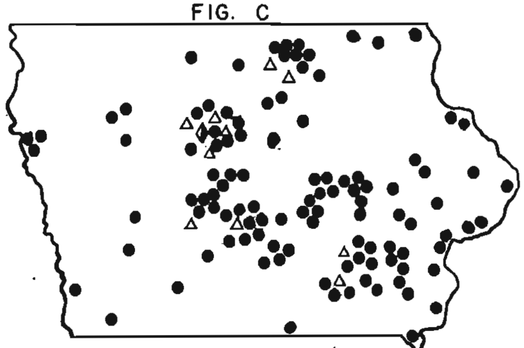
FIG. B



GEOGRAPHIC DISTRIBUTION OF COAL FOR 1935

NUMBERS REFER TO NUMBER OF PRODUCERS IN EACH TERRITORY.

FIG. C



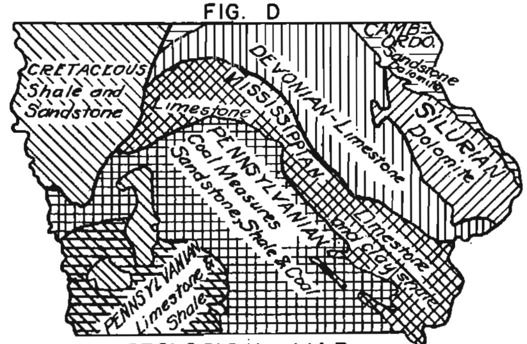
GEOGRAPHIC DISTRIBUTION OF:

◊ GYPSUM PRODUCERS FOR 1936

● CLAY & CLAY PRODUCTS PRODUCERS FOR 1920, PEAK YEAR.

△ CLAY & CLAY PRODUCTS PRODUCERS FOR 1936.

FIG. D



GEOLOGICAL MAP SHOWING MAJOR GEOLOGICAL DIVISIONS counties. These operators were chiefly those producing more than 1,000 tons of coal annually. In addition there were a large number of smaller producers.

The gypsum industry in Iowa is centered in a relatively small area in the immediate vicinity of Fort Dodge (Plate I, figure C), although some production has been obtained in the vicinity of Centerville in Appanoose county. The source of raw material at Fort Dodge is Permian (?), at Centerville Mississippian.

Limestone production is widespread in Iowa. As shown by Plate I, figure A, all counties but two in the eastern half and all counties in the southern third of the state produced this material in 1936. Output in northwestern Iowa is limited because limestone is only sparingly present there and where it does occur conditions are such that profitable extraction is difficult. All of the major geologic subdivisions except the Pleistocene and pre-Cambrian have yielded limestone production of commercial value in Iowa.

The production of sand and gravel is more widespread than for any other mineral product in the state. These materials are found at or near the surface in all parts of Iowa and have been exploited in every county, although the major portion is extracted in the northern and southeastern areas. They are chiefly Pleistocene in age although the Cretaceous has furnished considerable production.

Annual Total Mineral Production

Plate II represents the total mineral production in the state for the period of this report by value of individual minerals produced. The entire circle is equivalent to 100 per cent of total production of all minerals, and the segments are scale representations of the percentage of individual total productions.

The total value of coal led all other minerals for the period 1895-1938 with a cumulative value of 48.7 per cent of the total of all minerals produced. Cement ranked second with a value of 17.5 per cent, and clay and clay products third with a value representing 17.2 per cent of the total, followed by gypsum (8.3 per cent), lime and limestone (4.2 per cent), and sand and gravel (4.0 per cent). The remainder of the percentage is taken up by other minerals.

Table I shows that the total value of mineral production in Iowa advanced steadily from 1895 through 1916, except for a slight decline

TOTAL MINERAL PRODUCTION IN IOWA, 1895-1938

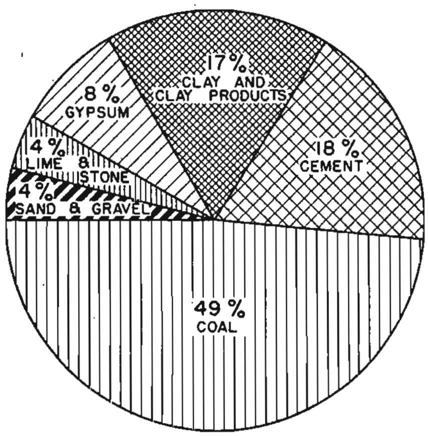


TABLE I

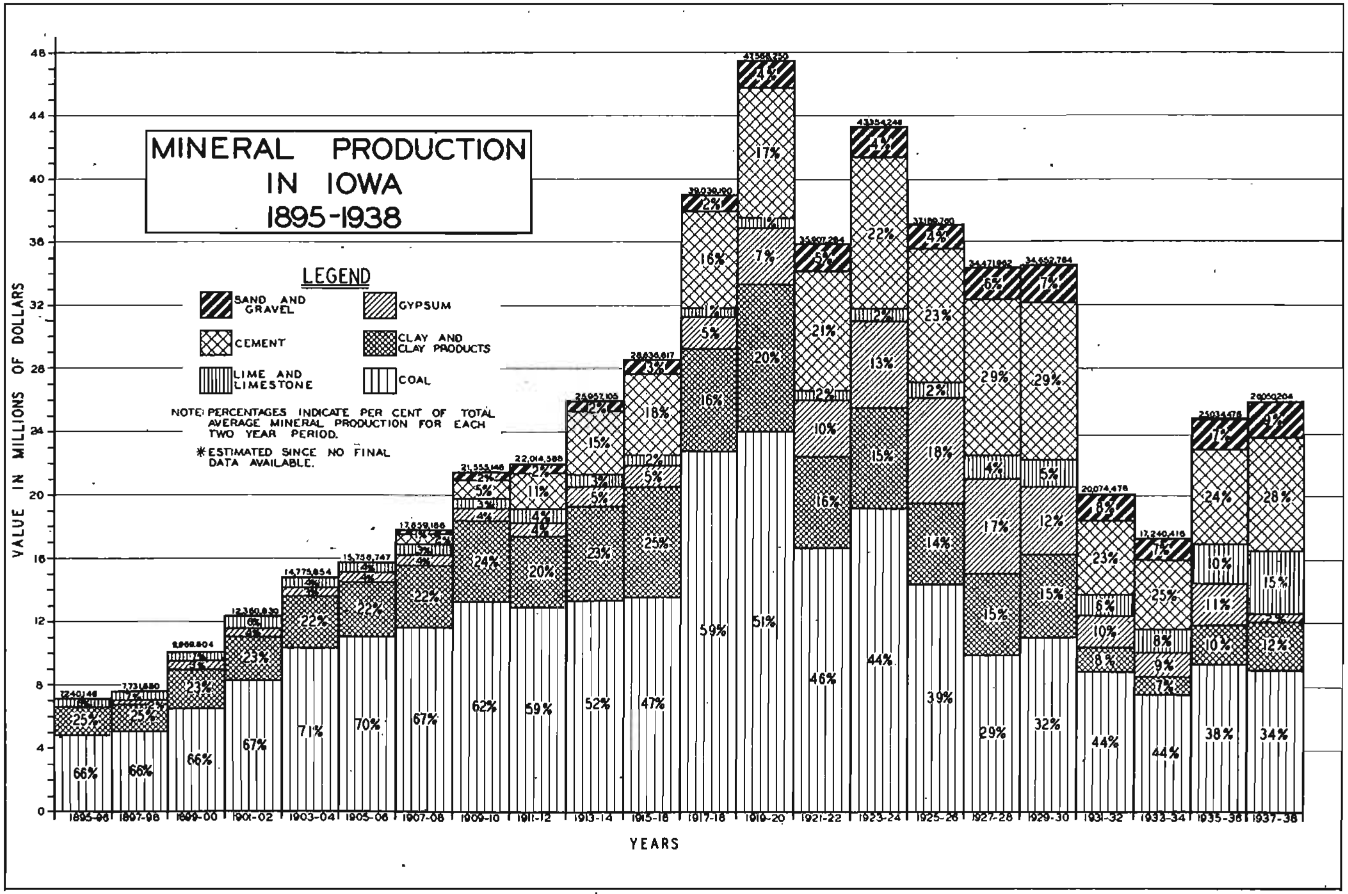
Annual Total Mineral Production in Iowa — 1895-1938

