ADMINISTRATIVE REPORT

TWENTY-FIRST ANNUAL

Report of the State Geologist

IOWA GEOLOGICAL SURVEY,
DES MOINES, December 31, 1912.

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

Gentlemen: I have the honor to report that during the year 1912 the work of the Iowa Geological Survey was carried forward in accordance with the plans approved by you at the beginning of the field season. Some new lines of work of great value to the state were begun, and some important investigations which were commenced in previous years were completed. The work of the Survey for the year 1912 may be summarized as follows:

AREAL GEOLOGY

Detailed areal work and geological mapping was begun in Audubon and Shelby, in Adair and in Lucas counties, and the surveys of Floyd and Clarke counties, upon which considerable work had already been done, were continued. The work in Audubon and Shelby counties was done by Prof. B. Shimek, in Adair county by Prof. J. E. Gow, in Floyd county by Prof. A. O. Thomas, in Clarke county by Prof. John L. Tilton, and in Lucas county by the Director of the Survey.

ROAD AND CONCRETE MATERIALS

Prof. S. W. Beyer and his assistants completed the field work on the road and concrete materials of the state. Some work in the laboratory has yet to be done before this important investigation will be completed. Professor Beyer will submit his manuscript for publication in 1913.

INDUSTRIAL WATERS

During the summer Professor Beyer with one field assistant began the study of the surface waters of Iowa in order to ascertain with definiteness their industrial applicability. Corporations and communities are in need of reliable information regarding the waters which are being used for industrial purposes. Undoubtedly great waste results where waters are used for purposes for which they are by no means adapted.

ARTESIAN WATERS

During the year a most thorough and valuable report on the artesian waters of the state was published by the Iowa Geological Survey in coöperation with the United States Geological Survey. This report is proving to be of great value to city officials, representatives of railways and other corporations, and to private citizens who are seeking information with reference to the water supplies of their respective localities. It is shown in this report that the underground waters of Iowa fall into two groups, namely, shallow or local waters and artesian waters. The former comprise those waters which are available for home, farm and village supply, and which commonly lie less than one hundred feet and rarely more than five hundred feet below the surface. They are usually obtained from bored, drilled, or driven wells and are fed directly by local rainfall, absorbed through the soils above. The artesian waters belong to rock strata below the country rock and circulate through the more permeable layers under greater or less pressure. Wells penetrating to these waters are artesian wells whether they flow at the surface or not.

Furthermore, the report shows that a sufficient knowledge of the attitude and nature of the deeper rocks of Iowa has been gained to permit satisfactory forecasts to be made in nearly all parts of the state relative to the depth at which artesian water may be found, its pressure, quantity, quality and availability for specific uses, and in the report forecasts are given for all towns of the state whose populations indicate that an artesian supply may be needed, and in which the artesian field has not been already fully exploited.

A part of the report deals with the chemical characters of the waters. The inorganic chemical substances have been determined in average and representative well waters in many localities of the state.

For the purposes of this report the state was divided into eight districts as follows: Northeast, East Central, Southeast, South Central, Central, North Central, Southwest and Northwest. Within each of these districts the county is taken as the unit. In connection with each county information is given with regard to the topography, geology, sources and distribution of the water supply, and the city and village supplies. Tables are given containing important facts in connection with the typical wells of the county.

The report was prepared by Prof. W. H. Norton and several collaborators. That part of the report dealing with the chemical characters of the waters was prepared by Professor Hendrixson.

THE DOLOMITES OF THE STATE

There is probably no place in the world where limestones and dolomites offer more interesting problems than in Iowa. The dolomites are the rocks which, near Maquoketa and elsewhere, are being used extensively for lime-making. They are, moreover, the rocks within which the lead and zinc deposits of Dubuque and adjacent areas are found. The Survey has undertaken a thorough study of these dolomites in order to ascertain not only their origin and composition but if possible their influence upon the deposition of metallic salts. The investigation has been undertaken by Francis M. Van Tuyl.

BIBLIOGRAPHY OF IOWA GEOLOGY

In the year 1894 the Iowa Geological Survey issued a bibliography of Iowa geology. The geological literature which has appeared since that date is so extensive that it seemed very desirable that a new bibliography be prepared. The Survey was fortunate in securing to prepare this new bibliography Dr. Charles Keyes, who was the author of the bibliography of 1894.

WATER POWER POSSIBILITIES IN IOWA

Before a safe statement can be made with regard to the water power possibilities in any state it is necessary to ascertain much detailed information as a result of investigations extending over several years. These investigations include:

First, daily stream gaging work at many places on the streams of the state for a period of years in order that the records may cover a cycle of low and high water periods of run-off.

Second, a detailed survey of the chief streams of the state including lakes and reservoir sites, dam sites, etc.

Third, the making of numerous discharge measurements at various times during the year and extending over a series of years at all the stations where gage readings are being made.

This kind of work requires the expenditure of fairly large sums of money. For instance, the State of Minnesota in coöperation with the United States Geological Survey has spent during the past few years about $53,000 in ascertaining the water power possibilities of that state. Last year Illinois spent more than $2,000 in this work and expects to spend an equivalent amount or more during each of several years. Up to the present time it has been possible for the Iowa Geological Survey to spend only a small sum for this important work. Three gaging stations have been maintained and some discharge measurements are being made each year. These stations are at Fort Dodge and Keosauqua on the Des Moines river and at Iowa Falls on the Iowa river. Readings are being made at Cedar Rapids by the Iowa Weather Bureau, and a gaging station is maintained by a private party at Stone City on the Wapsipinicon river. Unless additional appropriations are made available, it will be impossible to do more than is being done at present and it will be many years before complete and authoritative reports can be published.

Although complete data are not available for the State of Iowa, estimates have been made with regard to the water powers of some of the Iowa streams. Mr. M. O. Leighton, in the report of the Iowa State Drainage, Waterways and Conservation Commission, makes the following statements on page 122:

Drainage Systems	Max.H.P.	Min.H.P.
Western tributaries, Mississippi River	33,000	14,000
Northern tributaries, Missouri River	7,000	5,100
Des Moines River	194,000	52,300
Big Sioux River	2,800	1,500
Wapsipinicon River	10,700	4,380
Totals	247,500	77,280

With regard to what ought to be done in the way of legislation to protect the people of any state in connection with the water powers is a question, says Mr. W. G. Hoyt, of the Water Resources Branch of the United States Geological Survey, that is commanding the best thought and consideration of the people of this country. He says:

"The different States and Federal Government, it would seem to me, have been unable as yet to decide upon the best way of handling the whole proposition. In view of the many conflicting ideas on the subject, the safest method for a state to follow, in my mind, is to endeavor to make a detailed study regarding the water resources, in order that when the time comes for final settlement, all the facts of the case will be available."

It seems highly desirable that a detailed study be made of the water powers of Iowa, especially if legislation is introduced with a view to regulating water power as a public utility. If sufficient funds were available the study should include the following:

First. Collection of all existing facts regarding stream flow, river surveys, water power and water storage studies.

Second. The establishment of gaging stations on all the important streams of the state and the maintenance of them for a period of not less than ten years.

Third. The survey of all rivers which have not been surveyed in order that all the developed and undeveloped sites can be surveyed.

Fourth. The survey of possible reservoir sites in order that studies can be made regarding the future regulation of stream flow for power purposes and flood prevention.

Fifth. The publication of such data as are available either as preliminary reports from time to time or waiting a period of from three to five years and publishing one complete final report.

The Survey contemplates publishing as soon as sufficient facts are available a preliminary report on the water power possibilities of Iowa, but it is much to be desired that at an early date sufficient funds be appropriated to enable the Iowa Geological Survey to undertake the study of the streams of Iowa in as thorough a manner as is being done by some of our neighboring states.

CO-OPERATIVE TOPOGRAPHIC MAPPING*

For a number of years the United States Geological Survey, as a part of its work of mapping the area of the United States, has been making topographic maps of portions of Iowa and in recent years the Iowa Geological Survey has coöperated in this work of mapping our state. The areas covered by these maps are called quadrangles and are bounded by meridians of longitude and parallels of latitude rather than by political boundary lines. Hence they may include portions of two or three states, as in the case of the Elk Point sheet, which covers parts of Nebraska, South Dakota and Iowa. These maps, in addition to showing natural features, as rivers and lakes, and cultural features, such as towns, wagon roads and railroads, show by means of contour lines the elevations of the included area. The contour lines pass through all points having the same altitude, hence their closeness or distance indicates the steepness or flatness of the surface. All the topographic maps covering parts of Iowa have a contour interval of twenty feet; that is, the interval between contour lines represents a vertical distance of twenty feet on the ground.

Maps having a scale of 1:62500 cover an area one-fourth degree or fifteen minutes in length and breadth; that is, one-sixteenth of a square degree. The maps whose scale is 1:125000 are one-half degree in dimensions and have an area of one-fourth square degree.

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*Statement and table prepared by James H. Lees.

With a few exceptions, the maps are published on a sheet about 16x20 inches in size. The Omaha and vicinity sheet is 22x32 inches in size. In many cases an explanation of the maps is printed on the back of the sheet.

