State of Iowa
1961

# GEOLOGY AND GROUND-WATER RESOURCES OF CLAYTON COUNTY, IOWA

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Prepared Cooperatively by the United Statets Geological Survey
and the Iowa Geological Survey

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Published by the
STATE OF IOWA
Des Moines

# FOREWORD

This report, Water-Supply Bulletin No. 7, Geology and Ground-Water Resources of Clayton County, is one of a continuing series of studies exploring the intimate relationships existing between ground water and its host rocks. The area covered by this report is of unusual interest because, unlike most of Iowa, a large part of it has no glacial cover and the areas of recharge and discharge can be directly studied rather than inferred.

This report has been prepared in cooperation with the Ground Water Branch of the U. S. Geological Survey with aid and advice from other State and Federal agencies. It is hoped that these reports will be valuable not only to the people of the specific area studied but to all who are interested in our priceless asset, water.

H. GARLAND HERSHEY
State Geologist

Iowa City, Iowa
June, 1961

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# GEOLOGY AND GROUND-WATER RESOURCES OF CLAYTON COUNTY, IOWA

by

W. L. STEINHILBER, O. J. VAN ECK, and A. J. FEULNER

## ABSTRACT

Clayton County includes 784 square miles in northeastern Iowa and in 1960 had a population of 21,962. For the most part, the county is a dissected upland that is drained mainly by the southeastward flowing Turkey River and its principal tributary, the Volga River. The Turkey River empties into the Mississippi River, which flows southward along the eastern border of the county. The climate is humid continental, and the average annual precipitation is 33.01 inches. The economy of the county is based on farming and the raising of livestock. The natural resources of the county include soil, water, rock, sand, and timber.

Glacial deposits of Pleistocene age, ranging in thickness from a featheredge to slightly more than 100 feet, mantle the indurated rocks throughout much of the upland area in the central and western parts of the county. However, indurated rocks of Cambrian, Ordovician, and Silurian age are exposed in hillsides and valley walls throughout the county.

The principal aquifers in the county, in ascending order, are the Galesville sandstone of the Dresbach group, the Jordan and St. Peter sandstones, and the Galena and Hopkinton dolomites. The Galesville sandstone of Late Cambrian age yields large quantities of water to wells in the northeastern part of the county; the hardness of water ranges from 278 to 305 ppm (parts per million) and the dissolved-solids content ranges from 415 to 509 ppm. The Jordan sandstone of Late Cambrian age yields large quantities of water to several municipal wells in the eastern half of the county; the hardness of the water ranges from 238 to 431 ppm and the dissolved-solids content ranges from 252 to 461 ppm. The St. Peter sandstone of Middle Ordovician age yields small to moderate quantities of water to many farm and a few municipal wells in the eastern half of the county; the quality of the water is comparable to the water from the Jordan sandstone, although the hardness is slightly higher. The Galena dolomite of Middle Ordovician age is the principal aquifer for farm wells throughout all except the southwestern corner of the county.

Although locally it yields sufficient water for municipal requirements, in most places it yields only enough for domestic requirements. The hardness of the water ranges from 254 to 415 ppm and the dissolved-solids content ranges from 294 to 477 ppm. The Hopkinton dolomite of Middle Silurian age, which underlies only the southwestern part of the county, yields moderate quantities of water to wells. The water from this formation is less mineralized than the water in the other bedrock formations; the hardness ranges from 231 to 333 ppm and the dissolved-solids content ranges from 247 to 376 ppm.

Small quantities of water for domestic use are obtained from the glacial drift in southwestern Clayton County. In most places, however, the supply is not dependable.

Recharge to the aquifers in the county is by subsurface inflow, seepage, and direct precipitation. The Dresbach group and Jordan sandstone are recharged by subsurface inflow. The St. Peter sandstone is recharged mainly by subsurface inflow from the north and south and partly by downward seepage from overlying formations. The Galena dolomite is recharged mainly by infiltration of direct precipitation on the interstream outcrop areas and partly by downward seepage from the Maquoketa shale and partly by some subsurface inflow. The aquifer of Silurian age is recharged by infiltration of direct precipitation and presumably by downward seepage from the Iowan drift.

Discharge from the aquifers is by subsurface outflow, direct and indirect seepage, and springs. The Dresbach group and Jordan sandstone are discharged by subsurface outflow, although the Jordan discharges some water into Bloody Run Creek by seepage. Discharge from the St. Peter sandstone is partly by direct seepage into the streams along the eastern border of the county, partly by indirect seepage up through the Platteville limestone and Decorah shale in the lower reach of Turkey River, and partly by subsurface outflow to the west and southwest. Discharge from the Galena dolomite and from the aquifers of Silurian age is by seepage into streams that dissect the aquifers and by the numerous springs that issue from the aquifers. The amount of water discharged into the Turkey River drainage system by these seeps and springs is estimated to be at least 10 mgd (million gallons per day) during extended periods of drought and several times this amount during periods of average precipitation. The discharge by springs alone is estimated to be about 11 mgd during periods of near-average to average precipitation. Most of these springs discharge into the Turkey River, but some discharge into the smaller streams along the eastern border of the county.

An estimated 3,000 farm wells withdraw approximately 2 mgd of ground water from the aquifers in Clayton County. Most of this water is pumped from the St. Peter sandstone and the Galena and Hopkinton dolomites. Twelve municipalities in the county pump slightly less than 1 mgd of water from the county's ground-water reservoirs. More than half of the water pumped for municipal use is withdrawn from the Jordan sandstone and the underlying St. Lawrence formation. A few small industries withdraw approximately 200,000 gpd (gallons per day) from the aquifers in the county.

Additional water supplies could be developed from the Jordan sandstone, St. Peter sandstone, Galena dolomite, and aquifers of Silurian age without depleting the ground-water reservoir. Wells drilled into the Galena dolomite and aquifers of Silurian age in particular, should fully penetrate the complete aquifer.

# INTRODUCTION

## Purpose and Scope of the Investigation

The investigation upon which this report is based is part of a program of ground-water studies being made cooperatively by the Iowa Geological Survey and the United States Geological Survey. The ultimate aim of this cooperative program, which was started in 1938, is the complete appraisal of the ground-water resources of the state. The early emphasis of the cooperative program was on state-wide data collection, which formed the basis for a general understanding of the geohydrology of Iowa. The current emphasis of the program is on systematic investigations of county units (fig. 1), mainly because the county is a convenient unit to study and report on. Although much additional data must be collected and studied for these county reports, the basic data collected during the initial phase of the cooperative program provides the backbone for this and all future ground-water reports.

The detailed study of the geology and the occurrence, recharge, discharge, quality, and availability of ground water in Clayton County began in 1951 and continued intermittently through 1957. The investigation was made under the general supervision of

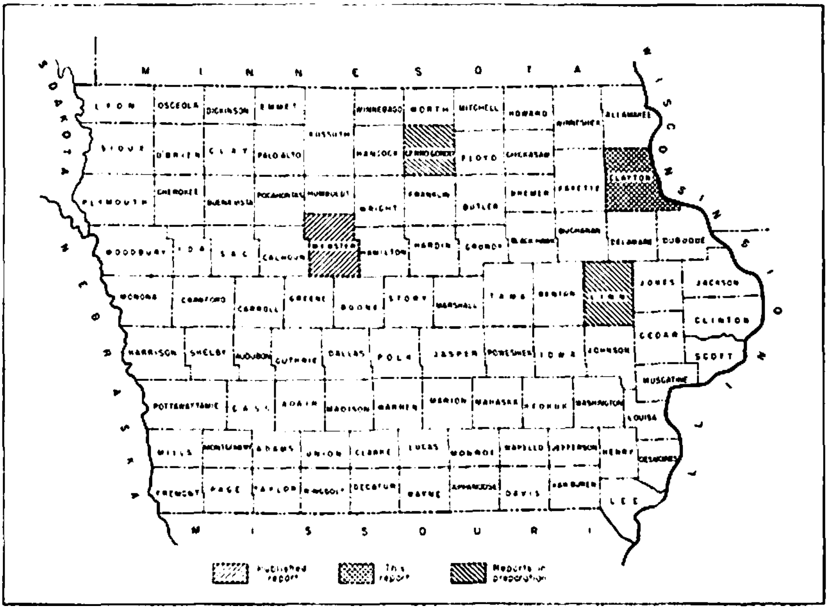

Figure 1.—Index map of Iowa showing progress of ground-water investigations.

A. N. Sayre, Chief of the Ground Water Branch, U. S. Geological Survey, and H. G. Hershey, State Geologist and Director of the Iowa Geological Survey.

Although this report deals specifically with the geology and ground-water conditions in Clayton County, much of the information contained in it is applicable also to quarrying, drainage projects, excavations for foundations and dams, and other operations that penetrate below the surface of the ground. Because all these operations are facilitated if detailed geologic information is known at any given site, this report presents information on the thickness, character, and extent of the stratigraphic units in the county. In addition, descriptions of the rocks exposed in quarries, road cuts, and elsewhere are presented at the end of this report.

### Location and Extent of the Area

Clayton County is in northeastern Iowa in the second tier of counties south of the Minnesota border (fig. 1). It is bounded on the north by Allamakee County, on the west by Fayette County, on the south by Delaware and Dubuque Counties, and on the east by the Mississippi River. The eastern boundary is irregular because of the winding course of the Mississippi River, but the other boundaries are straight lines. The county consists of 22 townships and includes an area of 784 square miles.

### Methods of Investigation

The geologic information for this report was obtained during approximately 3 months field work in the summer of 1951, and the hydrologic information was gathered during short field trips that continued intermittently through 1957. Rock exposures in 79 quarries and 17 road cuts were measured and described. Rock cuttings from 53 wells drilled before and during the investigation were examined. In addition, drillers' logs and hydrologic information were obtained from local drillers and well owners (table 6). Springs are abundant in the county, and particular attention was given to recording the location, discharge, and geologic source of 76 springs, which includes all the major ones. Water samples from 41 wells and 10 springs were collected and analyzed in the Water Laboratory Division of the State Hygienic Laboratory at Iowa City. The altitude of the land surface at wells and at geologic contacts was determined by barometric altimeter.

The field and office study of the surface and subsurface geology has made available considerable additional detail on the local stratigraphy and has resulted in a geologic map of Clayton County (pl. 1) that differs somewhat from earlier maps. County highway maps prepared by the Iowa State Highway Commission were used in compiling field data and in preparing the maps and diagrams for this report. Aerial photographs of Clayton County were particularly valuable in locating rock exposures and in tracing formation boundaries.