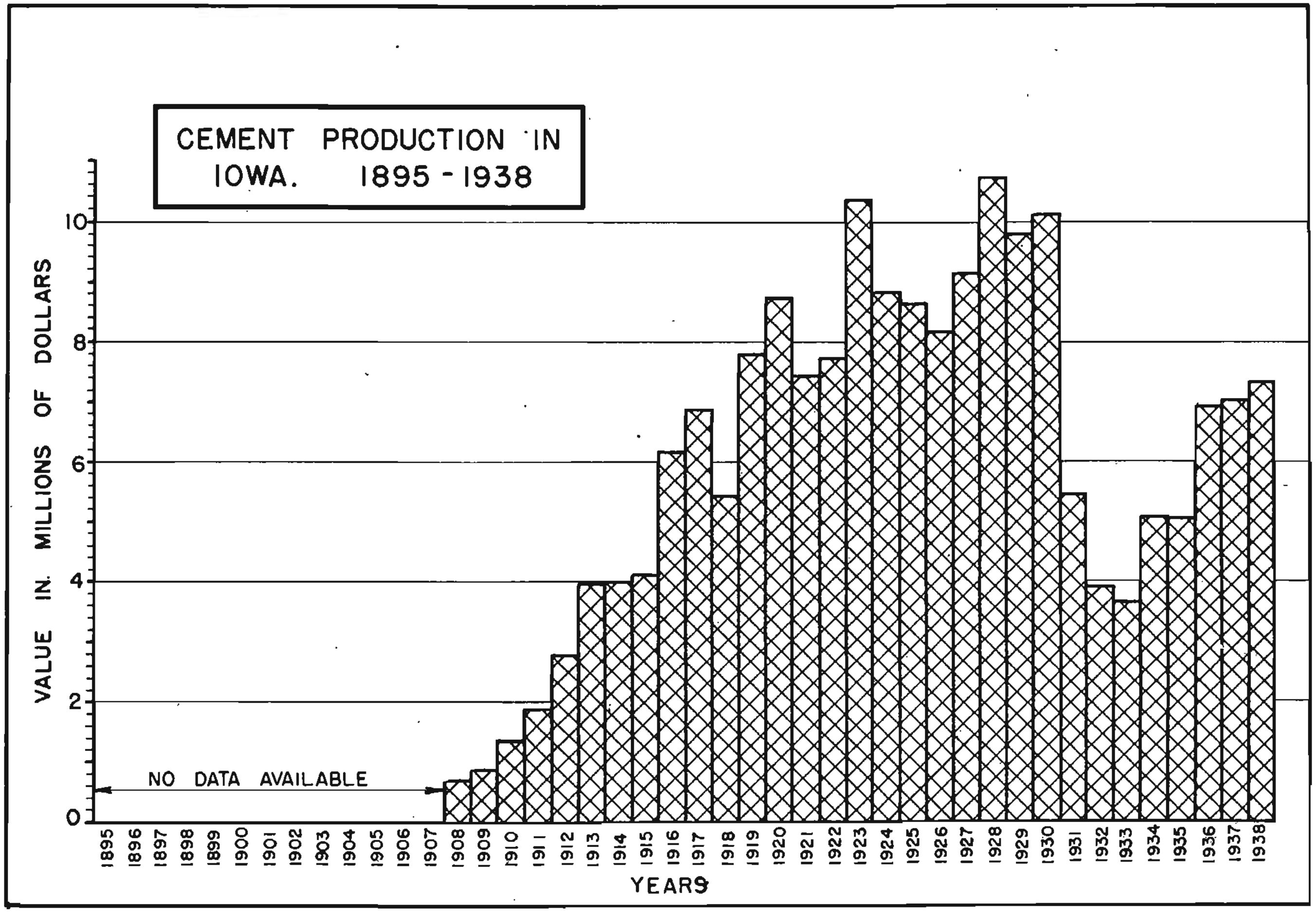
Year	Value	Average value for two year period	Year	Value	Average value for two year period
1895 1896		$ 7,240,146	1917 1918	$39,336,372 38,742,009	$39,039,190
1897 1898	$ 7,676,181 7,787,579	7,731,880	1919 1920	37,882,183 57,250,317	47,566,250
1899 1900	9,537,948 10,401,661	9,969,804	1921 1922	35,625,170 36,189,398	35,907,284
1901 1902	12,204,160 12,517,501	12,360,830	1923 1924	46,237,521 40,470,971	43,354,246
1903 1904	14,596,708 14,955,000	14,775,854	1925 1926	38,393,742 35,985,779	37,189,760
1905 1906	15,103,046 16,414,447	15,758,747	1927 1928	33,442,891 35,501,033	34,471,962
1907 1908	17,627,925 18,090,447	17,859,186	1929 1930	35,961,008 33,344,520	34,652,764
1909 1910	20,365,721 22,744,572	21,555,146	1931 1932	21,626,332 18,522,625	20,074,478
1911 1912	21,119,111 22,910,066	22,014,588	1933 1934	15,154,652 19,326,181	17,240,416
1913 1914	25,612,345 26,301,865	25,957,105	1935 1936	21,709,817 28,359,140	25,034,478
1915 1916	27,062,950 30,210,284	28,636,617	1937 1938	26,941,350 25,159,058	26,050,204

in 1911. Output was abnormally high during the war years of 1917-1918 and the post-war years 1919-1920. In 1920 mineral production reached a total value of $57,250,317, the greatest ever attained in Iowa and more than 11 millions of dollars greater than for 1923 the next most productive year. After a sharp decline in the period 1921-1922, and the strong recovery in 1923, total value began a downward trend during the year following, which continued until 1928-1929 when gains were slight. The depression which began in late 1929 caused some decrease in total value in 1930, but the full effect of general conditions was reflected in large decreases in the value of minerals produced in Iowa from 1931 through 1933. In 1933 total production amounted to $15,154,652 and was lower than for any year since 1905. Recovery began in 1934 and continued through 1936. The recession of 1937-1938 caused a drop in mineral production in the latter year.