These maps may be purchased from the Iowa Geological Survey, Des Moines, or from the United States Geological Survey, Washington, D. C.

Name of Map	Counties in Iowa Included	Area in square miles	Scale	Price—cents
Amana[a]	Parts of Linn, Johnson, Iowa, Benton	222.50	1:62500	10
Ames	Parts of Hamilton, Story, Boone	221.65	1:62500	10
Anamosa[b]	Parts of Linn, Jones	221.65	1:62500	10
Baldwin[c]	Parts of Jackson, Clinton, Jones	221.65	1:62500	10
Canton (S. Dak.-Iowa)	Part of Lyon	870.90	1:125000	10
Cedar Rapids[a]	Parts of Linn, Johnson	222.50	1:62500	10
Clinton (Iowa-Ill.)[d]	Part of Clinton	222.50	1:62500	10
Cordova (Iowa-Ill.)[d]	Parts of Clinton, Scott	891.73	1:125000	10
Davenport (Iowa-Ill.)[e]	Part of Scott	223.36	1:62500	10
Decorah	Parts of Allamakee, Clayton, Fayette, Winneshiek	870.90	1:125000	10
Des Moines	Parts of Polk, Warren	223.33	1:62500	10
Dewitt[e]	Parts of Clinton, Scott	222.50	1:62500	10
Durant[e]	Parts of Scott, Muscatine, Cedar	223.36	1:62500	10
Elk Point (S. Dak.-Neb.-Iowa)	Parts of Sioux, Plymouth	877.91	1:125000	10
Elkader (Iowa-Wis.)	Parts of Dubuque, Delaware, Clayton	877.91	1:125000	10
Fairfax[a]	Parts of Linn, Johnson, Iowa, Benton	891.73	1:125000	10
Farley[b]	Parts of Dubuque, Jones, Linn, Delaware	884.85	1:125000	10
Goose Lake (Iowa-Ill.)[d]	Part of Clinton	222.50	1:62500	10
Iowa City[a]	Parts of Johnson, Washington	223.36	1:62500	10
Kahoka (Mo.-Iowa-Ill.)	Part of Lee	911.94	1:125000	10
Knoxville	Part of Marion	224.21	1:62500	10
Lancaster (Wis.-Iowa-Ill.)	Parts of Clayton, Dubuque	877.91	1:125000	10
LeClaire (Iowa-Ill.)[d]	Parts of Clinton, Scott	223.36	1:62500	10
Madrid	Parts of Boone, Polk, Dallas	222.50	1:62500	10
Maquoketa[c]	Parts of Jackson, Clinton	221.65	1:62500	10
Marion[f]	Part of Linn	221.65	1:62500	10
Mechanicsville[g]	Parts of Jones, Cedar, Johnson, Linn	222.50	1:62500	10
Milan	Part of Scott	224.21	1:62500	10
Milo	Parts of Marion, Warren, Polk	224.21	1:62500	10
Monticello[b]	Part of Jones	221.65	1:62500	10
Nebraska City (Neb.-Iowa-Mo.)	Part of Fremont	226.73	1:62500	10
Oelwein	Parts of Clayton, Delaware, Buchanan, Fayette	877.91	1:125000	10
Omaha and vicinity (Neb.-Iowa)	Parts of Pottawattamie, Mills	459.00	1:62500	20
Oxford[a]	Parts of Johnson, Washington, Keokuk, Iowa	223.36	1:62500	10
Pella	Parts of Mahaska, Marion	224.21	1:62500	10
Peosta (Iowa-Ill.)[c]	Parts of Dubuque, Jackson, Clinton, Jones	884.85	1:125000	10
Rock Island (Iowa-Ill.)[e]	Parts of Clinton, Scott, Muscatine, Cedar, Jones	891.73	1:125000	10
Savanna (Iowa-Ill.)	Parts of Jackson, Clinton	221.65	1:62500	10
Shellsburg[f]	Parts of Linn, Benton	221.65	1:62500	10
Slater	Parts of Story, Polk, Boone	222.50	1:62500	10
Stanwood[g]	Parts of Jones, Cedar, Muscatine, Johnson, Linn	891.73	1:125000	10
Tipton[g]	Parts of Jones, Cedar	222.50	1:62500	10
Waukee	Parts of Polk, Warren, Madison, Dallas	223.36	1:62500	10
Waukon (Iowa-Wis.)	Parts of Allamakee, Clayton	870.90	1:125000	10
West Liberty[g]	Parts of Cedar, Muscatine, Johnson	223.36	1:62500	10
Wheatland[e]	Parts of Clinton, Scott, Cedar, Jones	222.50	1:62500	10
Wilton Junction[g]	Parts of Cedar, Muscatine	223.36	1:62500	10
Winthrop[f]	Parts of Delaware, Linn, Benton, Buchanan	884.85	1:125000	10

LIST OF QUADRANGLES IN IOWA IN WHICH TOPOGRAPHIC MAPPING HAS BEEN WHOLLY OR PARTIALLY COMPLETED; MAPS NOT YET PUBLISHED.

Name of Map	Counties of Iowa Included	Area in square miles	Scale	Price—cents
Attica	Parts of Marion, Monroe, Lucas	225.06	1:62500	10
Boone	Parts of Hamilton, Boone, Webster	221.65	1:62500	10
Chariton	Parts of Marion, Lucas, Warren	225.06	1:62500	10

Total area surveyed	11,890
Total area of state	56,147
Percentage of total area of state surveyed	21

Note 1.—The scale of 1:62500 equals approximately one mile per inch. The scale of 1:125000 equals approximately two miles per inch.

Note 2.—A line of precise levels was run in 1905 by the United States Geological Survey along the line of the Chicago, Rock Island and Pacific Railway from Council Bluffs to Des Moines across Adel, Avoca, Casey, Des Moines, Fontanelle, Harlan, Marne, Neola, Panora, Waukee, Wiota, and Omaha and vicinity quadrangles.

Note 3.—Folios have been published by the United States Geological Survey describing the geology of Elk Point and Lancaster quadrangles.

Note 4.—The United States Geological Survey has published a map of Iowa, without contour lines, on a scale of 8 miles per inch. Size of map, 28½x41 inches. Price 20 cents.

[a]Amana, Cedar Rapids, Iowa City, and Oxford sheets, on scale of 1:62500, have been reduced and form Fairfax sheet, on scale of 1:125000.

[b]Anamosa and Monticello sheets, on scale of 1:62500, have been reduced and form parts of Farley sheet, on scale of 1:125000.

[c]Baldwin and Maquoketa sheets, on scale of 1:62500, have been reduced and form parts of Peosta sheet, on scale of 1:125000.

[d]Clinton, Goose Lake and LeClaire sheets, on scale of 1:62500, have been reduced and form parts of Cordova sheet, on scale of 1:125000.

[e]Davenport, Dewitt, Durant and Wheatland sheets, on scale of 1:62500, have been reduced and form Rock Island sheet, on scale of 1:125000.

[f]Marion and Shellsburg sheets, on scale of 1:62500, have been reduced and form parts of Winthrop sheet on scale of 1:125000.

[g]Mechanicsville, Tipton, West Liberty, and Wilton Junction sheets, on scale of 1:62500, have been reduced and form Stanwood sheet, on scale of 1:125000.

COAL INVESTIGATIONS

The Survey has already furnished much valuable information about the coals of the state. Detailed studies have been made in the field but much laboratory investigation of our coals remains to be done. Not only should more accurate information be obtained with respect to the composition of the coals of our state, but also with respect to the conditions which affect the best values of the coal, the effect of washing our coals, the rate of deterioration of coals, etc. The expansion of markets for Iowa coal is a matter of great importance to the coal industry and indirectly to the people of the whole state. It will be necessary in order to promote the expansion to remove certain misapprehensions as to the quality of the coal of Iowa and to point out the best methods of burning the coal to get the greatest efficiency. During the present year Prof. A. W. Hixson has begun some detailed chemical work on the coals of Iowa. When Professor Hixson's report is published it undoubtedly will be of great value to all persons who are interested in the coal industry of the state.

NATURAL HISTORY BULLETINS

Prof. L. H. Pammel is preparing a bulletin on the weeds of Iowa. Each weed will be described in detail, its distribution within the state will be shown, and methods of extermination will be given.

Prof. B. Shimek, who is an authority on the loess, is preparing a bulletin on the Mollusca of Iowa including not only those species that are living today but those that thrived during the time of deposition of the loess.

OIL AND GAS IN IOWA

From time to time for many years statements have appeared in the press with regard to oil and gas having been found in Iowa. Moreover, several thousands of dollars have been spent in prospecting for these minerals in different parts of the state, and numerous letters continue to be received by the officers of the Survey not only from citizens of Iowa but from persons living in other states asking for information as to whether or not oil and gas have been found or are likely to be found in commercial quantities within the state. While developments of recent years have added nothing new to what has been written about oil and gas in previous reports of the Survey, it may be well to review the conditions obtaining in Iowa with reference to this subject.*

*A considerable part of the statement regarding oil and gas was prepared by Mr. James H. Lees, Assistant State Geologist.