Wells, springs, and rock outcrops in quarries, road cuts, and other places have been assigned numbers based on the rectangular system for subdivision of public land (see figure 2). The number consists of three units separated by hyphens. The first number indicates the township; the second the range; the third part consists of a number indicating the section, a letter identifying the 40-acre tract, and a serial number. The letters identifying the 40-acre tracts are assigned as indicated in the enlargement of a single section in figure 2. For example a well located in the SE¼SW¼ sec. 16, T. 92 N., R. 3 W., is designated as 92-3-16P1. If a second well were to be drilled in the same tract, it would be

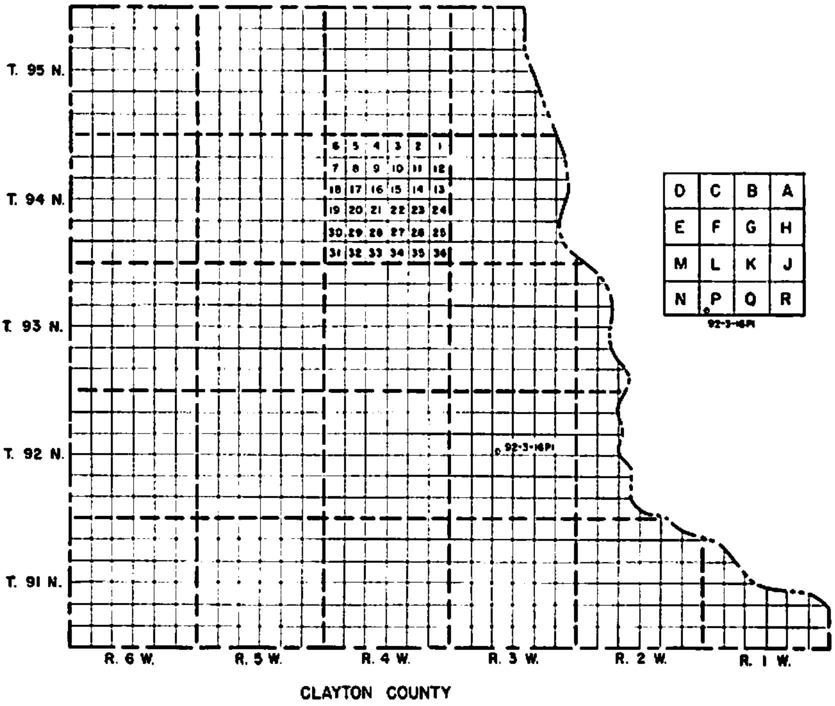

Figure 2.—Map of Clayton County illustrating the well-numbering system used in this report.

assigned the number 92-3-16P2. The same numbering system is applied to springs and rock exposures with the addition of the letter S for springs, Q for quarries, G for gravel pits, and E for other natural or artificial exposures.

### Previous Investigations

The first reference to the geology of Clayton County was made by Hall and Whitney (1858)[1] in a report on a reconnaissance study along the Mississippi River. White (1870), in a report on a geological survey of Iowa, also briefly described the geology of the county. Chamberlin and Salisbury (1885) and McGee (1891) mention Clayton County, but neither reference is more than incidental.

The topography, drainage, and general geologic features of Clayton County are discussed in considerable detail in a report by Leonard (1906). Subsequent reports on regional stratigraphic studies by Trowbridge (1917), Ladd (1929), Trowbridge and Atwater (1934), Scobey (1935), Tester (1937), Spivey (1939), Schuldt (1943), and Heyl and others (1955) also include some data on the geology of Clayton County. Many features of the Pleistocene and other surficial deposits are described and reviewed by Alden and Leighton (1915), Kay and Apfel (1929), and Kay and Graham (1943).

Reports by Norton and others (1912), Norton (1928), and Lees (1928) contain information on ground water in Clayton County. Stream-flow records and other surface-water data, some of which pertain to Clayton County, are given by Crawford (1942 and 1944), Mummey (1953), Bennion (1956), and Schwob (1958).

### Acknowledgments

Many residents of the county generously supplied valuable information regarding wells, quarries, and rock exposures. Municipal officials provided pumpage data, and well drillers and contractors furnished samples of well cuttings and many records. David E. Hoover, County Engineer of Clayton County, furnished information as to locations and bench marks. Appreciation is expressed, also, to colleagues of the Iowa Geological Survey for suggestions during this investigation. Catherine M. Feulner assisted in the field studies and in the preparation of some illustrations for this report.

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[1] Citations of litrature are made by giving the author's name and date, and refer to the selected references at the end of this report.

# GEOGRAPHY

## Topography and Drainage

Clayton County consists of two very distinct topographic regions; a more or less flat area underlain by unconsolidated Iowan glacial till and an extremely dissected area, where consolidated rocks are exposed in hillsides and cliffs. The surface in the southwestern corner of the county (fig. 23), which is covered with Iowan drift, has not been eroded in the comparatively short interval since the Iowan ice disappeared, so that it is a flat to gently rolling, poorly drained, boulder strewn, depositional till surface (pl. 4A). In sharp contrast with the flat area, is the extremely hilly part of the county that was not covered by Iowan drift. This older topography, which was maturely eroded during the long interval following Nebraskan and Kansan glaciation, is dissected by numerous valleys (pl. 4B), nearly all of which are spring-fed.

The major streams of the county are the Turkey and the Volga Rivers. The Turkey River enters the county 9 miles south of the northwest corner and crosses the county in a general southeasterly direction. The Volga River enters the county about 17 miles south of the northwest corner and almost parallels the Turkey River to Elkport, at which point the streams join. These two streams drain about four-fifths of the county. A small area along the northern border is drained by tributaries of the Yellow River and a small area in the southwest corner is drained by the Maquoketa River. A few small streams also enter the Mississippi River directly. The entire drainage system of the county is into the Mississippi River.

The discharge, during the period October 1, 1951 to September 30, 1952, of the Turkey River at the gaging station at Garber about a mile below the junction of the Turkey and Volga Rivers, and the precipitation at Elkader, during the same period are shown in figure 3. The total precipitation during the period was near the average.

## Climate

The climate of Clayton County is variable and is described as the humid continental type. The temperature at Elkader during 75 years of record has ranged from a high of 108°F. on July 13, 1936, to a low of —40°F. on January 30, 1951. The average annual temperature at Elkader is 46.3°F. The average for June, July, and August, the warmest months, is 66.7°F. The average period from the last killing frost in the spring to the first killing frost in the fall is 152 days (fig. 4).

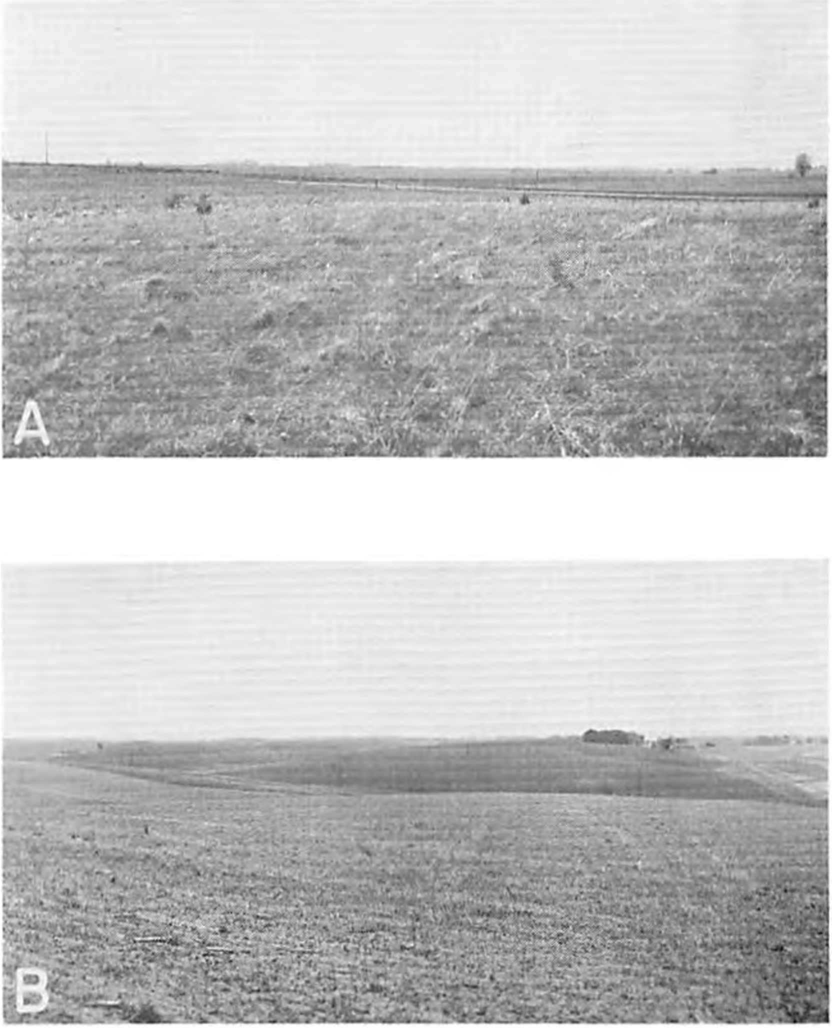

Plate 4.— *A*, View southeast of Strawberry Point, showing the flat undissected topography on the Iowan drift; *B*. View north of Strawberry Point, showing the dissected rolling topography of the Kansan drift.

The average annual precipitation at Elkader is 33.01 inches and during the 69 years of record has ranged from a minimum of 20.98 inches in 1901 to a maximum of 50.01 inches in 1902. Other years of extremes in precipitation were 1876 with 44.83 inches, 1910 with 22.28 inches, 1949 with 24.24 inches, and 1951 with 47.74 inches (fig. 5). About two-thirds of the precipitation falls during the period of May through September.