Plate III presents the relationships between the various mineral commodities represented. It shows by two year periods the total value of mineral production, the value of individual minerals produced and the percentage of the biennial total represented by each commodity.

The combined industries showed a general upward trend from 1895 to a maximum in 1919-1920, a general downward trend to 1933-1934


MINERAL PRODUCTION
IN IOWA
1895-1938
LEGEND
SAND AND GRAVEL
GYPSUM
CEMENT
CLAY AND CLAY PRODUCTS
LIME AND LIMESTONE
COAL
NOTE: PERCENTAGES INDICATE PER CENT OF TOTAL AVERAGE MINERAL PRODUCTION FOR EACH TWO YEAR PERIOD.
*ESTIMATED SINCE NO FINAL DATA AVAILABLE.
VALUE IN MILLIONS OF DOLLARS
YEARS
1895-96
1897-98
1899-00
1901-02
1903-04
1905-06
1907-08
1909-10
1911-12
1913-14
1915-16
1917-18
1919-20
1921-22
1923-24
1925-26
1927-28
1929-30
1931-32
1933-34
1935-36
1937-38


CEMENT PRODUCTION IN IOWA. 1895 - 1938
VALUE IN MILLIONS OF DOLLARS
0
2
4
6
8
10
NO DATA AVAILABLE
1895 1896 1897 1898 1899 1900 1901 1902 1903 1904 1905 1906 1907 1908 1909 1910 1911 1912 1913 1914 1915 1916 1917 1918 1919 1920 1921 1922 1923 1924 1925 1926 1927 1928 1929 1930 1931 1932 1933 1934 1935 1936 1937 1938
YEARS

and an uptrend until 1938. Coal, and clay and clay products, two of the leading mineral products followed these trends while other mineral commodities reached maximum productions after 1920.

The ranking positions of the various minerals over the 43-year period show coal to be the outstanding leader although output of this resource decreased in relative value after 1917-1918. Clay and clay products which ranked second from 1895 to 1920 yielded its place to cement in the ensuing years. Sand and gravel increased steadily from 1 per cent of the total mineral production in 1907-1908 to 9 per cent in 1935. Lime and limestone represented from 7 to 3 per cent of the total from 1895 to the beginning of the war period, dropped as low as 1 per cent in 1919-1920, then advanced steadily to 8 per cent of the total in 1935.

TABLE II

Cement Production in Iowa — 1895-1938

	Shipments			
			Average for two year period	
Year	Quantity (barrels)	Value	Value	Percent of total [a]
1895-1908	No data available			
1908		$ 690,105		2
1909		862,000[b]	$1,124,000	5
1910		1,386,000[b]		
1911	1,952,590	1,881,253	2,335,824	11
1912	3,190,354	2,790,396		
1913	3,455,800	3,972,876	3,990,895	15
1914	4,224,076	4,008,915		
1915	4,590,336	4,119,952	5,142,749	18
1916	4,853,789	6,165,547		
1917	4,428,765	6,870,863	6,147,394	16
1918	3,188,669	5,423,926		
1919	4,569,110	7,798,347	8,270,600	17
1920	4,421,783	8,742,854		
1921	4,151,439	7,439,983	7,574,648	21
1922	4,475,074	7,709,313		
1923	5,570,675	10,351,971	9,581,779	22
1924	4,881,613	8,811,587		
1925	4,856,849	8,674,563	8,420,952	23
1926	4,788,639	8,167,341		
1927	5,661,234	9,124,405	9,929,621	29
1928	6,880,731	10,734,838		
1929	6,586,111	9,781,159	9,944,371	29
1930	7,035,252	10,107,584		
1931	5,790,087	5,453,320	4,680,373	23
1932	4,373,642	3,907,427		
1933	2,770,656	3,651,921	4,373,421	25
1934	3,340,049	5,094,922		
1935	3,203,301	5,072,098	5,990,162	24
1936	4,407,624	6,908,225		
1937	4,598,453	7,046,021	7,186,534	28
1938	4,759,390	7,327,048		

a Percent of total value of all minerals produced in Iowa for the two year period designated.
b Estimated.

Cement

The history of cement production is given in Plate IV and Table II. Prior to 1931 the cement industry presented an enviable record of advancement in Iowa. In 1908, the first year for which data are available, the value of cement produced was $690,105 which represented 4 per cent of the total mineral production of the state; by 1923 it had increased to $10,351,971, about 20 per cent of the state total for all minerals, and in that time decreases occurred in only two years, 1918 and 1921. Production followed a moderate downward trend from 1924 to 1926, but the ensuing upswing included the highest production value recorded in Iowa. This peak was attained in 1928 when the value was $10,734,838. Values remained relatively stable until 1930, but in 1931, with building construction at an extremely low level, cement production suffered a sharp decline. Further decreases in 1932 and 1933 depressed the annual value in the latter year to $3,651,921 which was lower than for any year after 1912. Recovery of building construction was reflected in sharp increases in cement values in 1934 and this uptrend continued through 1938.

Quantity and value of production are not directly comparable because of variations in price. The peak quantity production was reached in 1930 when it amounted to 7,035,252 tons valued at $10,107,584, but in 1928 an output of 6,880,731 tons was valued at $10,734,838.

Since 1921 cement has outranked all other mineral products except coal in annual output value, in spite of the facts that large scale production of cement began as late as 1908 and the industry suffered exceptional declines during the depression.

Clay and Clay Products

The clay industry, including production of raw clay, shale and clay products ranked second to coal in total value from 1895 to 1921. Since then it experienced reversals which placed it fifth in rank in 1936.

As shown by Plate V and Table III advancement was relatively steady from 1895 to 1917 with increases in production returns for all years except 1896, 1900, 1905 and 1911. A sharp decline in 1918 was followed in 1919 by an even greater advance, and in 1920 an output valued at $10,489,232 represents a record for the period of this report. After a decrease in 1921 the industry remained fairly stable until 1929 except for a rise in 1923 and an equivalent drop in 1926.