SYSTEM	SERIES	FORMATION NAME		COLUMNAR SECTION	THICKNESS IN FEET.	CHARACTER OF ROCKS
QUATERNARY	PLEISTOCENE	Wisconsin			0-30+	BOWLDER CLAY, PALE YELLOW VERY CALCAREOUS.
		Peorian				SOIL BAND
		Iowan			0-30+	BOWLDER CLAY, YELLOW, WITH VERY LARGE BOWLDERS.
		Sangamon				SOIL, PEAT AND FOREST BEDS.
		Illinoian			0-100+	BOWLDER CLAY, YELLOW.
		Yarmouth				SOIL, PEAT AND FOREST BEDS.
		Kansan			0-400+	BOWLDER CLAY, BLUE, JOINTED, WITH INTERCALATED STREAMS AND POCKETS OF SAND AND GRAVEL.
		Aftonian			0-40+	PEAT & FOREST BEDS, SOIL BANDS, AQUEOUS GRAVELS.
		Nebraskan			0-30+	BOWLDER CLAYS, DARK, FRIABLE.
CRETACEOUS	UPPER CRETACEOUS	Colorado			150	SHALES WITH SOFT LIMESTONES, IN PLACES CHALKY.
		Dakota			100	SANDSTONES.
PERMIAN		Fort Dodge			20	RED SHALES AND SANDSTONES.
					20	GYPSUM.
CARBONIFEROUS	PENNSYLVANIAN	Missouri			600	SHALES AND LIMESTONES.
		Des Moines			750	SHALES AND SANDSTONES WITH SOME BEDS OF LIMESTONE.
	MISSISSIPPIAN	St. Louis			100	LIMESTONE, SANDSTONE & MARLY SHALES.
		Osage or Augusta			265	LARGELY CRINOIDAL LIMESTONE, WITH HEAVY BANDS OF CHERT, SOME SHALE.
		Kinderhook			120	SHALE, SANDSTONE AND LIMESTONE, LIMESTONE IN PLACES OOLITIC.
DEVONIAN	UPPER DEVONIAN	State Quarry			(40)	LIMESTONE, MOSTLY BRACHIOPOD COQUINA
		Lime Creek			(120)	MOSTLY SHALES (LOCALLY DEVELOPED FEATURES EACH LYING UNCONFORMABLY ON THE MIDDLE DEVONIAN.)
		Sweetland Creek			(20)	SHALE
	MIDDLE DEVONIAN	Cedar Valley			100	LIMESTONES, SHALY LIMESTONES, SOME DOLOMITE IN THE NORTHERN COUNTIES.
		Wapsipinicon			60-75	LIMESTONES, SHALES, AND SHALY LIMESTONES.
SILURIAN	NIAGARAN	Gower			120	DOLOMITE, NOT VERY FOSSILIFEROUS, LE CLAIRE PHASE EXTENSIVELY CROSS-BEDDED.
		Hopkinton			220	DOLOMITE, VERY FOSSILIFEROUS IN PLACES.
ORDOVICIAN	CINCINNATIAN	Maquoketa			200	SHALE, SHALY LIMESTONES, AND, LOCALLY, BEDS OF DOLOMITE.
	MOHAWKIAN	Galena			340	DOLOMITE IN PLACES; IN PLACES UNALTERED LIMESTONES
		Platteville			90	MARLY SHALES AND LIMESTONES.
	CANADIAN	St. Peter			100	SANDSTONE.
		Prairie du Chien	Shakopee		80	DOLOMITE
			New Richmond		20	SANDSTONE.
			Oneota		150	DOLOMITE.
CAMBRIAN	POTSDAMIAN OR SARATOGAN	St. Croix	Jordan		100	COARSE SANDSTONE
			St. Lawrence		50	DOLOMITE MORE OR LESS ARENACEOUS.
			Dresbach		150	SANDSTONE, WITH BANDS OF GLAUCONITE.
ALGONKIAN	HURONIAN	Sioux Quartzite			25	QUARTZITE.

General Geological Section of Iowa.

An inspection of the accompanying geological chart will reveal the succession of the rocks of the Iowa column and their character. The rock at the base of the column—the Sioux Quartzite—is, for the most part, a dense, fine-grained rock built up of grains of sand closely cemented with a siliceous matrix. It is practically impervious to any liquid or gaseous substance which might be found in the earth's crust, and, so far as Iowa is concerned, is of unknown thickness. It was penetrated at Sioux City to a depth of seven hundred and fifty feet.

But even more significant than these facts is the evidence that at the time the sands of this age were being laid down on the sea bottom in Iowa there were practically no forms of life present in the waters. Since oil and gas are generally conceded to be from organic matter, plant and animal, which has suffered decomposition in the rocks, it is evident that in an age when living forms were scanty there could be little, if any, oil or gas formed in the rocks deposited during that time.

Beneath the Algonkian rocks are rocks of Archean age. These are dominantly igneous rocks and only subordinately sedimentary rocks. No form of life ever existed in igneous rock, and, so far as evidence indicates, life was never plentiful in the Archean sedimentary rocks. From these facts it is evident that in Iowa it is useless to seek for oil and gas below the top of the Sioux Quartzite.

Passing up the geological section it may be said that the rocks of the Saint Croix stage are for the most part rather barren of fossils, and that even had life been never so prolific it would have counted for but little since these rocks are largely sandstones and hence would serve as poor conservators of the life forms which might have been present when they were being formed. Sandstones form excellent reservoirs for oil and gas which have been generated from some underlying productive rock. But as has been shown, the underlying rock in this case—the Sioux Quartzite—was devoid of organisms so far as we can learn. Hence the Cambrian rocks in Iowa offer no more fruitful field for research than does the basement upon which they rest.

Overlying the Cambrian sandstones in Iowa come the dolomites of the Prairie du Chien stage and the Saint Peter sandstone, both of which are as barren of life forms as the rocks below them. Hence it may be said with assurance that it is hopeless to look for gas or oil below the top of the Saint Peter sandstone. However reliable this horizon and that of the Saint Croix sandstones may be as producers of artesian water—and they are our chief aquifers—they are equally as certain to bring only failure to the adventurer who pierces their depths with the expectation of getting therefrom commercial quantities of petroleum or natural gas.

To quote here from the discussion of this subject in the administrative report of Dr. Samuel Calvin, included in Volume XI of these reports:

Next in ascending order comes the Platteville (Trenton) limestone, a formation that was laid down on a sea bottom fairly crowded with swarming forms of life. This limestone is impure; it contains a large amount of clay mixed either with the materials forming the layers of stone or laid down as beds of shale between the more stony layers. The Platteville formation was deposited under exceedingly favorable conditions for making it a productive source of gas and oil. It still contains large quantities of bituminous matter which by the slow distillation always going on must yield annually considerable volumes of gaseous or liquid hydrocarbons. At all the exposures of the lower Platteville, from Dubuque northward, the dry shaly partings between the ledges of limestone afford material so rich in bitumen that it is easily lighted with a match; it burns freely and emits a strong oily odor. Bituminous shale, precisely like that seen in the natural exposures, was brought up from the horizon of the Platteville in the deep well at Washington, Iowa; it has been recognized in other deep wells; the same shale, rich in bitumen, probably underlies the greater part of the state.

If then a great amount of bitumen is stored up in the Platteville limestone and is constantly evolving gas and oil by slow distillation, why are not gas and oil wells as common in Iowa as in the productive regions of Ohio and Indiana? Let it be answered that something more than petroleum-bearing rock is needed in order that oil may be obtained in quantities of commercial importance. It has been estimated by Professor Orton that the rocks beneath the surface over a very large part of Ohio contain at least 3,000,000 barrels of oil to the square mile, and yet not one gallon of this can be secured by the drill without the concurrence of at least two other conditions: (1) There must be a porous reservoir—sandstone or porous limestone—in which the oil or gas may accumulate, and this must be covered with shale or other impervious deposit to prevent the hydrocarbons from escaping to the surface and becoming lost as fast as they are generated. But reservoir and cover alone will not insure a supply. So long as the rocks lie flat or have a uniform dip there will be no accumulations of any importance. (2) The reservoir and cover must present a series of folds beneath the arches of which the oil and gas are entrapped and accumulated under high pressure. Three conditions, therefore, must exist conjointly—the source of supply in some form of organic matter, the porous reservoir and impervious cover, and the arched or folded condition of the beds. It is the last of these conditions that is wanting in Iowa. Our stratified rocks are not folded to any noteworthy extent. The compression and crushing which gave rise to the Appalachian mountains produced folds as far west as Indiana, and then the effects fade out. Iowa is too far away from other centers of crustal disturbance, such as the Ozark region of Missouri or the great mountain axes of the west; and so the rocks are without the folds which are so essential to the accumulation of the fluent hydrocarbons.