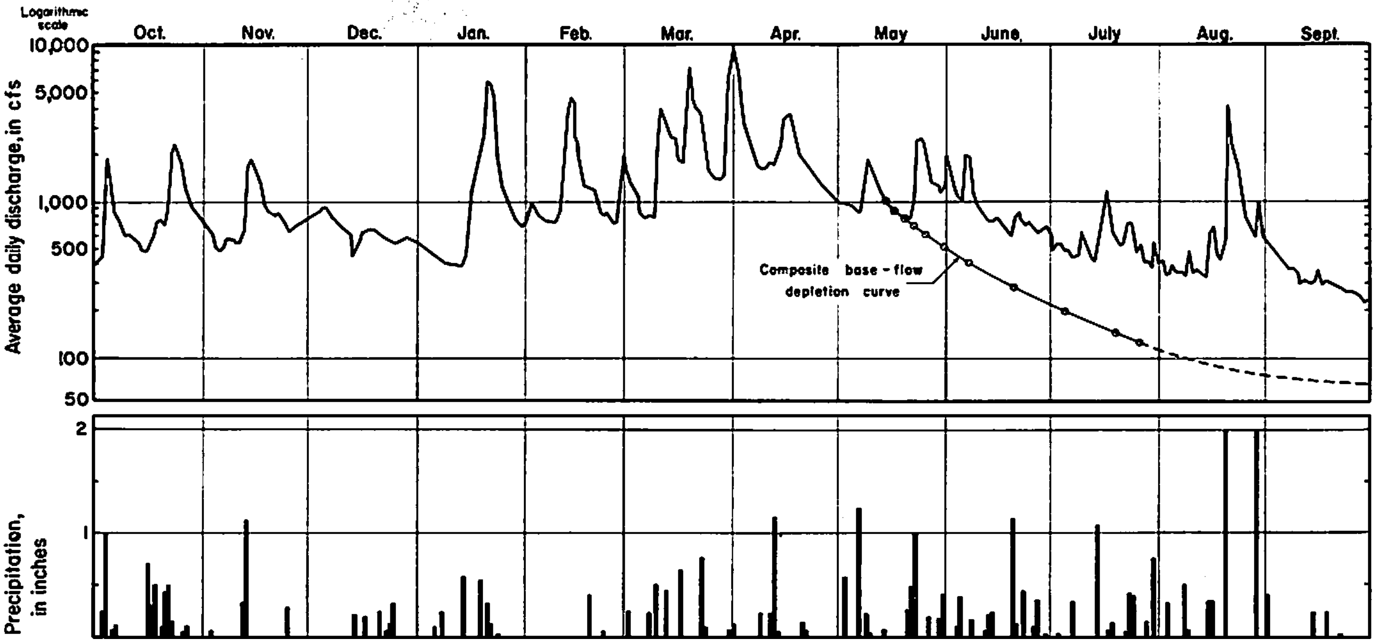

Figure 3.—Average daily discharge of the Turkey River at Garber and precipitation at Elkader for the period October 1951 through September 1952. Base-flow depletion curve plotted from stream-flow records of Iowa. (Data from Surface Water Branch, U. S. Geological Survey and U. S. Weather Bureau).

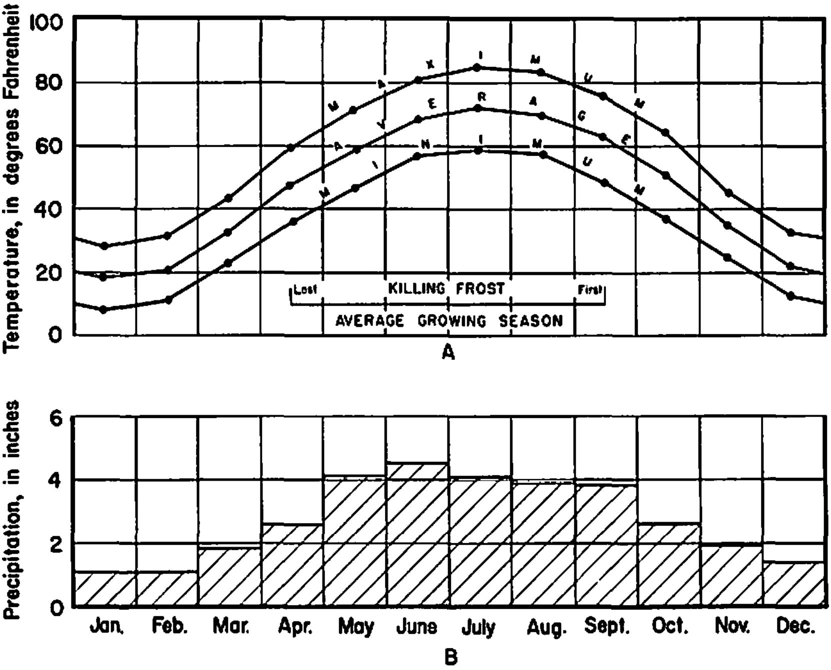

Figure 4.—Graphs showing (A) average and extremes of temperature by months, and (B) average monthly precipitation at Elkader, Iowa. (Basic data from U. S. Weather Bureau).

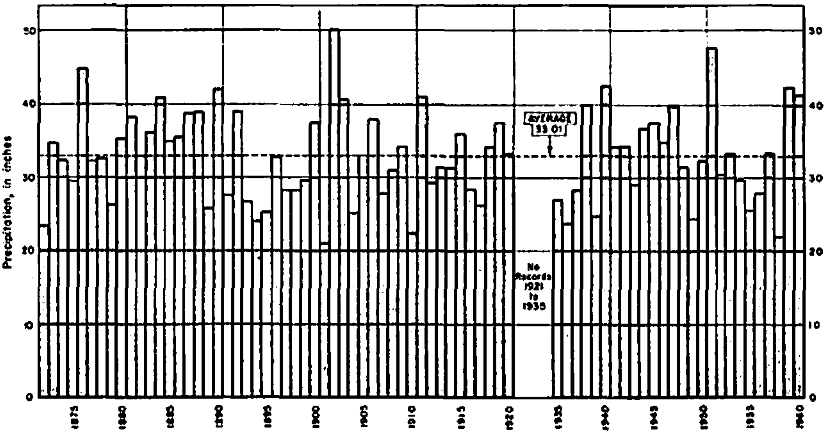

Figure 5.—Graph showing annual precipitation at Elkader, Iowa, for periods 1872-1920 and 1935-60. (Data from records of the U. S. Weather Bureau.)

### Agriculture and Industry

Agriculture in Clayton County consists largely of dairying and the growing of corn, wheat, oats, beans, hay, and sorghum cane. The raising of dairy and stock cattle accounts for a large part of the farm income.

Because agriculture is the major activity in the county, the supplying of farm materials and equipment and the processing of agricultural products constitute the principal industrial activities. In the 18 incorporated towns are 15 creameries, a canning company that operates seasonally, a tool manufacturing company, 3 small bottling companies, and a cheese factory.

### Natural Resources

Lead was once an important natural resource of Clayton County. Mining started near North Buena Vista in southeastern Clayton County in 1851 and later at Miners Creek northwest of Guttenberg. The latter locality formerly produced considerable lead; at one time two smelters were in operation on Miners Creek. The ore is no longer being mined because it is too lean to be mined profitably under present conditions.

The mineralogy and other features of the deposits at Guttenberg suggest a very weak type of ore deposition, such as might be expected of deposits near the limit of mineralization (Heyl and others, 1955, p. 239). The ore occurs as thin coatings of pyrite and marcasite on the wall rocks, with small galena crystals on the iron sulfide coatings, and a little barite. The deposits near North Buena Vista were found somewhat above the base of the Galena dolomite; those at Guttenberg were found at the base of the formation.

In the past, several plants manufacturing clay products have operated in the county, using loess, alluvium, and Maquoketa shale as raw material. Although the Maquoketa shale locally furnishes clay of good quality for the manufacture of clay products, the extreme variation in chemical composition prohibits extensive development. As the localized high quality shale deposits were worked out, all the plants closed down.

Lumbering is becoming an important part-time occupation for many farmers; much of the timber, which formerly was cut only for fence posts and for farm construction, has acquired a commercial value in the past few years. A large quantity of walnut and oak logs are now being shipped out of the county, and cutting continues throughout the year.

An interesting feature of the natural resources of Clayton County is a sand mine, operated by American-Marietta Company, Concrete Materials and Construction Division at Clayton, Iowa, (pl. 5). The mine at present extends about 2,500 feet along the face of the cliff and approximately 1,500 feet back into the hill. The sand is extracted by means of drifts driven into the face of the cliff, and the "room-and-pillar" method of mining is used. The rooms and pillars are approximately 50 feet in each dimension. The sand is sorted by air elutriation into three basic size grades. About 500 tons of sand are shipped daily, most of it going to foundries in Iowa.

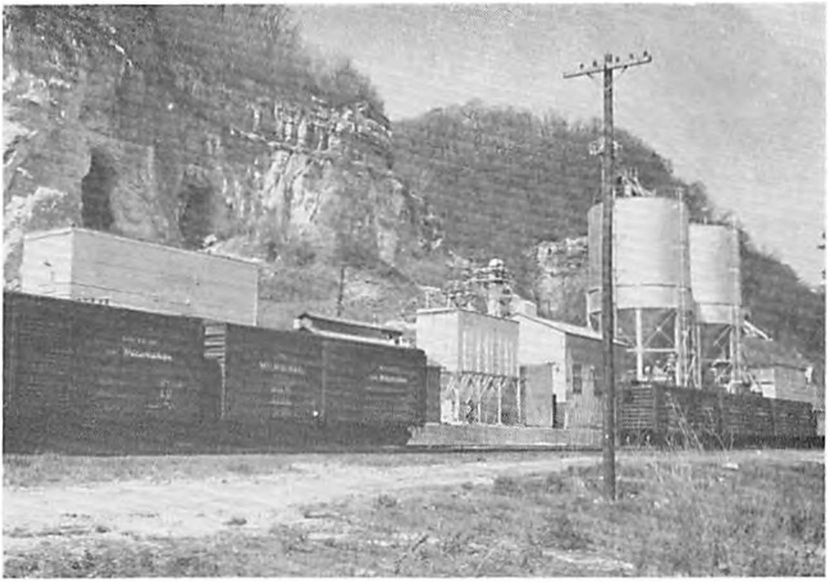

PLATE 5.—VIEW OF SAND MINE OPERATED BY CONCRETE MATERIALS AND CONSTRUCTION DIVISION AT CLAYTON.

About 80 rock quarries are known in Clayton County, although some of them are now abandoned (fig. 6). Some of the quarried rock is used locally for building stone, but most of it is crushed for use on roads. During 1952, 85 miles of road were surfaced and 141 miles resurfaced. The resurfacing projects required 62,000 cubic yards of rock, or 83,700 tons, and the surfacing projects required 85,000 cubic yards, or 114,750 tons. An average of about 94,000 cubic yards, or 127,000 tons of crushed rock is used yearly in Clayton County to surface 50 miles of roads and to resurface 100 miles.

A few sand and gravel pits have been opened on the terraces along the rivers of the county. The material is used extensively for road surfacing and concrete aggregate.

The natural features of Clayton County attract many tourists. Several state parks have been developed on the scenic heights overlooking the Mississippi River. Backbone State Park, on the Maquoketa River in northwest Delaware County, attracts many visitors to the southwestern part of Clayton County because of its easy access to boating, camping, and fishing.