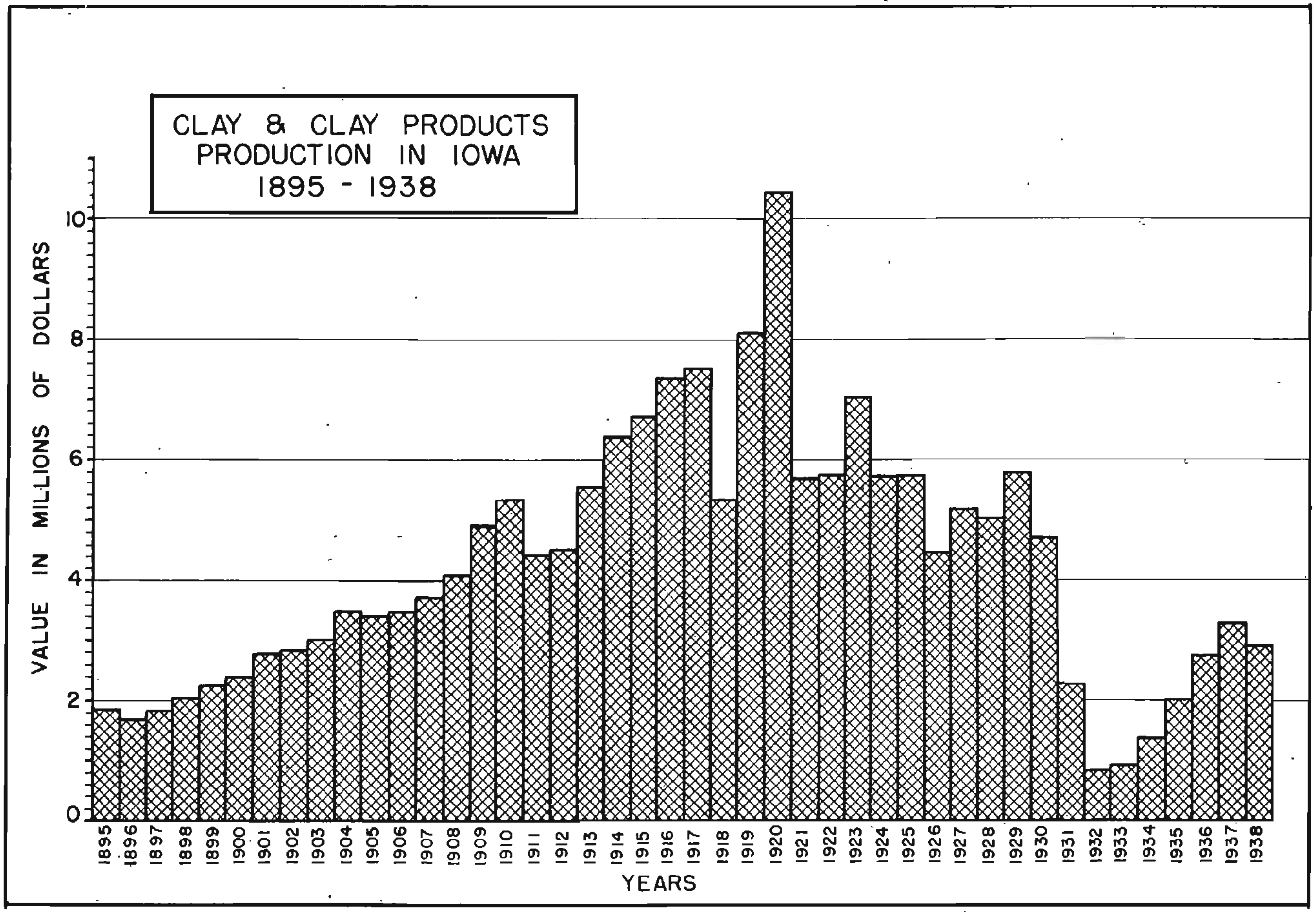

CLAY & CLAY PRODUCTS
PRODUCTION IN IOWA
1895 - 1938
VALUE IN MILLIONS OF DOLLARS
0
2
4
6
8
10
1895 1896 1897 1898 1899 1900 1901 1902 1903 1904 1905 1906 1907 1908 1909 1910 1911 1912 1913 1914 1915 1916 1917 1918 1919 1920 1921 1922 1923 1924 1925 1926 1927 1928 1929 1930 1931 1932 1933 1934 1935 1936 1937 1938
YEARS

Plate V

TABLE III

Clay and Clay Products Production in Iowa — 1895-1938

Year	Value	Average for two year period	
		Value	Percent of total [a]
1895	$1,870,292	$1,782,347	25
1896	1,694,402		
1897	1,821,247	1,939,135	25
1898	2,057,022		
1899	2,240,217	2,317,853	23
1900	2,395,488		
1901	2,774,200	2,808,895	23
1902	2,843,591		
1903	3,033,583	3,260,479	22
1904	3,487,376		
1905	3,408,547	3,442,892	22
1906	3,477,237		
1907	3,733,476	3,906,051	22
1908	4,078,627		
1909	4,916,513	5,125,774	24
1910	5,335,036		
1911	4,436,839	4,480,665	20
1912	4,524,492		
1913	5,575,581	5,990,788	23
1914	6,405,995		
1915	6,749,088	6,067,402	25
1916	7,385,716		
1917	7,543,225	6,431,036	16
1918	5,318,848		
1919	8,125,324	9,307,278	20
1920	10,489,232		
1921	5,711,583	5,725,516	16
1922	5,739,449		
1923	7,033,924	6,376,809	15
1924	5,719,694		
1925	5,726,239	5,110,663	14
1926	4,495,088		
1927	5,194,780	5,121,777	15
1928	5,048,774		
1929	5,791,175	5,252,311	15
1930	4,713,448		
1931	2,287,903	1,546,851	8
1932	805,799		
1933	917,548	1,146,008	7
1934	1,374,469		
1935	2,039,568	2,407,201	10
1936	2,774,833		
1937	3,301,548	3,107,770	12
1938	2,913,992		

a Percent of total value of all minerals produced in Iowa for the two year period designated.

The years of the depression, 1930-1932, were disastrous for the clay industry. Total values dropped from $5,791,175 in 1929 to $805, 375 in 1930. The latter value is far below that of any year after 1895 and less than one-tenth of the peak production value of 1920.

Recovery began in 1933 and continued through 1937 although total value was considerably below average for this period. The effect of the recession which began in late 1937 and continued into early 1938