Above the Platteville rocks there are several other formations in Iowa which represent petroleum-bearing rocks elsewhere in America. The Devonian, for example, is the productive horizon of Pennsylvania, while the lower beds of the Pennsylvanian series have yielded great quantities of both oil and gas in Kansas and Oklahoma. In the Iola and Neodesha fields of southern Kansas, for instance, the petroliferous beds are the basal strata of the Pennsylvanian, known here as the Cherokee shales. They are the equivalent in stratigraphic position and largely in composition of the lower part of the Des Moines stage of Iowa, that part which bears the most numerous, although not the most regular, coal beds. They are also coal-bearing in Kansas, but apparently are not so in the oil field.

These shales in their development in southern Kansas offer an apparent contradiction to the statement made above under the discussion of the necessary conditions for obtaining oil and gas. That is, the sandstones, "sands," which are the productive members, are not folded in synclines and anticlines, but the entire formation is monoclinal, with a dip to the northwest, caused doubtless by the Ozark uplift. The sandstones, however, occur either as lentils shut in by shale or as sandstone masses grading off laterally into shale. In either case they make excellent reservoirs and fulfil all the essential requirements for such purpose.

In Iowa, unfortunately, some of the conditions on which accumulation and recovery depend are absent, and no commercial quantities of oil or gas have been found in these horizons; indeed, no accumulations at all, so far as exploration has gone—and it must be conceded that it has been fairly thorough. Every deep boring, no matter what its primary object, is for the region involved and for the strata penetrated a test hole for oil and gas as much as for water or mineral or what not.

Since, as above stated, the Cherokee shales of the Kansas gas and oil belt extend into Iowa, these shales as developed in southern Iowa offer the best possibilities for finding the materials under discussion. But it must be borne in mind that the rocks of this stage are exposed immediately beneath the drift over a wide belt extending from Fort Dodge southeast into Missouri, and that no traces of these minerals have been found in this great area, and further that to the southwest, where the rocks are buried by later deposits, they have been penetrated by numerous drill holes with equally negative results. Furthermore, in Kansas the oil belt becomes less productive toward the north. All these facts seem to militate against the likelihood of oil or gas being found in this region. However, it is quite possible, especially in southwestern Iowa, that the geological conditions underlying Iola and Neodesha, Kansas, may exist in some limited areas which have not yet been explored by the drill.

There is one geological series in Iowa in which natural gas is known to occur and from which it has been utilized, namely, the Pleistocene, the series embracing the great drift sheets with their intercalated forest beds and other deposits. When the glaciers came down from the great northern snow fields they plowed up and overrode or incorporated into the load of detritus they were already carrying the forests and peat beds and other vegetation living upon the Iowa prairies. The gases evolved from the decomposition and distillation of these masses of vegetable matter in many cases found their way into pockets of sand and gravel buried in the sheets of bowlder clay which the glaciers left upon their disappearance. Some of these pockets have been tapped and usable quantities of gas found and put to use. The best known localities are in the neighborhood of Letts, Louisa county, and of Herndon in Guthrie county. These pockets have continued to yield gas for several years and have kept up the supply and pressure apparently undiminished. But from the nature of these deposits it can be seen that it would be useless to try to increase the supply by going deeper. Where this has been attempted as was done at Herndon about six years ago the outcome has been the only one which could reasonably be expected and which could have been prognosticated had the promotors of the scheme been willing to listen to reasonable arguments.

By way of summarizing what has been said regarding productive horizons, the following table extracted from Volume XII of these reports with slight additions may be inserted to show the geological distribution of oil and gas in the United States and Canada.

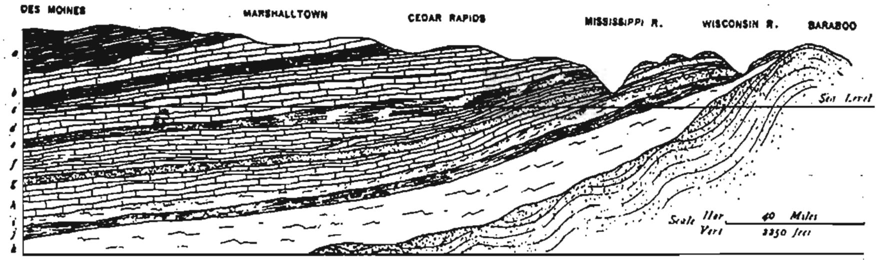
TABLE SHOWING THE GEOLOGICAL DISTRIBUTION OF OIL AND GAS.

Geological Periods.	Localities
Pleistocene or Quaternary	No productive oil wells in deposits of this period. Small reservoirs of gas, in the form of sealed in beds of sand or gravel, occur in the glacial deposits at Letts, Herndon and a few other points in Iowa.
Tertiary	Los Angeles and other oil-producing localities in California; Beaumont, Texas; Jennings, Louisiana; some oil fields in Wyoming; oil fields in Russia and in Peru.
Cretaceous	Florence, Boulder and Pikes Peak, Colorado; San Antonio, Elgin and Corsicana, Texas; some oil horizons in Wyoming and British Columbia.
Jurassic	In one field in Wyoming oil occurs in the Jurassic. No productive wells, however, are yet known to be supplied from reservoirs belonging to this formation.

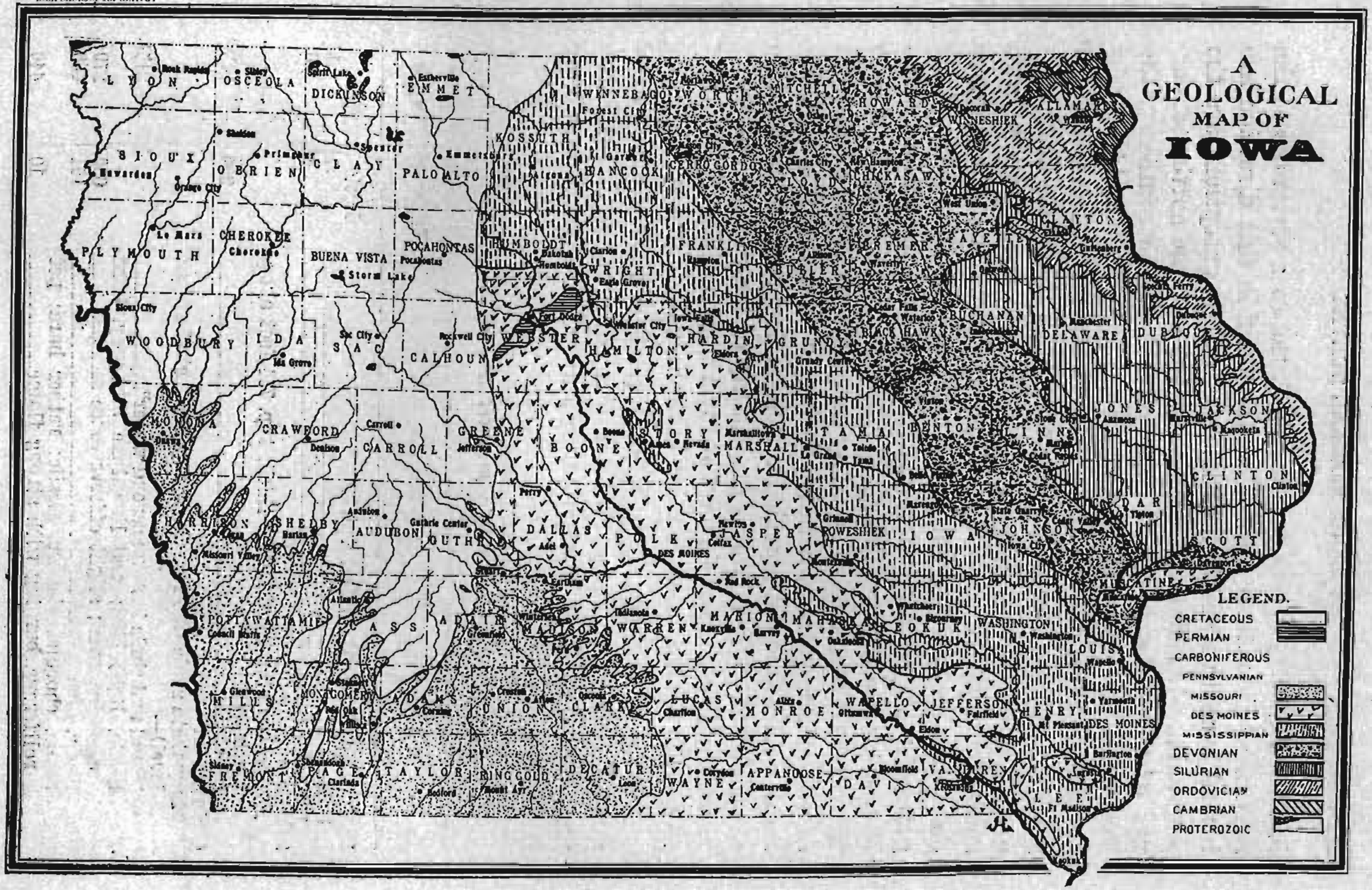
GEOLOGICAL DISTRIBUTION OF OIL AND GAS—Concluded

Geological Periods	Localities
Triassic	No known oil-producing horizons in the Triassic.
Carboniferous	*Upper Carboniferous.* Popo Agie field, Wyoming; field in northern Oklahoma; Neodesha, Chanute, etc., Kansas; in southeastern Illinois. *Lower Carboniferous.* Central Ohio; West Virginia; some in southeastern Illinois.
Devonian	Pennsylvania, western Ontario; some wells in central Ohio.
Silurian	No known productive wells, though oil occurs in the Medina sandstone in Canada, and the Niagara limestones about Chicago are, in places, saturated with oil. Some traces of oil at the same horizon in Cedar county, Iowa.
Ordovician	Oil and gas both abundant in certain localities, in the Trenton limestone, Gaspe, Canada; Lima and many other places in western Ohio; oil and gas fields in Indiana and Kentucky. Some Platteville shales in Iowa are rich in bitumen. In beds of Quebec age, Newfoundland.
Cambrian	No productive wells.
Algonkian	No probability and little possibility of productive wells.
Archean	No possibility of productive wells.