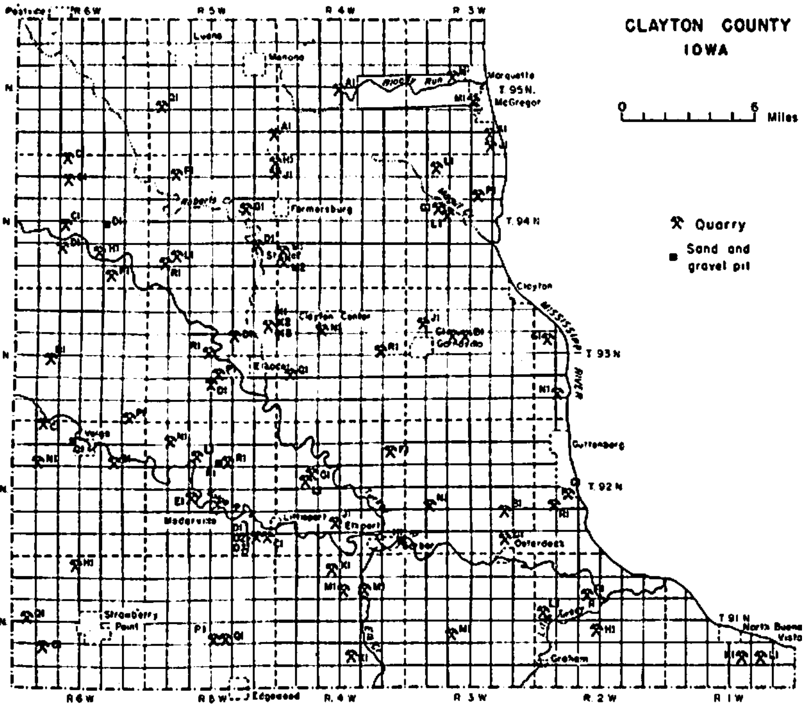

Figure 6.—Map showing location of rock quarries and sand and gravel pits in Clayton County, Iowa.

## Population

The population of Clayton County in 1960, according to the census, was 21,962, a decrease of 528 since 1950. Five towns in the county have a population of more than 1,000 and only one exceeds 2,000 (table 1). The total urban population is slightly more than half the total population of the county.

Settlement of the county was rapid between 1850 and 1870, and most of the towns were incorporated during that period. The population continued to increase until about 1900, but then began to decline gradually because improved farming techniques reduced the number of persons needed to operate farms. The decline in rural population was not balanced by a corresponding increase in the county's urban population because, according to Trowbridge and other (1936, p. 14-15), most farm-to-city migration is to the cities of 20,000 or larger.

### Transportation

The county is served by four branches of the Chicago, Milwaukee, St. Paul and Pacific Railroad. One branch extends across the northern part of the county through Marquette, Monona, and Luana. This branch is joined by a line from Elkader, which passes through St. Olaf. Another branch follows the Mississippi River through Marquette, McGregor, Clayton, and North Buena Vista, and a fourth branch crosses the southwest corner of the county through Strawberry Point and Edgewood.

TABLE 1. POPULATION OF CITIES AND TOWNS IN CLAYTON COUNTY, IOWA

| | Population | | |
|---|---|---|---|
| | 1940 | 1950 | 1960 |
| Clayton | 161 | 136 | 130 |
| Edgewood | 716 | 696 | 767 |
| Elkader (County Seat) | 1,556 | 1,584 | 1,526 |
| Elkport | 130 | 99 | 100 |
| Farmersburg | 296 | 263 | 250 |
| Garber | 158 | 153 | 148 |
| Garnavillo | 461 | 581 | 662 |
| Guttenberg | 1,860 | 1,912 | 2,087 |
| Littleport | 170 | 139 | 119 |
| Luana | 201 | 220 | 276 |
| Marquette | 747 | 641 | 572 |
| McGregor | 1,309 | 1,138 | 1,040 |
| Monona | 1,191 | 1,346 | 1,346 |
| North Buena Vista | 203 | 148 | 150 |
| Osterdock | 78 | 51 | 45 |
| St. Olaf | 191 | 158 | 169 |
| Strawberry Point | 1,223 | 1,247 | 1,303 |
| Volga | 377 | 423 | 361 |
| Total | 11,031 | 10,935 | 11,051 |
| Total population of Clayton County | 24,334 | 22,490 | 21,962 |

All-weather State and Federal highways extend to nearly all parts of the county. U. S. Highway 52 crosses the county in a northwesterly direction; at Froelich it is joined from the east by U. S. Highway 18. State Highway 13 passes through Strawberry Point and Elkader and continues northeastwardly to its junction with U. S. Highway 52.

During the navigation season on the Mississippi River, barges pass the area but very little freight enters or leaves the county by this means of transportation.

## GEOLOGY

### General Geology

The rocks that form the crust of the earth are divided according to origin, texture, and composition into three main classes. Igneous rocks are formed by solidification from molten or partially molten masses. Sedimentary rocks are formed by the deposition of sediments that were transported by water, ice sheets, or wind; by precipitation from solution; or by the accumulation of organic remains. Metamorphic rocks are formed through alteration of sedimentary and igneous rocks by heat and pressure.

Although the igneous and metamorphic rocks constitute the greatest volume of earth's crust, they are buried in most places beneath a mantle of sedimentary rocks that range in thickness from less than a foot to a few miles. These sedimentary rocks are of great economic significance because of their accessibility and their chemical and physical properties; they are the source of all the petroleum, many ore minerals, and most of the ground water.

Sedimentary rocks may be either unconsolidated or consolidated. The unconsolidated rocks consist chiefly of sand, gravel, silt, and clay. In Clayton County, the principal mode of occurrence is as glacial till. This unconsolidated rock, found on uplands and hillsides, is a mixture of clay and silt containing subordinate amounts of sand, gravel, and boulders (although, locally, sand may be the principal sediment—as in outwash areas) that was deposited by one or more continental glaciers. Another common type of unconsolidated sedimentary rocks in Clayton County is alluvium, which is a detrital material that was deposited in stream beds and along flood plains by the streams. One other common type in the county is loess, which is a wind-blown silt containing subordinate amounts of clay and very fine sand.

The consolidated sedimentary rocks exposed in Clayton County consist of sandstone, shale, limestone, and dolomite, which were deposited in ancient seas as sand, mud, and lime-mud over long periods of geologic time. The type of sediment deposited at any given locality at any given time was dependent on many factors, the most important of which were probably depth of water and position of the shoreline. Thus, an area that underwent mud accumulation under a given shoreline position, would have had the mud deposits covered by sand or lime-mud when the shoreline shifted nearer to or farther from the site of deposition. As can be seen from the varied rock types in Clayton County, the ancient shorelines must have shifted frequently during the geologic periods when these rocks were deposited.

The sedimentary rocks are divided into stratigraphic units, called formations, on the basis of definitive lithologic features. A formation is identified by a geographic name combined with either a lithologic term or the term "formation." For example, an exposure of dolomite near Galena, Ill., was described and named the Galena dolomite, and that term is applied to equivalent dolomite layers wherever identified in Illinois, Iowa, Wisconsin, and Minnesota. The formation name is equally applicable whether the formation crops out at the surface or is buried beneath younger layers of rock. Thus, the Galena dolomite, which crops out throughout much of eastern Clayton County (pl. 1) and underlies younger formations at varying depths in the rest of the county, possesses certain diagnostic features by which it can be identified as the same dolomite that crops out at Galena, Ill. Similarly, the sandstone formation that crops out in northeastern Clayton County (pl. 1) and is reached by drilling to varying depths in the remainder of the county (pl. 3) is called the St. Peter sandstone because the same sandstone layer is exposed and was first described along the St. Peter River (now called the Minnesota River) in Minnesota. Two or more successive formations with related lithologies may be combined into units called groups. The Galesville, Eau Claire, and Mt. Simon sandstones comprise the Dresbach group in most of the Upper Mississippi region (table 2). Some formations are subdivided into subunits called members. Thus, the Maquoketa shale is subdivided into the Brainard shale member, Ft. Atkinson dolomite member, Clermont shale member, and Elgin limestone member (table 2). These members of the Maquoketa shale are particularly well exposed in Clayton County.

Formations and groups are combined into larger units called series, which include all the sediments deposited during an epoch of geologic time. Similarly, series are grouped into larger units called systems, which include all the sediments deposited in a period of geologic time. Table 2 shows the stratigraphic units identified in Clayton County and the larger units to which they belong.

### Summary of Stratigraphy

Stratigraphy is the geologic science which treats of the description, organization, and classification of sedimentary rocks.

## TABLE 2. GENERALIZED SECTION OF THE GEOLOGIC FORMATIONS IN CLAYTON COUNTY, IOWA

| System | Sereis | Stratigraphic Unit or Formation | Subunit or Member | Maximum Thickness (feet) | Physical character | Water supply |
|---|---|---|---|---|---|---|
| Quaternary | | Recent deposits | | 35 | Soils and alluvial deposits of silt, sand, and gravel. | No large supplies have been developed, but moderate to large yields probably could be developed locally from alluvium in the Mississippi River valley. |
| | Pleistocene | Wisconsin | Iowan drift | 135 | Weathered till and loess. | Yields small quantities to dug wells. |
| | | Kansan drift | | | Weathered till and thin loess. Locally some weathered and iron-stained sand, gravel and silt. | |
| | | Nebraskan drift | | | Weathered till. | |
| Silurian | Niagaran | Hopkinton dolomite | | 125(?) 190 | Mostly yellow to buff massive dolomite, some limestone. | Yields moderately large quantities to wells and springs. |
| | Alexandrian | Kankakee limestone | | 140(?) | Yellow dolomite containing bands of white chert. | Yields small quantities of water to wells. |
| | | Edgewood | | 35 | Thin-bedded, yellow to gray sandy dolomite containing scattered nodules of chert. | Yields small quantities of water to wells and springs. |
| Ordovician | Cincinnatian | Maquoketa shale | Brainard shale | 126 | Grayish-green shale. | Not a source of water supply. |
| | | | Ft. Atkinson dolomite | 40 | Grayish-yellow dolomite containing numerous nodules of chert. | Yields small quantities of water to wells and springs. |
| | | | Clermont shale | 40 | Bluish-green shale. | Not a source of water supply. |
| | | | Elgin limestone | 110 | Fine-grained argillaceous dolomite, and some shale. | Yields small quantities of water to wells. |
| | Mohawkian | Galena dolomite | Dubuque dolomite | 50 | Thin-bedded dolomite and limestone interbedded with brown shale. | Yields moderately large quantities of water to wells and springs. |
| | | | Stewartville dolomite | 77 | Massive, brown dolomite. | Yields water to springs and some wells. |
| | | | Prosser limestone | 132 | Grayish-brown dolomite containing layers of chert in lower part. | Yields moderately large quantities of water to wells. Large quantities of water issue from springs at its base. |
| | | Decorah shale | Ion member | 23 | Green calcareous shale interbedded with limestone. | Not a wource of water supply. |
| | | | Guttenberg limestone | 27 | Thin-bedded light-gray limestone and dolomite. | Yields small quantities of water to wells. |