TABLE IV

Coal Production in Iowa—1895-1938

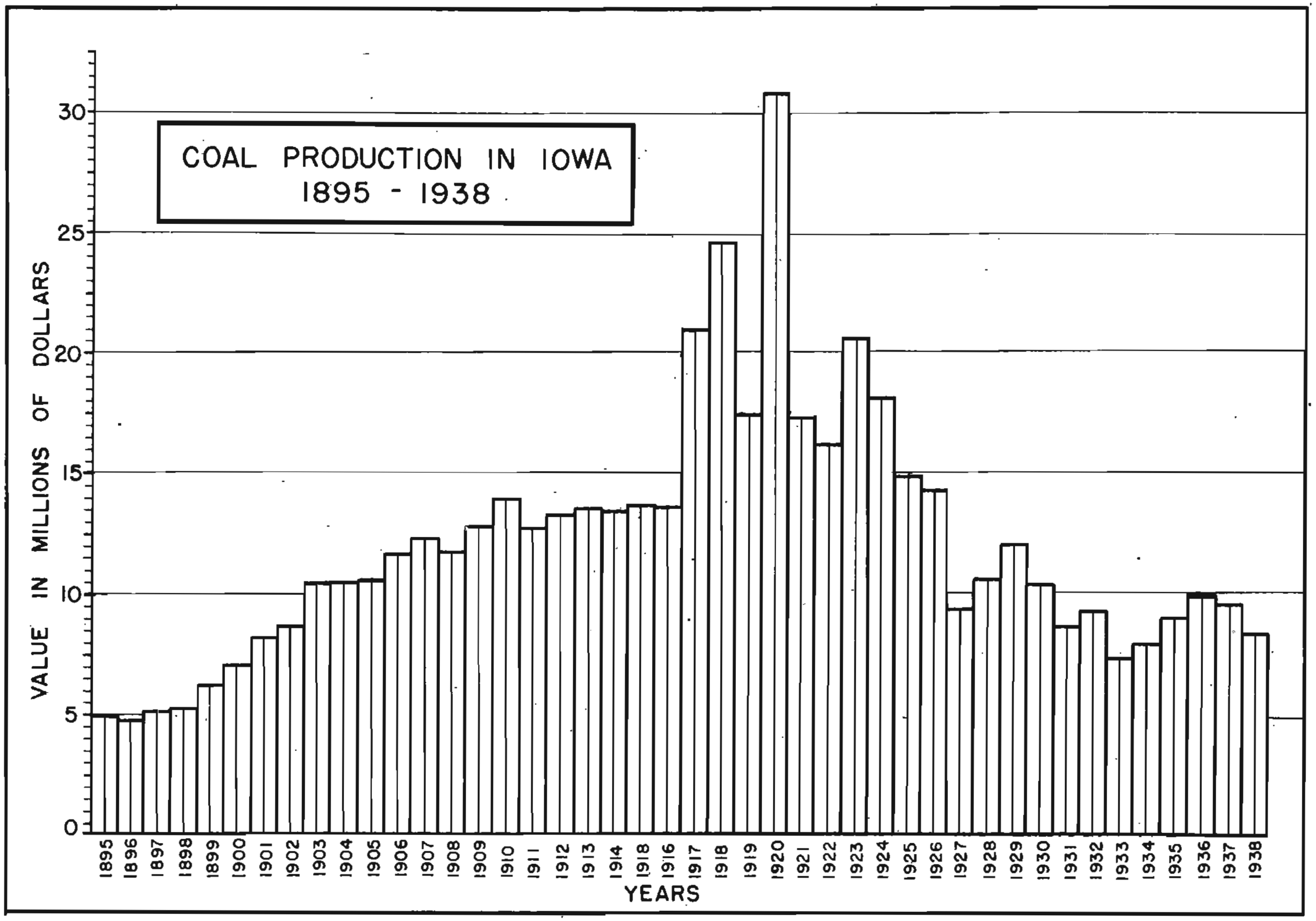
Year	Quantity (tons)	Value	Average for two year period: Value	Average for two year period: Percent of total [a]
1895	4,156,074	$ 4,982,102	$ 4,805,062	66
1896	3,954,028	4,628,022		
1897	4,523,494	5,098,103	5,110,645	66
1898	4,500,810	5,123,187		
1899	4,928,477	6,137,576	6,557,521	66
1900	5,105,151	6,977,466		
1901	5,663,016	8,051,806	8,356,047	67
1902	5,527,263	8,660,287		
1903	6,365,233	10,439,139	10,439,317	71
1904	6,507,655	10,439,496		
1905	6,798,609	10,586,381	11,102,918	70
1906	7,266,224	11,619,455		
1907	7,574,322	12,258,012	11,982,207	67
1908	7,161,310	11,706,402		
1909	7,757,762	12,793,628	13,348,770	62
1910	7,928,120	13,903,913		
1911	7,331,648	12,663,507	12,907,798	59
1912	7,289,529	13,152,088		
1913	7,525,936	13,496,710	13,430,390	52
1914	7,451,022	13,364,070		
1915	7,614,143	13,577,608	13,553,995	47
1916	7,260,800	13,530,383		
1917	8,965,830	21,096,408	22,899,822	59
1918	8,192,195	24,703,237		
1919	5,624,692	17,352,620	24,073,233	51
1920	7,813,916	30,793,847		
1921	4,531,392	17,256,800	16,687,900	46
1922	4,335,161	16,119,000		
1923	5,710,735	20,517,000	19,307,000	44
1924	5,468,450	18,097,000		
1925	4,714,843	14,807,000	14,510,500	39
1926	4,625,487	14,214,000		
1927	2,949,622	9,304,000	9,914,500	29
1928	3,683,635	10,525,000		
1929	4,241,069	11,948,000	11,166,500	32
1930	3,892,571	10,385,000		
1931	3,388,355	8,575,000	8,914,500	44
1932	3,862,435	9,254,000		
1933	3,194,983	7,217,000	7,539,500	44
1934	3,366,992	7,862,000		
1935	3,650,163	9,002,000	9,471,000	38
1936	3,960,700	9,940,000		
1937	3,637,054	9,529,000[b]	8,934,500	34
1938	3,250,000[b]	8,340,000[b]		

[a] Percent of total value of all minerals produced in Iowa for the two year period designated.
[b] Estimated.

resulted in a drop in the output value of clay and clay products in the latter year.

Coal

For the details of coal production, see Plate VI and Table IV. The annual value of coal production showed a relatively steady increase from 1895 to 1916, although after 1902 the advance was not as rapid


COAL PRODUCTION IN IOWA
1895 - 1938
VALUE IN MILLIONS OF DOLLARS
0
5
10
15
20
25
30
1895 1896 1897 1898 1899 1900 1901 1902 1903 1904 1905 1906 1907 1908 1909 1910 1911 1912 1913 1914 1918 1916 1917 1918 1919 1920 1921 1922 1923 1924 1925 1926 1927 1928 1929 1930 1931 1932 1933 1934 1935 1936 1937 1938
YEARS

as it was prior to that year. War industries caused abnormally sharp increases in 1917 and 1918, but post-war conditions caused an almost equally sharp drop in 1919. An output valued at $30,793,847 in 1920 established an all-time production record in Iowa. After 1920 the trend was generally downward until 1933 although increases over the previous year occurred in 1923, 1928, 1929 and 1932. Coal reached the depression low in 1933 when production value was $7,217,000 which was lower than any year since 1900 and represented a value of 23 per cent of the peak output of 1920. Production increased from 1933 through 1936, but in 1937 and 1938 the estimated value declined.

The quantity of coal produced followed in general the same trends as the total value. Notable differences, however, are that peak quantity production was attained in 1917 when the output was 8, 965,830 tons, and the minimum production for the period of this report was 2,949, 622 tons in 1927. These apparent discrepancies between quantity and value are explained by variations in price.

Gypsum

Plate VII and Table V show trends in production of gypsum. Gypsum production followed a general upward trend from 1895 until 1927. Advancement was slow and erratic until 1916, but after that year gains were more rapid. Increases in value over the preceding year occurred in 1917, 1919, 1920, 1922-1925 and 1927. The greatest annual value of production on record for Iowa was attained in 1925 when it amounted to $6, 734,271 and in 1926 and 1927 the values were over 6.5 and 6.7 millions of dollars respectively. The years 1928-1933 were disastrous for the gypsum industry in the state; the value of production dropped at the rate of more than a million dollars a year for five successive years, and the low was reached in 1933 when the value was $1,357,407. Recovery began in 1934, however, and continued through 1936, the last year for which comparable figures are available.