The accompanying sketch map of Iowa together with the geologic section may serve to elucidate the distribution and relations of the various formations discussed in this report. It will



Geological section from Baraboo, Wisconsin, to Des Moines, Iowa, showing the general stratigraphy of the region. The drift is not shown. The chief aquifers are the Saint Peter, the Jordan and the Dresbach sandstones. The line of juncture of the Dresbach sandstone and the Huronian is hypothetical. *a* Des Moines; *b* Mississippian; *c* Devonian; *d* Niagaran; *e* Maquoketa; *f* Galena-Platteville; *g* Saint Peter; *h* Prairie du Chien; *i* Jordan sandstone; *j* Saint Lawrence; *k* Dresbach.


A
GEOLOGICAL
MAP OF
IOWA
LEGEND.
CRETACEOUS
PERMIAN
CARBONIFEROUS
PENNSYLVANIAN
MISSOURI
DES MOINES
MISSISSIPPIAN
DEVONIAN
SILURIAN
ORDOVICIAN
CAMBRIAN
PROTEROZOIC
LYON
OSCEOLA
DICKINSON
EMMET
WINNEBAGO
WORTH
HOWARD
WINNESHIEK
SIOUX
O BRIEN
CLAY
PALO ALTO
KOSSUTH
HANCOCK
PLYMOUTH
CHEROKEE
BUENA VISTA
POCAHONTAS
HUMBOLDT
WRIGHT
FRANKLIN
BUTLER
BREMER
WOODBURY
IDA
SAC
CALHOUN
WEBSTER
HAMILTON
HARDIN
GRUNDY
BLACK HAWK
BUCHANAN
DELAWARE
MONONA
CRAWFORD
CARROLL
GREENE
BOONE
STORY
MARSHALL
TAMA
BENTON
LINN
JONES
JACKSON
CLINTON
CEDAR
HARRISON
SHELBY
AUDUBON
GUTHRIE
DALLAS
POLK
JASPER
POWESHIEK
IOWA
JOHNSON
SCOTT
MUSCATINE
POTTAWATTAMIE
CASS
ADAIR
MADISON
WARREN
MARION
MAHASKA
KEOKUK
WASHINGTON
LOUISA
MILLS
MONTGOMERY
ADAMS
UNION
CLARKE
LUCAS
MONROE
WAPELLO
JEFFERSON
HENRY
DES MOINES
FREMONT
PAGE
TAYLOR
RINGGOLD
DECATUR
WAYNE
APPANOOSE
DAVIS
VAN BUREN
LEE
DES MOINES

be seen that with a few exceptions all the rock series dip to the southwest from their area of outcrop and in this direction are buried beneath sediments of later age. The exceptions are the Algonkian—the Sioux Quartzite—in the extreme northwest corner of the state, whose surface pitches to the southeast, the Permian in Webster county which simply overlies older rocks and is not certainly known to exist elsewhere in Iowa, and the Cretaceous which in all its development in this state lies immediately under the Pleistocene deposits. In northwestern Iowa some of the intermediate formations are absent, and the younger ones overlap directly onto the oldest rocks with a great time gap between, as, for example, at Hull, where Cretaceous sandstones overlie truncated beds of Cambrian age. This is due to the reversal of the dip caused by the presence of the great mass of Algonkian quartzites which formed a shoreline during Cambrian and succeeding periods. These facts are mentioned to show that there is even less probability of the presence of reservoirs of oil or gas in this part of Iowa than to the south and east where the geological succession is much better developed.

A few well sections from different parts of the state may be of value to show the succession and character of the strata. The first well described is of peculiar interest in that it was sunk in the hope of finding oil.

Record of strata in prospect hole at Maquoketa.

	Thickness	Depth
Residual and recent (6 feet thick):	Feet	Feet
Soil	1½	1½
Clay, hard, yellow	4½	6
Silurian:		
Niagaran dolomite (209 feet thick; top, 754 feet above sea level)—		
Dolomite	209	215
Ordovician:		
Maquoketa shale (225 feet thick; top, 545 feet above sea level)—		
"Sand and shale in seam second water"	½	215½
Shale, light blue; and limestone blue-gray, hard, close textured; slight effervescence	63½	279
Shale, blue	151	430
Shale, chocolate-brown, fissile; rather hard; petroliferous, burning with strong flame	10	440

Record of strata in prospect hole at Maquoketa.

	Thickness	Depth
	Feet	Feet
Galena dolomite (255 feet thick; top, 320 feet above sea level)—		
Dolomite, porous, subcrystalline, gray; in log called "hard white shale"	46	486
Dolomite, light buff, crystalline; in log, "mixed lime and shale hard"	79	565
Dolomite, light buff, cherty; in angular sand	130	695
Decorah shale (15 feet thick; top, 65 feet above sea level)—		
Shale, bright green, fissile, fossiliferous; with dark gray, fossiliferous, nonmagnesian, pyritiferous limestone; log—"slate and shale"	15	710
Platteville limestone (46 feet thick; top, 50 feet above sea level)—		
Limestone, gray, earthy, compact, nonmagnesian	5	715
Limestone, brown, nonmagnesian, hard; in flaky chips	7	722
Limestone, light gray, soft, earthy	28	750
Shale, blue, plastic, with some chips of brown limestone; in log, "slate soft, blue" (Glenwood shale of Iowa State Survey)	6	756
Saint Peter sandstone (59 feet thick; top, 4 feet above sea level)—		
Sandstone, clean, white; grains well rounded, moderately coarse, many having diameter of 1 millimeter or more	59	815
Continental deposits of time interval between Shakopee and Saint Peter (?) (241 feet thick; top, 55 feet below sea level)—		
Sandstone, fine, brick-red; considerable red argillaceous or ferric admixture; when washed in hot water, drillings remain pink owing to films of ferric oxide on grains of quartz sand; grains rounded, many broken, said by driller to contain seams of red shale; in log, "red sandstone"	241	1,056
Oneota dolomite (54 feet thick; top, 296 feet below sea level)—		
Dolomite, light yellow-gray; with much dark red and dark brown hard fine-grained shale, some light green shale, a fine yellow quartz sand, a fragment of red fine-grained sandstone set with pieces of green shale; all except dolomite probably foreign, at 1056	54	1,110
"Shale, soft gray;" of log; sample supposed to represent this stratum consists of sand grains of Saint Peter facies, but with an occasional grain showing secondary enlargement; rather fine, with considerable foreign red and light green shale and some chert and chips of dolomite		

Record of strata in prospect hole at Maquoketa.

	Thickness	Depth
Cambrian:	Feet	Feet
Jordan sandstone (80 feet thick; 350 feet below sea level)—		
"Sandstone, soft water;" of log; sample said to represent this stratum consists for the most part of angular sand of light gray dolomite with some arenaceous admixture; a sample at 1,125 feet is of sandstone, some grains showing secondary enlargements, along with some chert and dolomite	80	1,190
Saint Lawrence formation (198 feet thick; top, 430 feet below sea level)—		
Dolomite, light yellow-gray	110	1,300
Dolomite, purple-brown	20	1,320
Dolomite, light gray	68	1,388
Dresbach sandstone (208 feet thick; top, 628 feet below sea level)—		
Sandstone, soft, white; grains well rounded, fairly uniform in size, largest 1 millimeter in diameter	208	1,596
Undifferentiated Cambrian strata (120 feet penetrated; top, 836 feet below sea level)—		
Sandstone; in buff sand with the appearance of dolomite to unaided eye, but seen under the microscope to consist of microscopic grains of crystalline quartz with dolomitic cement, along with some fine rounded grains of quartz sand and some glauconite at	----------	1,596
Sandstone as above, with some gray shale	54	1,650
Sandstone of same composition as above; white	45	1,695
Sandstone, fine-grained, light buff; in minute detached grains and in angular chips as above	5	1,700
Sandstone, white, clean, fine; grains imperfectly rounded, most grains from 0.0075 to 0.01 inch in diameter; "quicksand" of log	16	1,716

It may be noted in passing that the boring was carried nine hundred and sixty feet below the base of the Platteville, the lowest oil-bearing horizon in America.

For central Iowa there may be selected from the numerous deep wells of the region that drilled at Greenwood Park, Des Moines, as it goes lower than any of the others. It will be seen that it penetrates far into the Cambrian and so reaches through all productive horizons.