## TABLE 2. GENERALIZED SECTION OF THE GEOLOGIC FORMATIONS IN CLAYTON COUNTY, IOWA—Continued

| | | | | | | |
|---|---|---|---|---|---|---|
| | | Platteville limestone | Spechts Ferry member | 18 | Very fossiliferous gray to green shale interbedded with thin layers of dolomite. | Not a source of water supply. |
| | | | McGregor member | 35 | Thin-bedded, gray limestone and dolomite. | Yields small quantities of water to wells. |
| | | | Pecatonica dolomite | 16 | Massive, gray to buff, mottled dolomite. | Yields small quantities of water to wells. |
| | | | Glenwood shale | 25 | Thin-bedded, green shale. | Not a source of water supply. |
| | Chazyan | St. Peter sandstone | | 112 | Loosely cemented, fine to medium-grained quartz sandstone. | Yields small to large quantities of water to wells. |
| | Beekmantownian | Prairie du Chien formation | Willow River dolomite | 95 | Light-gray to buff sandy dolomite with some chert. | Yields small quantities of water to wells. |
| | | | Root Valley sandstone | 25 | Very light-brown to white sandstone. | Not important as an aquifer. |
| | | | Oneota dolmite | 215 | Massive, vuggy, buff to gray cherty dolomite. | Yields small quantities of water to wells. |
| Cambrian | St. Croixan | Jordan sandstone | | 120 | Loosely cemented, medium to coarse-grained, well-sorted buff to white sandstone. | Yields large quantities of water to wells. |
| | | St. Lawrence formation | | 170 | Coarsely crystalline, silty, gray dolomite with some glauconite. | Yields small to moderate quantities of water to wells. |
| | | Franconia sandstone | | 130 | Glauconitic, dolomitic fissile shale interbedded with coarse-grained glauconitic sandstone. | Not a source of water supply. |
| | | Dresbach group | Galesville sandstone | 140 | Medium-to coarse-grained, white to gray sandstone. | Yields large quantities of water to wells in northeast. |
| | | | Eau Claire sandstone | 120 | Partly fissile, gray, silty shale and dolomitic cemented siltstone. | Not a source of water supply. |
| | | | Mt. Simon sandstone | 115+ | Coarse, colorless to pink and gray sandstone with gray to green micaceous shale. | Yields large quantities of highly mineralized water to wells in northeast. |
| Precambrian | | Undifferentiated red beds. | | 37+ | Soft, silty, red shale and medium to fine-grained sandstone. | Yields no water to wells. |
| | | Crystalline rocks | | | In adjacent counties the rocks are pink, biotite granites. | Yields no water to wells. |

Hence, the stratigraphy of Clayton County is the study and description of the rock formations that underlie the county.

Clayton County is underlain by Precambrian igneous and metamorphic rocks that are commonly referred to as basement complex at depths varying from about 1,200 feet in the northeastern part to about 2,600 feet in the southwestern part. This basement complex is overlain by a succession of stratified sedimentary rocks that belong, in ascending order, to the Cambrian, Ordovician, and Silurian systems. The oldest rock exposed in the county is the Jordan sandstone of Cambrian age. Formations older than the Jordan sandstone crop out in Allamakee County, Iowa, and in southeastern Minnesota and southwestern Wisconsin. Formations overlying the Jordan sandstone, in ascending order, are the Prairie du Chien formation, St. Peter sandstone, Platteville limestone, Decorah shale, Galena dolomite, and Maquoketa shale of Ordovician age, and the Edgewood limestone, Kankakee limestone and Hopkinton dolomite of Silurian age. Because these formations dip toward the southwest, progressively younger strata are exposed toward the west, southwest, and south. The areal distribution of the outcropping geologic formation is shown on plate 1, and the stratigraphic sequence, thickness, lithology, and dip of these rocks are illustrated on plate 3. The thickness, physical character, and water-bearing characteristics of the formations are summarized briefly in table 2 and are described in detail in the section on geologic formations and their water-bearing characteristics.

Unconsolidated rock materials, which overlie the consolidated rocks, in many places in Clayton County, consist mainly of till, glacial outwash, and wind-blown silt (loess). The areal distribution of the Iowan and Kansan drifts is shown in figure 23. Alluvial deposits occur along the flood plains and terraces of the rivers and creeks in the county.

The stratigraphic nomenclature used in this report is that used by the Iowa Geological Survey and does not conform in every detail with the nomenclature used by the U. S. Geological Survey.

### Geologic History

During Early and Middle Cambrian time, the land surface in what is now Clayton County was above sea level and thus was subject to erosion. The land surface subsided below sea level during Late Cambrian time and sediments, mainly sand, began to accumulate on the floor of the sea. Because the sea was shallow, slight crustal movements caused the floor of the sea to be raised above sea level from time to time, temporarily halting deposition and exposing the accumulated sediments to erosion. However, the change from the upper sandstone of the Cambrian system to the lower dolomite of the Ordovician system seems to be gradational rather than abrupt, indicating that deposition was not interrupted by a withdrawal of the sea. A retreat of the sea after the deposition of the dolomitic Prairie du Chien formation exposed the upper surface of that formation to eroson, and it was upon the eroded surface of the Prairie du Chien that the St. Peter sandstone was laid down. After the subsequent deposition of the Platteville limestone, Decorah shale, Galena dolomite, and Maquoketa shale, the sea again withdrew and widespread erosion occurred. The sea invaded the area once more and in it were deposited, in succession, the Edgewood and Kankakee limestones and the Hopkinton dolomite of Silurian age. How great a thickness of sediments accumulated on top of the Hopkinton and was later removed cannot be determined, because the surface in Clayton County over which the great continental ice sheets advanced in the Pleistocene epoch of the Quaternary period was the eroded surface of the Silurian and Ordovician rocks; there remained no record of deposition throughout the long span of geologic time between the Silurian and the Quaternary periods.

As the first of the Pleistocene glaciers, the Nebraskan, passed over the county, the irregularities of the bedrock surface were largely filled with deposits of till, sand, and gravel. These materiels were almost completely removed by erosion during the ice-free period before the advance of the second, or Kansan, glacier. The Kansan ice sheet covered only part of Clayton County and it also left a veneer of glacial drift. The Kansan drift has been continuously exposed to erosion to the present day except where protected by the later Iowan till and loess. The deposits of the Iowan glacier, the last glaciation in the county, were laid down so recently, geologically speaking, that they have not been perceptibly eroded. As the Iowan glacier retreated, the newly exposed till provided the silt and clay that were the source of the loess deposits that accumulated around the periphery of the Iowan till plain. As the Iowan ice retreated yet farther north the exposed drift together with associated valley trains served as a source of the loess that mantled the entire area. The only sediments of significance that have been deposited in the county since the Iowan glacier melted consist of alluvium in the stream valleys.

### Structure

The sedimentary rocks of Clayton County dip to the southwest at about 18 feet per mile. A slight flexure (called an anticline) trends southwardly across the county (fig. 18). The maximum closure on this anticline (distance between the crest of the flexure and its base) is about 60 feet.

A cross section drawn from the southwestern part to the northeastern part of the county (pl. 3) shows the regional dip as well as the thickness of the rock units. The variation in the thicknesses of some formations are due to depositional hiatuses rather than structural control.

## GROUND WATER

The following discussion of ground water pertains specifically to Clayton County. A wider discussion on the subject of ground water in Iowa is given by Norton and others (1912), Norton (1928), and Lees (1935), and the general principles of ground water are reviewed in detail by Meinzer (1923b) and Tolman (1937).

### PRINCIPLES OF OCCURRENCE

All water below the land surface is called subsurface water to distinguish it from surface and atmospheric water. Ground water is that part of the subsurface water that occurs in a zone of saturation, the upper surface of which is called the water table (fig. 7). The remainder of the subsurface water occurs in the zone of aeration, which is between the land surface and the water table. Water in this zone is typically divided into three parts: soil water, intermediate or vadose water, and capillary water (fig. 7).

Water held in the soil by adhesive and cohesive forces that act against the force of gravity is referred to as soil water. It is the soil water that furnishes the water requirements of plants and crops. When more water than can be held by these adhesive and cohesive forces enters the soil zone during the nongrowing season, most of the excess seeps down to the intermediate zone. However, very little of this excess water passes through the soil zone during the growing season, because vegetation intercepts it and

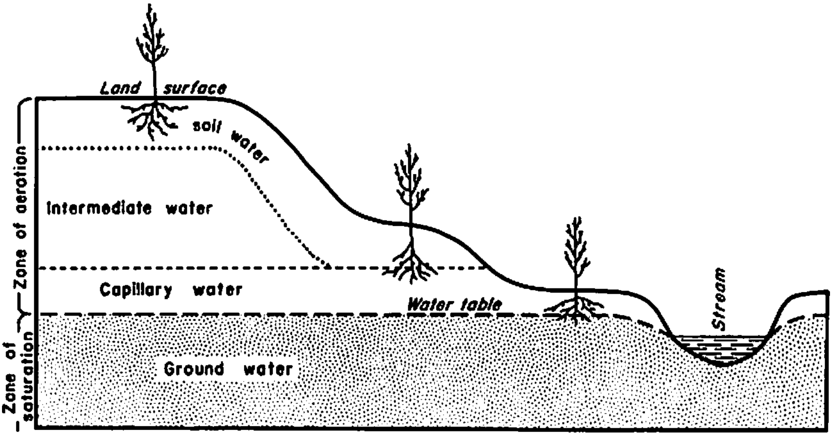

Figure 7.—Diagram showing divisions of subsurface water (Modified after Meinzer, 1923b).

discharges most of it into the atmosphere by the process known as transpiration.

The mechanics of water movement in the intermediate zone of aeration are not completely understood. Before the excess water from the soil can move through the intermediate zone to the zone of saturation, the rock particles must be wetted and the air in the rock openings must be displaced. This process can perhaps be compared to pouring water onto a sponge. If the sponge is dry when water is poured onto its top surface, a large amount of water is absorbed before any water seeps through to the bottom surface; however, if the sponge is damp, the water will almost immediately pass through to the bottom surface. Similarly, the amount of water that passes completely through the intermediate zone and the rate at which the water moves are governed by the amount of water entering the zone and the character, dryness, and thickness of the zone. The water may pass directly below the water table or be held for an indefinite time in the capillary fringe, if one is present.

Water in the capillary fringe is continuous with water in the zone of saturation but is held above the water table by capillarity acting against the force of gravity. The finer grained a rock material, the smaller the diameter of the capillary openings; and the smaller the diameter of the capillary openings, the higher water will rise in them. Thus the height that the capillary fringe stands above the water table is governed by the grain size of the material overlying the water table, standing higher in fine material and lower in coarse material. If the material is very coarse, the capillary fringe may be non-existent.

Locally, any one or all of the subdivisions of the zone of aeration may be absent. Where the zone of saturation extends to the surface of the ground, no zone of aeration is present.

Water that reaches the water table becomes part of the vast body of ground water in the zone of saturation. This is the water that supplies springs and wells and forms the base flow of perennial streams during dry periods. This is the water with which this report is concerned.

The depth to which the zone of saturation extends is very indefinite. Ground water has been found in some very deep mines and oil wells; however, many mines at much shallower depths are dry. Obviously, the depth to which ground water occurs at any locality is dependent primarily on the existence of rock openings. In Clayton County, as in all of Iowa, the rock openings of the sedimentary rocks are filled with water from the water table downward to at least the surface of the Precambrian crystalline complex.

The zone of saturation can be pictured as a great subterranean reservoir that became filled with water. The water in this reservoir moves from recharge areas of higher hydrostatic head to discharge areas of lower hydrostatic head. The hydraulic gradient is the slope of a line, usually measured in feet per mile, from the hydraulic head in the recharge area to the hydraulic head in the discharge area.