The quantity of production was somewhat more uniform than was the value. The peak production of 723,942 tons was reached in 1927 and the depression low came in 1933 with an output of 163,243 tons.

It should be noted that the tables show quantities and values of calcined and uncalcined gypsum and that the columnar diagram is based on these figures rather than the value of crude gypsum mined, except

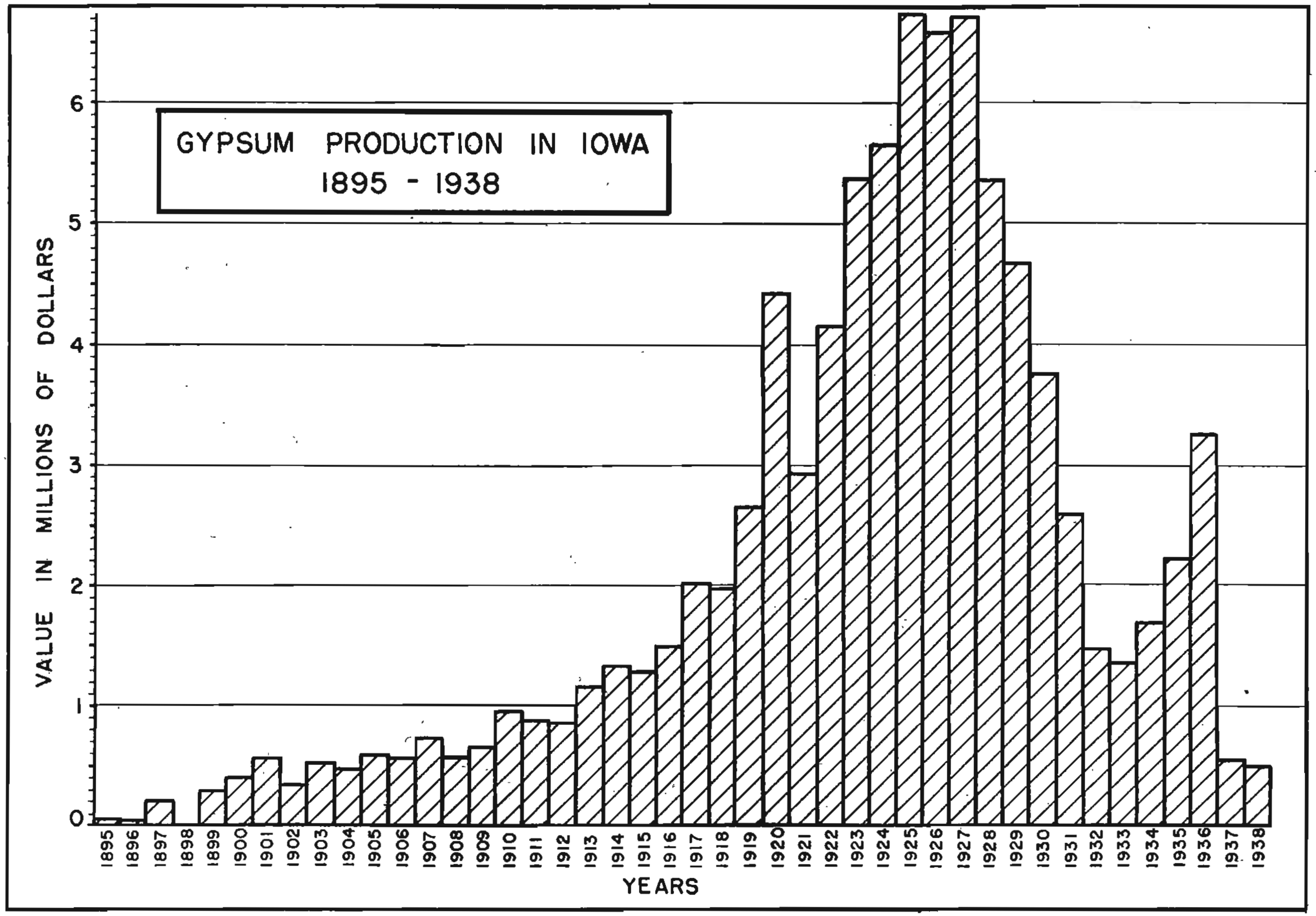

GYPSUM PRODUCTION IN IOWA
1895 - 1938
VALUE IN MILLIONS OF DOLLARS
0
1
2
3
4
5
6
YEARS
1895
1896
1897
1898
1899
1900
1901
1902
1903
1904
1905
1906
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TABLE V

Gypsum Production in Iowa — 1895-1938

Year	Sold calcined and uncalcined			
			Average for two year period	
	Quantity (tons)	Value	Value	Percent of total [a]
1895	17,200	$ 36,600	$ 35.310	
1896	14,937	34,020		
1897		195,000[b]	195,000	2
1898				
1899	75,574	296,220	344,985	3
1900	75,000[b]	393,750		
1901	125,000[b]	562,500	450,117	4
1902	120,779	337,735		
1903	120,504	523,008	496,220	3
1904	117,297	469,432		
1905	131,408	589,055	581,276	4
1906	160,139	573,498		
1907	181,799	730,383	647,536	4
1908	179,987	564,688		
1909	206,517	655,602	799,725	4
1910	267,623	943,849		
1911	240,922	871,752	858,690	4
1912	315,559	845,628		
1913	385,414	1,157,939	1,239,698	5
1914	400,250	1,321,457		
1915	406,966	1,278,128	1,387,461	5
1916	434,263	1,496,795		
1917	387,210	2,041,997	1,994,206	5
1918	275,897	1,946,414		
1919	333,680	2,634,444	3,528,704	7
1920	432,239	4,422,965		
1921	301,587	2,922,700	3,534,441	10
1922	452,451	4,146,182		
1923	566,724	5,368,532	5,512,935	13
1924	640,953	5,657,339		
1925	702,661	6,734,271	6,661,237	18
1926	683,201	6,588,203		
1927	723,942	6,713,497	6,034,355	17
1928	719,736	5,355,214		
1929	670,203	4,668,856	4,205,087	12
1930	458,992	3,741,319		
1931	309,200	2,588,126	2,028,270	10
1932	169,719	1,468,414		
1933	163,234	1,357,407	1,513,881	9
1934	178,792	1,670,356		
1935	205,516	2,215,270	2,738,579	11
1936	314,599	3,261,388		
1937	387,255[c]	533,162[c]	514,529	
1938	364,920[c]	495,896[c]		