Record of strata in Greenwood Park well at Des Moines.

	Thickness	Depth
	Feet	Feet
Pleistocene (14 feet thick; top, 872 feet above sea level):		
Till, buff, sandy, with a few pebbles; noncalcareous	14	14
Carboniferous:		
Pennsylvanian—		
Des Moines stage (484 feet thick; top, 858 feet above sea level)—		
Shale, black, brittle, carbonaceous	1	15
Shale, gray, "fossiliferous"	1	16
Shale, black, carbonaceous, calcareous, highly pyritiferous	3	19
Shale, gray	4	23
Shale and limestone, bluish gray, highly fossiliferous	15	38
Shale, varicolored	67	105
Shale, bluish gray, highly and finely arenaceous, hard	10	115
Shale, bluish gray, slightly calcareous	60	175
Shale, dark drab and black, carbonaceous	11	186
Shales, gray, drab, and purplish; practically noncalcareous; 1 foot of grey chert at 284 feet	312	498
Mississippian—		
Saint Louis limestone and Osage stage (200 feet thick; top, 374 feet above sea level)—		
Chert and shale; heavy bed, very hard to drill; most of the sample is an argillo-calcareous powder; the shale is reported as caving in from above, but its calcareous nature indicates that it is in part interstratified with chert and limestone	170	668
Limestone and chert, brownish gray	30	698
Kinderhook stage (160 feet thick; top, 174 feet above sea level)—		
Shale, light blue and gray	40	738
Shale, terra cotta red, highly calcareous	10	748
Shale, light blue-gray	25	773
Shale, light gray, highly calcareous; fine cherty residue	85	858
Devonian (80 feet thick; top, 14 feet above sea level):		
Limestone, light buff; much gray chert	80	938
Silurian (507 feet thick; top, 66 feet below sea level):		
Limestone, light blue-gray, crystalline, saccharoidal: effervescence slow; considerable white gypsum	20	958
Limestone, cherty, crystalline, blue-gray; effervescence moderately rapid	53	1,011
Limestone, cherty, crystalline, saccharoidal, dark blue-gray and buff; effervescence indicates magnesian limestone, but not dolomite	97	1,208
Gypsum and shale; gypsum gray and white, in flakes; shale green, perhaps from above	15	1,223
Limestone, light blue-gray, highly seleniferous; some flakes of gypsum	145	1,368
Limestone, cherty, arenaceous; grains of sand, minute, rounded; much shale in rounded fragments, perhaps from above	22	1,390
Dolomite, buff, crystalline, granular with much chert and some chalcedonic silica; 3 samples	55	1,445

Record of strata in Greenwood Park well at Des Moines.

	Thickness	Depth
Ordovician:	Feet	Feet
Maquoketa shale (33 feet thick; top, 573 feet below sea level)—		
Shales; in large fragments; purplish yellow and green; noncalcareous; finely laminated	33	1,478
Galena dolomite to Platteville limestone (508 feet thick; top, 606 feet below sea level)—		
Dolomite; in yellow-gray powder; cherty	260	1,738
Dolomite, yellow, buff and brown; mostly cherty; residue finely quartzose; 5 samples	200	1,938
Shale, green, very slightly calcareous	8	1,946
Dolomite, brown, arenaceous	30	1,976
Shale, dark green, hard, "fossiliferous"; practically noncalcareous	10	1,986
Saint Peter sandstone (39 feet thick; top, 1,114 feet below sea level)—		
Sandstone, fine, white; grains moderately well rounded	39	2,025
Prairie du Chien stage—		
Shakopee dolomite (124 feet thick; top, 1,153 feet below sea level)—		
Shale; greenish powder of dolomite, chert, fine quartz sand, green shale, and pyrite	7	2,032
Dolomite, arenaceous, cherty	30	2,062
Shale, drab, calcareous; in finest powder; grains of buff, cherty dolomite	23	2,085
Dolomite, gray	5	2,090
Dolomite, gray; minute rounded vesicles resembling matrix of oolite from which grains have been dissolved	5	2,095
Dolomite	5	2,100
Shale; as at 2,085 feet, "exceedingly hard to drill"	40	2,140
New Richmond sandstone (94 feet thick; top, 1,277 feet below sea level)—		
Dolomite, arenaceous, gray; 2 samples	9	2,149
Shale, drab, calcareous	5	2,154
Sandstone, white, fine, calciferous	10	2,164
Dolomite, buff	8	2,172
Sandstone, clean white quartz sand; grains rounded	10	2,182
Dolomite, buff	15	2,197
Sandstone, buff; grains broken, much dolomite	11	2,208
Sandstone, friable, white, fine	2	2,210
Shale, drab, slightly calcareous	4	2,214
Sandstone, white	5	2,219
Dolomite, buff, white; much quartz sand	3	2,222
Shale	2	2,224
Sandstone, gray and buff, calciferous; most of grains broken	14	2,238
Shale, light blue	5	2,243
Oneota dolomite (175 feet thick; top, 1,371 feet below sea level)—		
Dolomite of various tints, many cherty; argillaceous at 2,250, 2,272, 2,333, 2,340 feet; arenaceous at 2,270 and 2,333 feet; at 2,305 feet there is 17 feet of white, blue and green chert; 32 samples	175	2,418

Record of strata in Greenwood Park well at Des Moines.

	Thickness	Depth
	Feet	Feet
Cambrian (582 feet penetrated; top, 1,546 feet below sea level):		
Sandstone, white; fine grains, mostly rough surfaced; some dolomite	12	2,430
Dolomite, brown; in chips	2	2,432
Sandstone	4	2,436
Dolomite, rough, gray and brown	4	2,440
Sandstone, fine, white and reddish; 3 samples	12	2,452
Shale, light blue-gray	2	2,454
Sandstone, calciferous, buff	4	2,458
Dolomite, arenaceous, gray, buff, and brown; 6 samples	30	2,488
Shale, light blue-gray	10	2,498
Dolomite, gray and buff, siliceous	9	2,507
Sandstone, gray, fine, calciferous	27	2,534
Marl, highly quartzose, dolomitic, argillaceous, yellowish powder; 2 samples	19	2,553
Sandstone, calciferous, gray and white; 3 samples	12	2,565
Sandstone; in sand and small chips superficially resembling dolomite; calciferous, glauconitic, close-grained; grains white, gray and buff; 10 samples	145	2,710
Shale and dolomite; shale hard, bright green, slaty; dolomite white, highly siliceous, with much greenish, translucent amorphous silica, 2 samples; over one-half of the second sample soluble in acid	20	2,730
Sandstone, buff; in powder, glauconiferous; rock is termed sandstone although composed chiefly of light colored particles which effervesce freely in acid; fragments of crystalline quartz form but a small proportion of the drillings	20	2,750
Sandstone, saccharoidal; dark with purplish tinge, dark color due to numerous grains of glauconite, purplish tinge to ferruginous stains on quartz sand; sand grains of crystalline silica, rough surfaced, imperfectly rounded, many fractured	130	2,880
Dolomite, dark gray, greenish, macrocrystalline, glauconiferous; sparingly arenaceous	5	2,885
Sandstone, greenish; grains microscopic	5	2,890
Shale, dull gray, fine-grained, and exceedingly finely laminated	5	2,895
Sandstone, glauconiferous, calciferous; grains imperfectly rounded, with hard, dark green slaty shale	15	2,910
Marl; in buff flour; microscopically arenaceous; calciferous; glauconiferous	50	2,960
Marl, pink; calciferous, arenaceous; one-third of drillings by weight insoluble in acid; to bottom of well	40	3,000

In southwestern Iowa there are several wells of considerable depth, but since the dip of the stratified rocks carries these to great depths in this part of the state the lowest formations are not reached. However, the well at Dunlap, Harrison county, 1,535¾ feet deep, reaches the Ordovician. The deep well at the

Institution for Feeble-minded Children at Glenwood, Mills county, 1,910 feet deep, penetrates the Mississipian strata for about 800 feet, and the prospect well at Bedford, Taylor county, 2,400 feet deep, pierces the Silurian rocks for 575 feet. It may be added that at Nebraska City, just over the river from the southwest corner of Iowa, a test hole was drilled to a depth of 2,870 feet, passing through the Saint Peter sandstone and so testing all possible productive zones. Since, as above stated, the productive horizons of the states to the southwest of Iowa lie in the Pennsylvanian series, it will be seen that these horizons have been penetrated in all these wells as well as in numerous other deep wells of the region.

Record of strata of deep well at Bedford.