The amount of ground water in storage and the rate of ground-water movement are governed in large measure by the character and structure of the rocks in the zone of saturation. If the rocks in the zone of saturation were of uniform character, having pore spaces and other rock openings of uniform number, shape, size, and interconnection (uniform porosity and permeability), then the amount of ground-water storage per unit volume of rock would be the same throughout the reservoir, and the rate of movement of the water would be at some constant velocity from the recharge area to the discharge area. However, as mentioned in the section on general geology, the sedimentary rocks are not of uniform character; rather, they are a heterogeneous sequence of strata that differ markedly in physical and water-bearing properties. The porosity and permeability vary not only from formation to formation, but also within a formation. Because of the variations in porosity, the amount of water stored in one formation will be greater or less than that stored in another of equal thickness. Likewise, because they differ in permeability one formation may transmit water faster or slower than another of equal thickness. Clay, shale, and unfractured limestone may have a high porosity and so be capable of storing a great quantity of water, but because they are so nearly impermeable such rocks transmit water very slowly. Rocks that are impermeable, or nearly so, are called aquicludes, or confining beds. Most medium- to coarse-grained sandstones, fractured limestones, and sand and gravel deposits, which have large, interconnected pore spaces or other openings, are capable of both storing and transmitting large quantities of water. Such rocks are called aquifers, or water-bearing beds, and are the beds from which wells obtain water.

Aquifers are divided into two categories—water table and artesian. A water-table aquifer is not overlain by a confining bed and the hydrostatic head of the water is the water table.

Thus, water levels in wells drilled into these aquifers do not rise above the point where water was encountered (fig. 8). An artesian aquifer is overlain by a confining bed, and the hydrostatic head of the water is above the confined surface. Thus, the water level in a well drilled into an artesian aquifer is above the point where the water was encountered when the well was being drilled (fig. 8). Water-table aquifers can grade into artesian aquifers, and in Clayton County this is a common occurrence.

### Water-Table Conditions

The water table may be defined as that isobaric surface, within the earth's crust, at which the hydrostatic pressure is equal to the atmospheric pressure. In practice, however, the water table is that surface which coincides with the water levels in wells that tap water-table aquifers. Contour lines depicting the shape of the water table in humid regions show that the water table conforms to the general land surface, but with subdued relief.

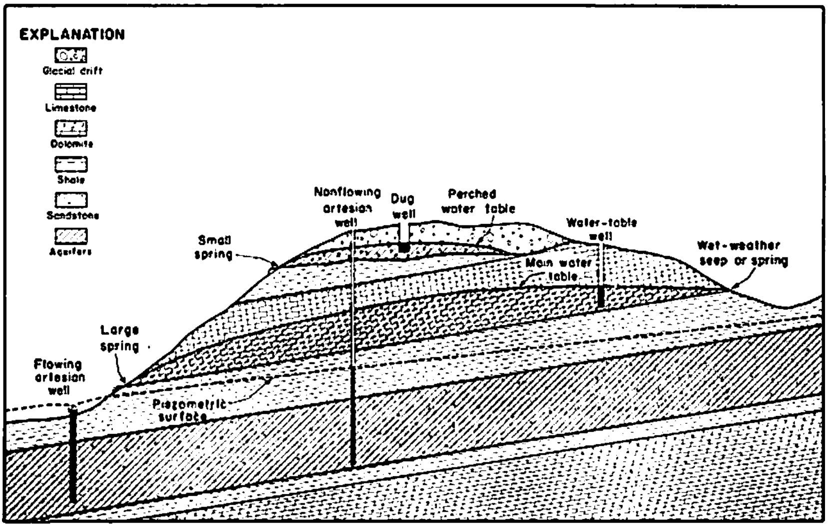

Figure 8.—Generalized diagram illustrating the occurrence of ground water under perched, water-table, and artesian conditions.

Only parts of Clayton County are underlain by a water-table aquifer. Water-table conditions exist where sandy zones in the glacial drift extend to the surface or where the floor of a valley is underlain by unconsolidated sand and gravel. Several wells in the southwestern part of the county obtain sufficient water from sandy zones in the Iowan drift for limited domestic and stock use. These wells range in depth from 12 to 49 feet, and most of them are dug. Some drive-point, drilled and dug wells, ranging in depth from 18 to 30 feet, obtain water from sand and gravel underlying the floodplains of the Mississippi, Turkey, and Volga Rivers. Water-table conditions also exist in some of the bedrock aquifers, particularly the St. Peter sandstone and Galena dolomite, where they crop out east of the Kansan drift border. The water in these aquifers, however, is under artesian conditions to the west where they dip below younger formations.

A water-table aquifer functions as a reservoir. When the discharge exceeds the recharge the amount of water in storage declines; when the recharge exceeds the discharge the amount increases. Changes in the amount of water in storage are indicated by rises and declines of the water table. Periodic measurements of the water level in wells show whether a net gain or loss in storage has occurred in an aquifer. Figure 9 shows typical declines of the water table which indicate net loss in storage, during the period April to December of 1951, in the glacial-drift aquifer at Strawberry Point.

The water-table aquifers in Iowa are recharged principally by local precipitation. The most favorable periods for recharge are after the spring thaw before appreciable growth of vegetation and again in the fall after the first killing frost but before the ground becomes frozen. Obviously, if precipitation is low during these periods, recharge will be low. Recharge is retarded, but not stopped, during the growing season by depletion of the soil water by evaporation and transpiration, and during the winter by frozen ground. Figure 10, which shows the fluctuation of the water level in a shallow well near Harcourt, Iowa, for the year 1948, illustrates the relation between precipitation and recharge to a water-table aquifer during favorable and unfavorable periods. The large amount of precipitation during the summer months was mostly consumed by vegetation and very little water reached the water table, whereas smaller amounts of precipitation during March and April caused a marked rise in the water table. Sometimes, however, during periods of extremely heavy precipitation in the summer months, excess water is available to recharge the water-table aquifer (fig. 11). Also, if the ground is not completely frozen and the precipitation is in the form of rain instead of snow, recharge can occur during the early winter months (fig. 11).

Natural discharge from a water-table aquifer is through springs and seeps (fig. 8) and by evaporation and transpiration. The water table normally slopes more or less gently toward a point of discharge, such as a spring or stream, and the rate of ground-water movement is proportional to the gradient of the

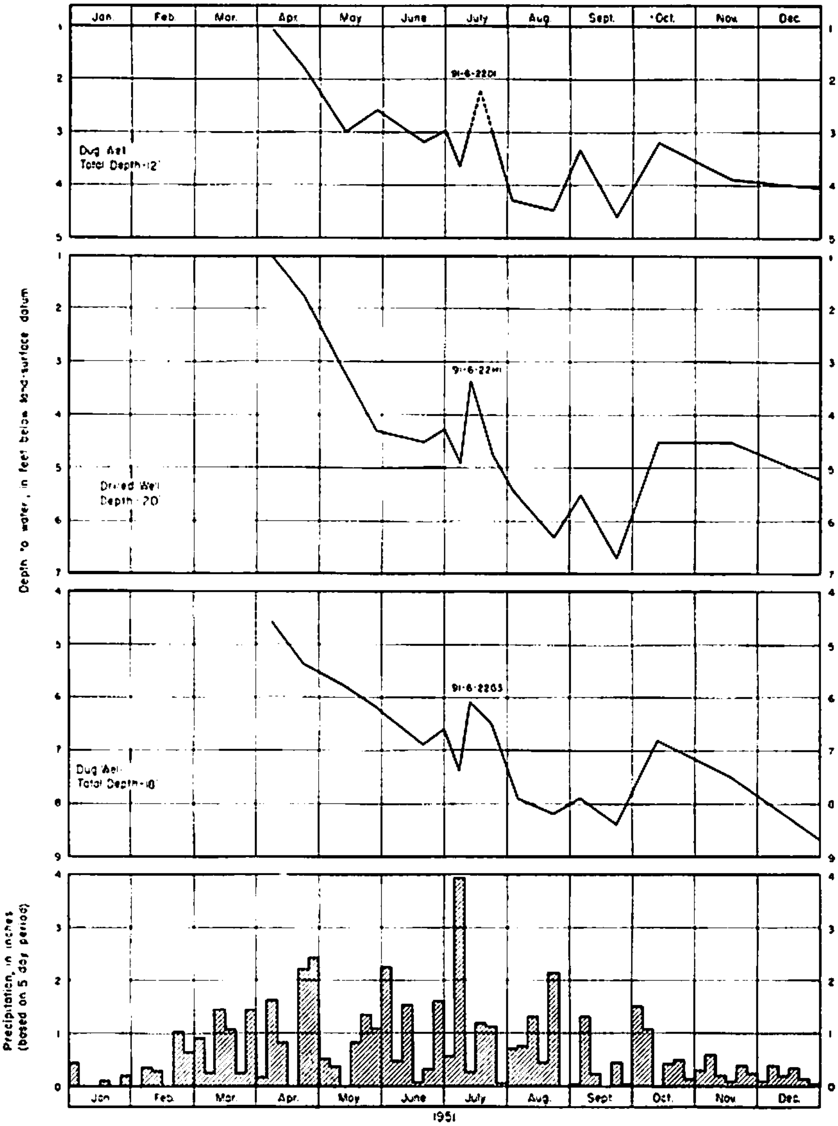

Figure 9.—Hydrographs showing fluctuations in water levels for wells 91-6-22D1, 91-6-22H1, and 91-6-22G3, at Strawberry Point and monthly precipitation at Elkader during 1951.

water table, among other factors. Therefore, as long as the water table has a gradient toward a discharge point, water is being continually discharged from the aquifer. This continual discharge explains the steady decline of the water table during periods of little or no recharge (fig. 10).