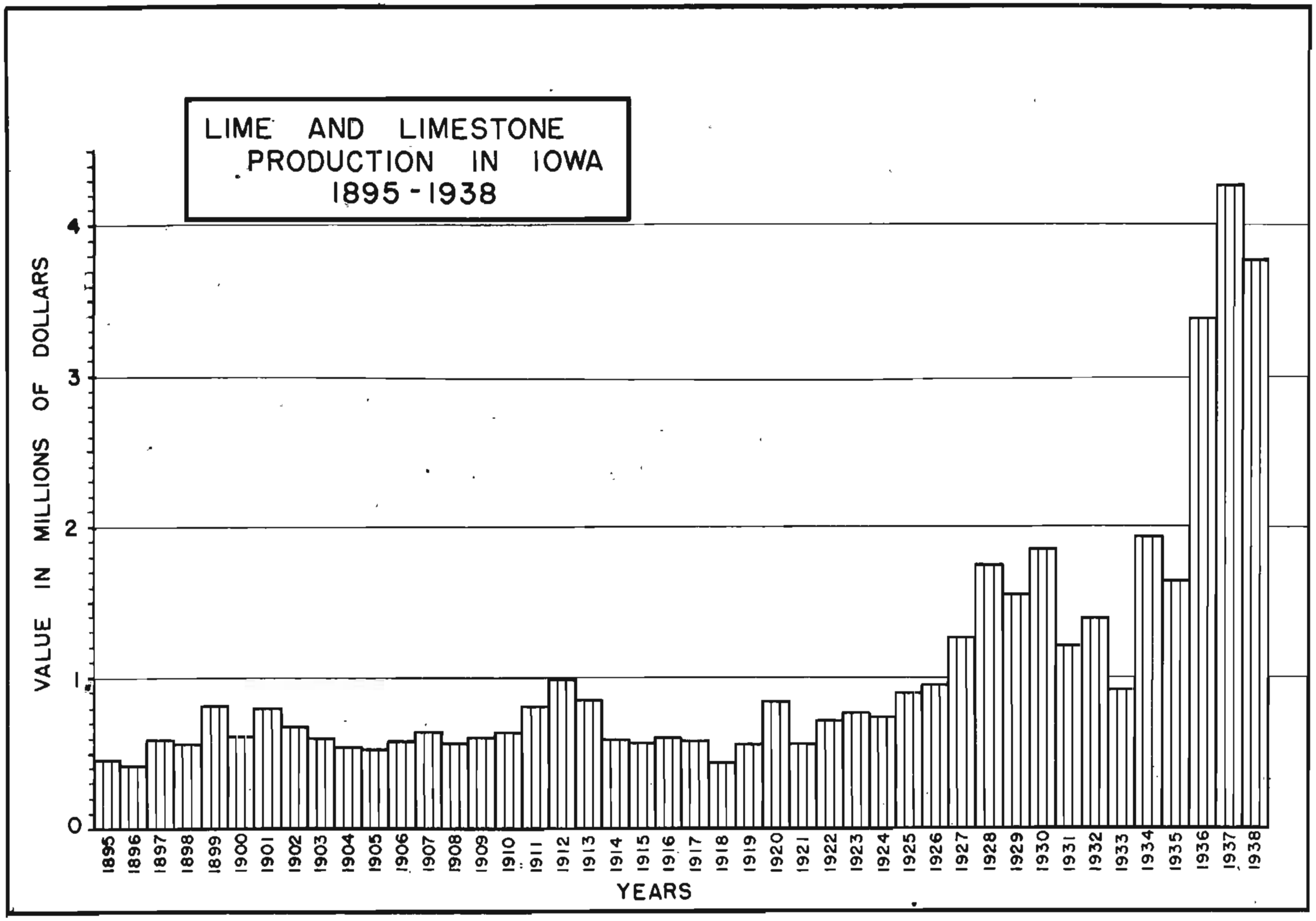
[a] Percent of total value of all minerals produced in Iowa for the two year period designated.
[b] Estimated.
[c] Mined, not comparable to earlier years.

for 1937-1938 when the only figures available are for crude gypsum mined.

Lime and Limestone

Production of lime and limestone during the period 1895-1938 is unique in that it does not follow the trends of production of other

PLATE VIII


LIME AND LIMESTONE
PRODUCTION IN IOWA
1895 - 1938
VALUE IN MILLIONS OF DOLLARS
0
1
2
3
4
1895
1896
1897
1898
1899
1900
1901
1902
1903
1904
1905
1906
1907
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1938
YEARS

TABLE VI

Lime and Limestone Production in Iowa — 1895-1938

Year	Quantity (short tons)	Value	Average for two year period: Value	Average for two year period: Percent of total [a]
1895		$ 455,076	$ 438,732	6
1896		422,388		
1897		587,144	575,365	7
1898		563,586		
1899		809,924	707,405	7
1900		604,886		
1901		796,852	735,106	6
1902		673,361		
1903		597,965	570,067	4
1904		542,170		
1905		533,509	555,645	4
1906		577,782		
1907		648,135	608,955	3
1908		569,775		
1909		609,922	624,876	3
1910		639,831		
1911		817,121	907,678	4
1912		998,236		
1913		854,814	724,747	3
1914		594,681		
1915		577,295	593,914	2
1916		610,534		
1917	709,956	580,750	512,775	1
1918	451,840	444,800		
1919	519,030	567,356	703,950	1
1920	620,565	840,544		
1921	423,270	563,427	641,315	2
1922	627,443	719,203		
1923	611,866	775,134	757,383	2
1924	610,408	739,632		
1925	808,288	904,669	928,405	2
1926	944,371	952,141		
1927	1,278,056	1,267,033	1,504,642	4
1928	1,666,270	1,742,252		
1929	1,625,000	1,560,066	1,705,449	5
1930	1,814,291	1,850,832		
1931	1,271,710	1,210,705	1,300,085	6
1932	1,591,235	1,389,465		
1933	1,050,190	920,532	1,427,448	8
1934	2,276,440	1,934,364		
1935	1,840,080	1,645,937	2,521,646	10
1936	4,003,550	3,397,356		
1937	4,294,310	4,276,891	4,029,685	15
1938	3,369,570	3,782,480		

a Percent of total value of all minerals produced in Iowa for the two year period designated.

minerals in Iowa (Plate VIII and Table VI). The outstanding features of the industry from 1894 to 1921 are the above-average productions in 1899, 1901-1902, 1910-1913 and 1920, and the even tenor of output values for the remainder of the period. It is striking that the world war and post war conditions which inflated most other mineral productions affected limestone only slightly. In 1922, however, a strong upswing started which carried through 1930, interrupted only in 1924 and 1926 by curtailment in production.

The effects of the depression influenced the limestone industry less than any other mineral commodity, and although the value of limestone production fell off in 1930-1932 it remained well above average and in 1934 exceeded the value of any preceding year with an output totalling $1,934,364. After a decline in 1935 the value of production increased greatly in the succeeding years and was far above average from 1936 to 1938. An output of 4,294,310 tons valued at $4,276,891 in 1937 established a record for limestone production in the state. No production of lime has been reported in Iowa since 1930.