	Thickness	Depth
	Feet	Feet
Pleistocene:		
Drift, no samples or record	38	38
Carboniferous:		
Pennsylvanian—		
Missouri stage (722 feet thick; top, 1,060 feet above sea level)—		
Limestone, light gray, nonmagnesian, soft; earthy luster; permeated with minute ramifying, smooth-surfaced masses of calcite	6	44
Limestone, argillaceous, light gray, soft; earthy luster; and shale, plastic	6	50
Shale, drab, unctuous, noncalcareous; 8 samples	40	90
Shale, bluish drab, calcareous	5	95
Limestone, earthy, light blue-gray	5	100
Shale, drab, calcareous; 3 samples	15	115
Limestone, light blue-gray, soft, argillaceous; with shale	5	120
Shale, drab, calcareous	5	125
Limestone and shale; limestone, soft, whitish; rapid effervescence; numerous Fusulina; encrinital; 5 samples	25	150
Limestone, light gray, soft, earthy; a little chert	5	155
Shale, greenish drab; some limestone with crinoid stems	10	165
Shale, as above; some black, carbonaceous and a little blue-gray limestone	5	170
Limestone, light brown, white, gray, hard, compact; and greenish shale	5	175
Limestone; light blue-gray, argillaceous; and light yellow-gray with crinoid fragments; greenish shale	5	180
Limestone, yellow, gray, hard	5	185
Shale, dark brick-red, calcareous; 2 samples	10	195
Shale; greenish drab, calcareous, siliceous; and ocher-yellow, hard, siliceous, calcareous; 2 samples	10	205
Shale, hard, greenish drab; so highly siliceous with minute particles of quartz that it might be termed an argillaceous sandstone	5	210

Record of strata of deep well at Bedford—Continued.

	Thickness	Depth
	Feet	Feet
Shale, greenish drab, plastic, pyritiferous; some hard, yellow, fossiliferous limestone	15	225
Shale, blue-drab, soft, laminated; harder siliceous layers	25	250
Shale, drab, laminated; 6 samples	30	280
Shale, drab, with some laminae of black coaly shale	5	285
Shale, green, fossiliferous	5	290
Shale, green, fossiliferous; some drab limestone and chert	5	295
Shale, hard, red; 2 samples	5	300
Limestone, hard, drab, with shale	10	310
Shale, drab, fossiliferous	10	320
Limestone, hard, fine-grained, siliceous	5	325
Limestone, yellow-gray; and white, soft; earthy luster; 3 samples	15	340
Shale, green and black, carbonaceous	5	345
Limestone, soft, yellow, macrocrystalline	10	355
Shale, drab; 5 samples	25	380
Shale, drab; some drab limestone	5	385
Shale, drab; with sand of flinty drab limestone	5	390
Shale, reddish; with dark green-gray argillaceous limestone	5	395
Shale, red; a little brown siliceous limestone	10	405
Shale, drab; 4 samples	15	420
Limestone, light yellow-gray; crystalline in sand; 4 samples	20	440
Shale, greenish drab	10	450
Limestone, light yellow-gray; much shale	5	455
Shale, greenish; some drab limestone, flinty	10	465
Limestone, light yellow-gray	10	475
Shale, drab; 4 samples	20	495
Limestone, white; large fragments of shale	21	516
Shale, drab; some black at 516, with limestone at 525; 4 samples	19	535
Limestone, white and gray	15	550
Shale, black, fissile, combustible; and hard, gray limestone	5	555
Shale, dark drab	10	565
Shale, greenish; with white limestone in concreted powder	5	570
Sandstone, white; microscopic grain; calciferous; with shale	5	575
Limestone, white and light gray	10	585
Shale, dark drab	5	590
Limestone, hard, gray, siliceous; shale	5	595
Shale, dark drab	5	600
Limestone, yellow-gray, rather hard; much shale in large fragments	15	615
Shale, dark drab; nodules and masses of gray chert	15	630
Shale, light brown, calcareous	5	635
Shale, greenish; with gray limestone and chert	5	640
Limestone, gray; much shale	5	645
Shale, drab; black at 645; gritty at 650 and 655; with limestone at 670; sandy at 670, 675, 695, 700; coaly at 705	65	710

Record of strata of deep well at Bedford—Continued.

	Thickness	Depth
	Feet	Feet
Sandstone, fine, gray; 3 samples	15	725
Shale, dark drab; some black; fissile	10	735
Limestone, gray, finely arenaceous	10	745
Shale, drab and reddish brown; 2 samples	10	755
Limestone, light gray	5	760
Des Moines stage (580 feet thick; top, 338 feet above sea level)—		
Shale, varicolored; highly arenaceous at 765 and 770; reddish brown at 785, 790, 940 and 1,065; black at 855, 1,045, 1,055 and 1,060	400	1,160
Sandstone; drillings mostly shale	5	1,165
Shale, black	15	1,180
Sandstone, fine, white; much shale in drillings; 8 samples	40	1,220
Shale	5	1,225
Sandstone	10	1,235
Sandstone, in fine gray meal, the particles of which resemble flint macroscopically but are composed of minute quartzose grains with considerable yellow chert at 1,250, with considerable shale in all drillings; 10 samples	50	1,285
Sandstone, clean, fine, yellow-gray, composed of minute irregular grains	5	1,290
Sandstone, coarser; some grains reaching 1 mm. in diameter	5	1,295
Sandstone, green-gray, fine-grained	5	1,300
Sandstone, yellow-gray, coarser; grains irregular in shape and far from uniform in size	5	1,305
Sandstone, fine, blue-gray; shale in drillings probably from above	35	1,340
Mississippian (355 feet thick; top, 242 feet below sea level)—		
Limestone, gray; rapid effervescence	5	1,345
Limestone, yellow-white, soft; earthy; 4 samples	20	1,365
Limestone, gray, rather hard, conchoidal fracture; lithographic texture	15	1,380
Limestone, soft, gray, earthy, argillaceous	20	1,400
Limestone; as above; and gray, fine-grained sandstone	5	1,405
Limestone, light drab, argillaceous	20	1,425
Limestone and chert; drillings largely chert and chalcedonic silica	10	1,435
Limestone, drab; less chalcedony	5	1,440
Chert, white and gray; in places brown, and limestone, often siliceous; 17 samples	85	1,525
Limestone, soft, gray, earthy; a little chert	5	1,530
Limestone, soft, white and light gray; saccharoidal; some chert	5	1,535
Chert and limestone; limestone nonmagnesian; 14 samples	85	1,620
Limestone, buff; slow effervescence; much gray chert	5	1,625
Limestone, brown; moderate effervescence	5	1,630
Limestone, brown; rapid effervescence, calcite crystals	15	1,645
Limestone, gray, oolitic; rapid effervescence; 4 samples	20	1,665
Shale, blue, fine-grained, gritless, calcareous; in concreted powder; 6 samples (Kinderhook)	30	1,695

Record of strata of deep well at Bedford—Continued.

	Thickness	Depth
	Feet	Feet
Devonian (130 feet thick; top 597 feet below sea level):		
Limestone, light gray; rapid effervescence	10	1,705
Limestone, light blue-gray, compact, fine-grained; in thin flaky chips	10	1,715
Limestone, yellow; in sand; rapid effervescence	15	1,730
Shale, drab, clayey, highly calcareous	5	1,735
Limestone; white and mottled gray at 1,735; gray from 1,740-1,755; buff at 1,755 and 1,760; light gray, subcrystalline, dense at 1,765 and 1,770; all of rapid effervescence	40	1,775
Shale, or highly argillaceous limestone; gray, in noncon-creted powder	10	1,785
Limestone; buff; in fine meal; rapid effervescence	15	1,800
Limestone, gray; in fine meal; rapid effervescence; argilla-ceous at 1,810; 5 samples	25	1,825
Silurian (575 feet thick; top, 727 feet below sea level):		
Limestone and shale; limestone, gray in meal, rapid effer-vescence; shale, brick-red, highly pyritiferous, in fine meal, and powder not concreted; some fine ill-rounded quartz grains at 1,830; color of mass of drillings, brick-red	20	1,845
Limestone, yellow; drillings pink from admixture with fine meal and powder of red shale, probably from 1,825; lime-stone in meal and sand, crystalline; rapid effervescence; some irregular rounded quartz grains in drillings which also may be from above; 14 samples	70	1,915
Dolomite, dark gray; in fine crystalline meal; some calcite	20	1,935
Dolomite, buff	10	1,945
Dolomite, dark gray, argillaceous	5	1,950
Unknown; drillings washed away	20	1,970
Dolomite, light brown; in crystalline meal	7	--------
Marl, in fine white powder, not concreted; calciferous, argil-laceous; large amount of anhydrite	4	2,009
Dolomite, as at 1,970; calcite rhombs and a few crystals of anhydrite	6	2,015
Dolomite, light yellow; in finest crystalline meal; numerous crystals of anhydrite	20	2,035
Dolomite, light brown; in floury meal; residue of anhydrite	35	2,070
Dolomite, light greenish gray, argillaceous; much anhydrite and dolomitic marl	5	2,075
Dolomite, light gray, less argillaceous; considerable anhy-drite	10	2,085
Dolomite, bright yellow; in meal; considerable anhydrite	15	2,100
Dolomite, brown; in coarser meal	5	2,105
Dolomite, light brown; in much finer meal; anhydrite rather plentiful	--------	2,105
Limestone; somewhat magnesian, judging from efferves-cence; light yellow and buff; argillaceous; some anhydrite in drillings	15	2,160
Dolomite, buff; in fine crystalline, sparkling meal	8	2,168
Dolomite, light gray, argillaceous; in finest powder, not concreted	2	2,170
Dolomite; in fine brown or yellow meal, not concreted; some anhydrite	35	2,205

Record of strata of deep well at Bedford—Concluded.