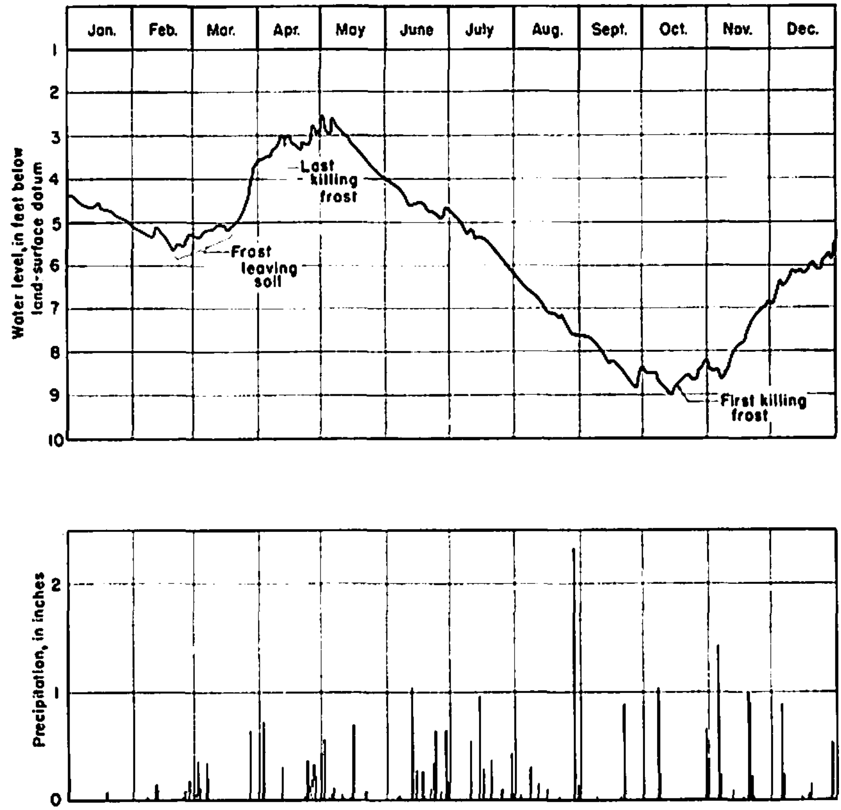

Figure 10.—Graph showing daily fluctuation of water level in a shallow well near Harcourt, Webster County, Iowa, and daily precipitation at Fort Dodge, Iowa, 1948. (From Hale, 1955)

### Artesian Conditions

If an aquifer is overlain by a confining bed of relatively impermeable material and the hydrostatic head of the water in the aquifer is above the base of the confining bed, the aquifer is termed artesian. The number of artesian aquifers that may occur at depth is governed by the number of confining beds in the geologic section. Each aquifer may have a different hydrostatic head. The level at which the water stands in a well that taps an artesian aquifer coincides with the piezometric surface of the

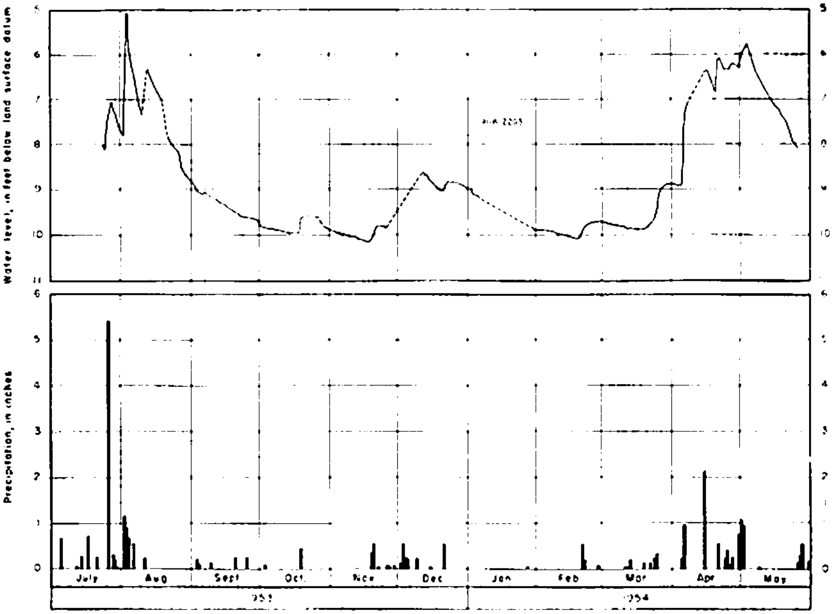

Figure 11.—Hydrograph of well at Strawberry Point showing seasonal changes in ground-water storage, and daily precipitation at Elkader for the period July 1953 through May 1954.

aquifer. The piezometric surface of an aquifer may, in some places, be above the land surface. If a well is drilled into an aquifer, where its piezometric surface is above land surface, water will flow from the well (fig. 8). Artesian conditions exist throughout Clayton County; however, the artesian pressure is sufficient to produce flowing wells only in the northeastern corner of the county.

Artesian aquifers function not only as reservoirs, but also as conduits for transmitting water. The areas of recharge and discharge may be at great distances from the place of use, or they may be close by. In Clayton County, the aquifers below the St. Peter sandstone receive recharge from some unknown distance outside the county; likewise, the discharge from these aquifers is outside the county, although the Jordan sandstone is believed to discharge some water into Bloody Run Creek in the northeastern corner of the county. The St. Peter sandstone and the Silurian formations receive their recharge partly within and partly outside the county and the Galena dolomite is recharged mostly within the county; the principal discharge from these aquifers, particularly the Galena, is within the county.

Unlike water-table aquifers, the deeper artesian aquifers in Clayton County, such as the St. Peter and Jordan sandstones and the Dresbach group commonly do not respond to variations in local precipitation and, therefore, usually are not affected by local drought conditions. The piezometric surfaces of these aquifers remain fairly stable until water is withdrawn by wells drilled into the aquifers. The shallower Galena dolomite, however, is responsive to variations in local precipitation in Clayton County because its principal recharge areas are within the county.

Water in an aquifer may occur under artesian conditions at one place and under water-table conditions at another Aquifers that are artesian where deeply buried generally contain water under water-table conditions in their outcrop area. In particular the Galena dolomite is unconfined east of the Kansan drift border (pl. 1 and fig. 24) ; elsewhere in the county it is artesian. In their outcrop areas in Clayton County, the Galena dolomite is recharged (fig. 21 and pl. 1) and the St. Peter sandstone is discharged (fig. 19 and pl. 1).

## WATER-BEARING PROPERTIES OF COMMON ROCK TYPES

### Sand and Gravel

The terms sand and gravel as used in this report refer to aggregates of particles ranging in size from 0.0625 to 64 millimeters. In Clayton County, unconsolidated deposits of this size range consist chiefly of river terrace deposits and alluvial fill along the major streams and are of late Pleistocene or of Recent age. Locally, coarse sand deposits of pre-Kansan age underlie the glacial till.

The ease with which sand and gravel aquifers will yield water to a well depends largely on the size of the particles, the degree of sorting, and the amount of cementing material present (fig. 12). The larger particle sizes generally have larger pore spaces and these pore spaces are usually interconnected to form relatively large conduits for the movement of water. However, if the material contains an assortment of particles of various sizes, the larger pore spaces may be occupied by the smaller particles and

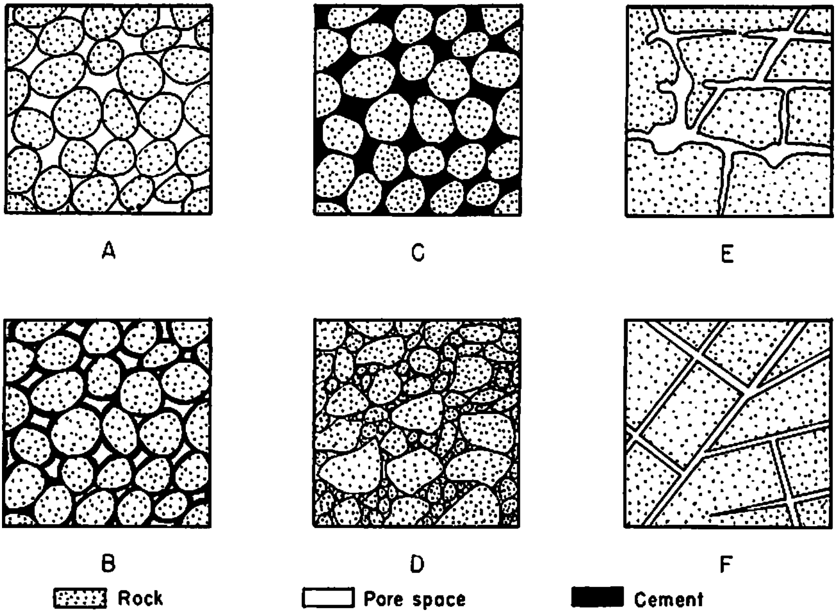

Figure 12.—Diagram showing the nature of interstices in several types of rocks. A—well-sorted sand having open pores; B—well-sorted sand having the pores partly closed by cementing material; C—well-sorted sand having the pores completely closed by cementing material; D—poorly sorted sedimentary deposit having low porosity; E—rock with well-developed solution openings; F—rock with porosity due to fracturing. (Modified after Meinzer, 1923b.)

the rate of movement through the material may be correspondingly less. In the same way, partial cementation after deposition generally reduces permeability.

Well-sorted, fine grained sand deposits commonly are unsatisfactory aquifers, not only because this material transmits water slowly, but also because wells that are finished in this material are difficult to construct and develop by the usual drilling methods. During construction by the cable-tool method, the hole may cave continually and casing is difficult to drive. If the water in the material is under a high hydrostatic head, the sand "boils up" into the hole—a condition known as "quicksand" to the driller—and finishing the well becomes a difficult task. Developing the well is almost impossible, because the coarse-grained material that is needed to form a natural gravel pack outside the screen is lacking; consequently, the well becomes a "sand pumper", as fine sand is pulled into the well whenever the pump is turned on. This fine sand may cause considerable damage to the pump installation; in addition, its presence is objectionable in the water supply.

Because most beds of sand and gravel are poorly sorted, wells drilled into them must be developed so as to remove the finer grains from the water-bearing material. Sand and gravel deposits generally yield water readily to wells. However, as none of these deposits is very thick or extensive in Clayton County, they are tapped by only a few wells. Most of the wells are along the major streams and the Mississippi River. Wells on islands in the Mississippi River are made by driving sand points a few feet into the zone of saturation.

### Silt and Clay

Silt and clay are rock materials consisting of particles that are less than 0.0625 millimeters in diameter. Such deposits have a high porosity and are capable of holding large amounts of water. However, because the aggregate surface of the interstices, or pores, within these fine materials is very high and a great amount of water is held by molecular attraction, saturated silt and clay will yield only a small fraction of their water to gravity flow and so are not considered to be aquifers. If sand and gravel are intermixed with silt and clay, the combined materials would be no more permeable and would store less water than the silt and clay alone. Although silt and clay are poor aquifers, the material is important because they constitute the confining beds for artesian aquifers in the unconsolidated rocks.

Much of Clayton County is covered by a coating of windblown silt, or loess. As is true of other silt deposits, loess is very porous but not very permeable. Where the loess is over 10 feet thick, as it is in some areas of Iowa, enough water will drain from this material into a fully penetrating well to supply limited domestic or stock requirements. In Clayton County, however, the loess generally is less than 5 feet thick, and no wells are known to be finished in this material.

### Sandstone

Sandstone is composed of grains of sand held together by a cement. The grains range in diameter from 0.0625 millimeters up to 2 millimeters. Some sandstones are composed predominantly of one mineral; whereas others are composed of several. All sandstones, however, contain accessory minerals. In Clayton County the sandstones are composed predominantly of quartz and the common accessory minerals are tourmaline, garnet, magnetite, ilmenite, iron oxide compounds, and mica.