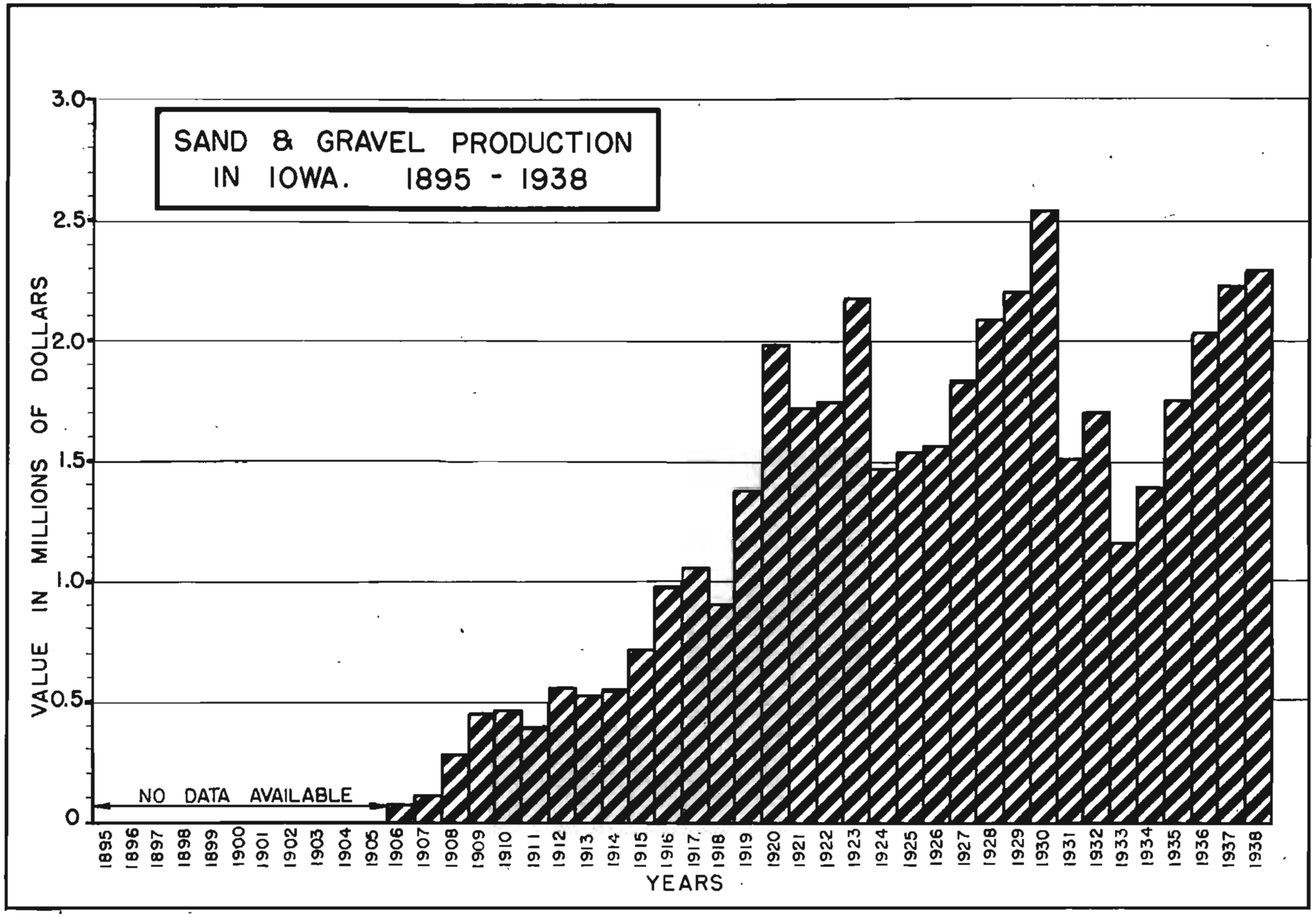
The quantity produced followed the trend of values rather closely. The peak was reached in 1934 when 2,276,440 tons were produced. An indication of the relative advancement of limestone is seen in the fact that in 1918 it represented about 1 per cent of total mineral production in Iowa while in 1933-1934 it represented 8 per cent of the total.

A relatively small production of sandstone is included in the table and columnar diagram.

Sand and Gravel

The trend of production for sand and gravel (Plate IX and Table VII) was generally upward from the first year data are available (1906) through 1923, although declines over the previous year occurred in 1911, 1913, 1918, and 1921. After a sharp reversal in 1924 an upswing started that culminated in 1930 with a production valued at $2,599,107 which exceeded that in any other year in the history of the industry. Large declines occurred in the depression years of 1931 and 1933. In 1933 the value dropped to $1,165,006 which was less than for any year after 1918. The industry started a strong upward trend in 1934 which continued without decline through 1938. In 1938, when most other mineral commodities were affected by the recession, the sand and gravel industry reported an output valued at $2,299,732, the second largest in the history of production in Iowa.

The quantities of sand and gravel produced varied greatly. It was greater than 1,000,000 tons from 1909 to 1927, greater than 2,000,000 tons since 1927 and the maximum of 6,994,286 tons was marketed in 1938.


SAND & GRAVEL PRODUCTION
IN IOWA. 1895 - 1938
VALUE IN MILLIONS OF DOLLARS
3.0
2.5
2.0
1.5
1.0
0.5
0
NO DATA AVAILABLE
1895
1896
1897
1898
1899
1900
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1938
YEARS

TABLE VII

Sand and Gravel Production in Iowa — 1895-1938

Year	Quantity (short tons)	Value	Average for two year period: Value	Average for two year period: Percent of total [a]
1895-1905	Data not available			
1906	184,673	$ 74,380		
1907	461,784	110,501	$ 198,472	1
1908	881,804	286,444		
1909	1,530,904	458,829	461,846	2
1910	1,798,762	464,863		
1911	1,349,004	393,649	478,529	2
1912	2,231,615	563,409		
1913	2,698,032	528,066	542,467	2
1914	2,253,254	556,868		
1915	3,002,806	720,795	850,533	3
1916	3,321,691	980,272		
1917	2,090,441	1,060,586	982,446	2
1918	2,004,444	904,307		
1919	2,093,471	1,383,764	1,688,602	4
1920	2,467,644	1,993,441		
1921	2,641,982	1,726,958	1,739,595	5
1922	2,690,798	1,752,233		
1923	3,597,160	2,181,881	1,827,473	4
1924	2,427,626	1,473,066		
1925	3,297,785	1,546,900	1,557,953	4
1926	2,701,982	1,569,006		
1927	3,981,143	1,839,176	1,967,065	6
1928	3,423,619	2,094,955		
1929	4,043,609	2,211,752	2,378,519	7
1930	4,333,737	2,545,287		
1931	3,403,396	1,511,278	1,609,076	8
1932	5,230,562	1,706,874		
1933	4,343,781	1,165,066	1,279,533	7
1934	4,349,362	1,394,000		
1935	5,732,742	1,756,851	1,902,566	7
1936	6,293,984	2,048,282		
1937	6,397,154	2,235,103	2,267,417	9
1938	6,994,286	2,299,732		

a Percent of total value of all minerals produced in Iowa for the two year period designated.

The average price per ton of sand and gravel was low from 1906 to 1915, but increased in the ensuing years and maintained a relatively high level until 1932 when it dropped and remained depressed through 1938.