	Thickness	Depth
	Feet	Feet
Anhydrite marl; in light cream-colored or whitish powder; 10 samples	55	2,260
Anhydrite marl; in bright buff powder; dolomite	20	2,280
Anhydrite marl, cream-colored; 9 samples	45	2,325
Dolomite and anhydrite; in fine buff meal	15	2,340
Anhydrite marl, argillaceous; in yellow powder	10	2,350
Shale, slightly calcareous and gypseous; in gray powder	5	2,355
Dolomite, light buff; in fine meal	5	2,360
Shale, calcareous; in gray powder	5	2,365
Dolomite; in fine buff meal	5	2,370
Limestone, magnesian, or dolomite; in gray powder and meal; residue argillaceous and cherty and with considerable anhydrite	15	2,385
Dolomite, buff; in angular sand	10	2,395
Shale, calcareous; considerable anhydrite	5	2,400

In southeastern Iowa there is evidence of upwarps of the nature of low domes in which the older terranes are much nearer to the surface than they would have been if the dome structure were absent. This dome or anticlinal structure is, as has been already stated, one of the favorable conditions for the accumulation of oil and gas. Yet in none of the several artesian wells that have been sunk in southeastern Iowa has any oil or gas been found. Whether or not oil or gas will be found in low anticlines which may exist between points already penetrated by deep wells, remains to be proved.

The section of the deep well in Crapo Park at Burlington will serve to show the character of the rock strata in this part of the state.

Record of strata in Crapo Park well at Burlington.

	Thickness	Depth
	Feet	Feet
Pleistocene:		
Loess and drift	18	18
Carboniferous:		
Mississippian (422 feet thick; top, 667 feet above sea level)—		
Limestone, buff; effervescence rather slow; some chert in small chips	23	41
Limestone, buff and white, granular; rapid effervescence	37	78
Limestone, light yellow; in fine meal; rapid effervescence; some chert	19	97

Record of strata in Crapo Park well at Burlington.

	Thickness	Depth
	Feet	Feet
Limestone, buff; in fine meal and flour; rapid effervescence; some chert	13	110
Limestone, magnesian or dolomite, blue-gray, crystalline	39	149
Shale, blue and drab (Kinderhook)	291	440
Devonian and Silurian (140 feet thick; top, 245 feet above sea level)		
Limestone; in light gray, highly argillaceous powder; rapid effervescence	140	580
Ordovician:		
Maquoketa shale (108 feet thick; top, 105 feet above sea level):		
Shale, light gray, highly calcareous; in powder	38	618
Shale, drab	70	688
Galena dolomite and Platteville limestone (257 feet thick; top, 3 feet below sea level)—		
Dolomite, light buff, crystalline-granular; with hard brown bituminous shale at 868 feet; 5 samples	207	895
Limestone, buff, finely granular; rapid effervescence	31	926
Dolomite, light yellow; in sand and powder	19	945
Saint Peter sandstone (120 feet thick; top, 260 feet below sea level)—		
Sandstone, fine-grained, white; some limestone; grains of considerable range in size, moderately well rounded	10	955
Sandstone, clean, white; somewhat coarser than above	45	1,000
Sandstone; as above; much hard, green shale like the basal shale of the Platteville limestone	40	1,040
Sandstone, clean, white; largest grains reach 0.7 millimeter in diameter	10	1,050
Sandstone; as above; largest grains slightly exceed 1 millimeter in diameter	15	1,065
Prairie du Chien stage (565 feet thick; top, 380 feet below sea level)—		
Dolomite, light gray; some chert	35	1,100
Marl, white and pink, highly dolomitic; large residue of fine quartz sand and argillaceous material and flakes of chert; 3 samples	235	1,335
Dolomite; in fine, light yellow, crystalline meal	15	1,350
Sandstone and pink oolitic chert	10	1,360
Dolomite, arenaceous, or sandstone, calcareous, all in fine, yellow sand	20	1,380
Dolomite, light yellow, highly arenaceous; angular grains of pure dolomite and rounded grains of quartz sand	20	1,400
Marl, white; residue minutely quartzose	10	1,410
Chert and dolomite	9	1,419
Dolomite, buff and light gray; in fine sand; cherty; 4 samples	56	1,475
Unknown; drillings washed away	44	1,519
Dolomite and chert	6	1,525
Chert and dolomite, gray	20	1,545
Dolomite, gray, cherty, and arenaceous	25	1,570
Dolomite, light brown, cherty	15	1,585
Dolomite, gray, cherty	45	1,630

Record of strata in Crapo Park well at Burlington.

	Thickness	Depth
	Feet	Feet
Cambrian:		
Jordan sandstone, Saint Lawrence formation, and underlying Cambrian strata (800 feet penetrated; top, 945 feet below sea level)—		
Unknown, drillings washed away	40	1,670
Sandstone, clean; grains well rounded; largest reaching 1 millimeter in diameter	20	1,690
Sandstone, calcareous, or dolomite, arenaceous, buff; dolomite in angular particles with rounded quartz grains	35	1,725
Unknown; drillings washed away	275	2,000
Sandstone, light gray, in fine angular meal; minute grains of quartz and of glauconite with dolomitic cement or matrix; 4 samples	95	2,095
Dolomite, gray; in fine chips, minutely quartzose, 3 samples	35	2,130
Sandstone; as from 2,000-2,095 feet; brownish, highly glauconiferous	95	2,225
Sandstone; fine grains of clear quartz, some pink, some with secondary enlargements	10	2,235
Sandstone, gray, glauconiferous, calciferous; grains varying in size, some being large and well rounded	35	2,270
Sandstone; as from 2,000 to 2,095 feet	5	2,275
Sandstone; in loose grains of clear quartz, largest, diameter of 1 millimeter	85	2,360
Unknown; drillings washed away	40	2,400
Sandstone, dark brown, glauconiferous; in rounded grains and minute siliceous particles; chips of drillings have rough surfaces (due to projecting granules) and not the smooth fractures of quartzite		
Sandstone, yellow; in chips of minute grains of quartz and glauconite and some rounded quartz grains, embedded in dolomitic matrix or cement; chips crumble easily after digestion in acid; drillings contain considerable hard green shale	5	2,400 2,405
Sandstone, buff, calciferous, glauconiferous; much hard green shale	5	2,410
Sandstone, buff, calciferous, glauconiferous; much green and reddish shale	10	2,420
Shale, hard, dark green and reddish, fissile; and sandstone, calciferous and glauconiferous; in angular chips; grains minute and angular	10	2,430

By way of summary it may be stated that oil in commercial quantities has never been found in Iowa. Gas has been found and no doubt will continue to be found in various parts of the state in small quantities in sands and gravels of Pleistocene age. At no time has the Survey made the statement that oil and gas will never be found in commercial quantities in the indurated rocks of Iowa. But the Survey has asserted and continues to assert that all the evidence that has been gained from a study of the geology of the state, especially in connection with the many deep wells that have been drilled in efforts to get supplies of water, points consistently to the conclusion that it would be a waste of money and effort to drill deep wells with the sole purpose of obtaining commercial quantities of either oil or gas. It is an erroneous notion held by some people that it is necessary only to bore deep enough to get supplies of petroleum and natural gas in any desired quantities and in any locality.

It is the function of the Survey to encourage the development of the resources of the state. But it is also the function of the Survey to furnish such information to the people of the state as will discourage them from investing large sums of money in enterprises which are not even speculations but which from their very nature are doomed to failure.

PLEISTOCENE MAMMALS OF IOWA

For many years, parts of the skeletons of extinct mammals have been found in the Pleistocene deposits of Iowa. But it has been chiefly within the last ten years that many of the most interesting discoveries have been made. Among these are included many well preserved fossils of mastodons, mammoths, horses, camels, sloths, bear and other animals that were found in the Aftonian gravels of western Iowa, and which have been discussed at considerable length by Professor Shimek in the report of the geology of Harrison and Monona counties, published in Volume XX of the publications of the Survey. Moreover, the Aftonian remains have been described somewhat fully by Dr. Samuel Calvin in two papers published in volume twenty and volume twenty-two of the Bulletin of the Geological Society of America. In other papers, also, reference has been made to this most interesting fauna. But my predecessor, Doctor Calvin, recognized the need of a more comprehensive report than any that had been published, a report in which not only the fauna of the Aftonian deposits but also the remains from other horizons of the Pleistocene might be fully described and illustrated, and, furthermore, a report in which the interrelations of the various kinds of life might be considered not alone from the standpoint of their distribution and association in Iowa, but in connection with the Pleistocene of the whole North American continent.

For such a task the Survey is to be congratulated in having had the services of Dr. O. P. Hay of the National Museum, Washington, D. C., an authority on the vertebrate paleontology of the Pleistocene period.

I take pleasure in submitting to you the paper of Doctor Hay, entitled, "The Pleistocene Mammals of Iowa," and recommend that it be published as Volume XXIII, which is the Twenty-first Annual Report of the Iowa Geological Survey.

Respectfully submitted,

GEORGE F. KAY.