Many different varieties of sandstone are differentiated on the basis of the kind of cement that holds the grains together. The cementing material generally is silica, calcite, dolomite, clayey material, or iron oxides. The color of a sandstone depends largely on the cementing material. The lighter colors generally are the result of a calcitic, dolomitic, siliceous or clayey cement. A calcareous sandstone will effervesce when tested with acid, and a clayey sandstone has the characteristic odor of clay when moistened. Yellow, red, or brown sandstone generally is cemented with iron oxides as is the St. Peter sandstone at Pikes Peak State Park, in northeastern Clayton County.

The porosity and permeability of sandstone are dependent on the grain size and degree of sorting of the constituent particles, and on the amount of interstitial cement. Large supplies of water are obtained from sandstone in Clayton County. The St. Peter sandstone yields water to some farm wells and municipal wells at Garnavillo and St. Olaf. The Jordan sandstone yields water to municipal wells at Elkader, Farmersburg, Guttenberg, and Monona. The Dresbach group supplies the municipal wells at McGregor and Marquette.

### Limestone and Dolomite

Limestone and dolomite are carbonate rocks that closely resemble each other. Chemically, limestone is primarily calcium carbonate and dolomite is primarily calcium-magnesium carbonate. These carbonate rocks can be easily distinguished by means of the acid test; limestone effervesces rapidly in cold dilute hydrochloric acid whereas dolomite is visibly less active in the same acid.

Limestone and dolomite commonly contain open joints through which ground water may move (fig. 12). Where such joints are lacking, most limestone and some dolomite is relatively impermeable. Although limestone and dolomite are nearly insoluble in pure water, ground water contains carbon dioxide and so is capable of dissolving these rocks and enlarging the joints to form channels and caverns through which water may move freely. Where these solution caverns are close to the surface, sinkholes may be formed by the collapse of the cavern roofs. These sinkholes may become important points of recharge to the carbonate aquifer.

The yield from wells that penetrate carbonate rocks depends on the number, size, and extent of openings in the rocks; the greater the number and size of the openings encountered by a well, the greater will be the yield. However, because the openings in carbonate rocks are irregular in distribution, it follows that the yield from wells that penetrate these rocks varies widely and irregularly. Not only do yields vary widely in wells finished in the same carbonate formation in different areas, but also in different carbonate formations in the same area. In fact, it is not unusual to find dry holes only a few tens of feet from a producing well.

Limestone seems to have significantly less intergranular porosity than dolomite. Although the porosity may not be great enough to permit rapid movement of water, the porous zones probably are more susceptible to solution and the formation of channels through which water can move freely. Hence, the dolomite formations generally are more productive aquifers than the limestone formations.

Because limestone and dolomite are soluble in acid, the production of wells drilled into fractured water-bearing limestone or dolomite can often be greatly increased by introducing hydrochloric acid into the well to enlarge the crevices and clean out residual clays that may be present in the crevices. A well drilled for the U. S. Fish Hatchery near Manchester, south of Clayton County line, obtained water from solution openings in dolomite of Silurian age. This well had been pumped at the rate of 170 gpm with a drawdown of water level of 108 feet. The well was acidized and then pumped at the rate of 315 gpm with a drawdown of water level of 95 feet.

An estimated 80 percent of the farm wells and the municipal wells at Edgewood, Luana, Strawberry Point, and Volga obtain water from the carbonate rocks in Clayton County (table 6).

### Shale

Rock consisting of clay minerals or a mixture of clay and silt in consolidated, bedded form is called shale. This type of rock, like silt and clay, has a high porosity and can hold large quantities of water, but because of its low permeability yields little water to wells. However, water moves through shale along joints or bedding planes where these are well developed and particularly where the shale is weathered. Although generally a poor aquifer, shale is important in the ground-water reservoir because it forms the confining bed for artesian aquifers in the consolidated rocks. Shale tends to slump and yield objectionable sediment to water pumped from wells, therefore the shale sections in most wells are cased off.

Most of the springs of Clayton County are located at or just above the contact of carbonate rocks lying upon shale. In the southern and southwestern part of the county, hundreds of springs and seeps flow from the contact between the Brainard shale member of the Maquoketa shale and Edgewood limestone.

## GROUND-WATER RECHARGE

Recharge of ground water comprises the processes by which water is absorbed and added to the zone of saturation (Meinzer, 1923a, p. 46). The three main processes involved in recharge are the infiltration of local precipitation, seepage, and subsurface inflow. Of these processes, the infiltration of local precipitation is the most important in the recharge of the shallow aquifers in Clayton County.

A large part of precipitation that reaches the ground runs off directly to the streams, but some of the water enters the ground, and under favorable conditions reaches the zone of saturation. The quantity of water that will enter the ground is governed by the quantity and intensity of rainfall, the infiltration capacity of the soil, the local topography, the amount and type of vegetation, and the rate of evaporation. Other than the topography, these factors are all variables and make an extremely complex problem (see Wisler and Brater, 1949, p. 32-38, 175-185). However, the qualitative relation between quantity and intensity of precipitation and the amount of recharge is illustrated in figure 11. The hydrograph shows that a rainfall of 5.4 inches on July 26, 1953 caused a rise in water level of about 1 foot, whereas a rainfall of 2.5 inches during the interval of August 2-4 caused a rise in water level of 2.9 feet. This comparison indicates that an intensive rain of short duration results in less ground-water recharge than a more gentle rain of longer duration.

When conditions are favorable for recharge, the shallow dug wells in the area of the Iowan drift show an almost immediate response to local precipitation (fig. 11). Some of the consolidated rock aquifers, such as the Galena dolomite, also are recharged largely by infiltrating local precipitation; but in some places, the rise in water level is delayed by the distance the water must travel to reach the aquifer. Recharge to the Galena dolomite takes place mainly on the highlands between the stream valleys, where surface runoff is much slower.

Recharge by seepage from surface waters is dependent largely on local precipitation although the effects are delayed. Streams and bodies of ponded water whose water surface is above that of the adjacent water table commonly lose water to the zone of saturation; these are known as influent streams and ponds. Some of the intermittent streams in Clayton County lie above the zone of saturation and water may seep downward to the water table in those reaches where the stream bed consists of permeable materials. Seepage from undrained depressions on the Iowan drift in the southwestern corner of the county recharge the drift aquifer. A special type of large-scale seepage occurs in northwestern Clayton County, where sinkholes occur in the limestone terrain. During periods of heavy precipitation, much runoff accumulates in these sinkholes and seeps to the water table.

Some of the recharge to the St. Peter sandstone in Clayton County is in the form of seepage, although different from that described above. In the areas between the major streams, where erosion has not dissected the Galena dolomite, the hydraulic head of the water in the Galena dolomite is greater than that of the water in the St. Peter sandstone and there is movement of water downward to the St. Peter. The Galena dolomite in the interstream areas is recharged in the same way. Recharge to the Galena dolomite and St. Peter sandstone are discussed in more detail under the section, "Geological Formations and their Water-bearing Characteristics." The aquifer of Silurian age is undoubtedly recharged to some extent by seepage from the glacial-drift aquifer.

Subsurface inflow comes from initial recharge to the aquifer by precipitation outside the county and subsequent down-gradient inflow into the county. This water may move long distances and be in storage for many years before being drawn from wells in Clayton County. The Jordan sandstone and the underlying formations are recharged mainly by subsurface inflow, but some of the overlying formations (figs. 19 and 21) are also recharged to some degree by inflow from outside the county.

## GROUND-WATER DISCHARGE

### Natural Discharge

Although recharge to the aquifers in Clayton County is more-or-less continuous, the amount of water in storage within the aquifer is kept within relatively narrow limits by discharge through springs and seeps, subsurface outflow, transpiration and evaporation, and artificial discharge. The major ground-water discharge in Clayton County is from springs and seeps and subsurface outflow.

*Springs and Seeps.* Springs and seeps are the major form of discharge from the aquifers overlying the St. Peter sandstone. A few hundred springs flow from the Galena dolomite, Maquoketa shale, and Edgewood limestone; a lesser number flow from the Platteville limestone, Decorah shale, Kankakee limestone, and Hopkinton dolomite. A special effort was made to locate and inventory all the major springs in the county. These larger springs and some typical smaller ones are shown on plate 2. The geologic occurrence, discharge data, and water use of the selected springs are presented in table 5. Chemical analyses of the water from 10 springs are given in table 4; 8 of these analyses are graphically illustrated in figure 13.

Springs are most common on hillsides along the contact of the Edgewood limestone with the Brainard shale member of the Maquoketa shale and along or close to the contact of the Galena dolomite with the Decorah shale. Most of these springs flow at a rate of a few gallons a minute or less. However, at least 10 springs flow at rates exceeding 100 gpm and one spring (94-5-31R1S) flows at an average rate of 5,000 gpm. A large number of springs flow also from the Maquoketa shale, particularly along the contacts of the carbonate members with the shale members.

The flows of these springs are substantially less than those from the Edgewood limestone and Galena dolomite, ranging from less than 1 gpm to 25 gpm. A lesser number of springs discharge from the Hopkinton dolomite, Kankakee limestone, Platteville limestone, and Decorah shale. The rate of flow from these springs is small, although one spring from the Hopkinton dolomite flows at a rate of 50 gpm.

The amount of discharge that will occur is governed by the amount of ground water in storage. During periods of greater recharge, discharge is greatly increased; but even during periods of little recharge, discharge continues, although at progressively decreasing rates. During 1951, when the original fieldwork for this paper was done, spring lines were especially well developed because the rainfall during the period was greater than during any similar period in the last half century (fig. 5). Big Spring (94-5-31R1S), which has an average flow of 5,000 gpm, flows at a rate of 10,000 gpm for a short time immediately following periods of heavy rains. Similarly, the flows of the other springs in the county fluctuate in response to variations in the amount of precipitation. Thus, many measurements of spring flows over a period of years are necessary in order to determine a valid average flow for each spring. Because the springs in table 5 were measured once only, it is impossible to calculate the exact amount of ground-water discharged by the springs in the county. However, the flow measurements can be used to approximate the order of magnitude of the total spring discharge. The total amount of water discharged by the springs shown in table 5 is about 7,500 gpm. The combined discharge from the numerous small springs in the county that were not measured probably is on the order of 400 to 500 gpm. Thus the total discharge approximates 8,000 gpm, or about 11.5 mgd. Because most of the flow measurements were made during a period of above average precipitation, the average discharge from springs in Clayton County probably is somewhat less than 11 mgd. However, the average discharge cannot be too much less than 11 mgd, because the average flow of Big Spring, which comprises about two-thirds of the total spring discharge, was used in the calculations. Thus, an estimated 11 mgd is discharged by the springs in Clayton County during periods of average to above average precipitation.

Most of the larger and several of the smaller springs in Clayton County are utilized (table 5). Big Spring (94-5-31R1S) supplies water for a private fish hatchery, and spring 93-3-2R1S is used as the water supply for the village of Clayton. Spring 92-5-9L1S formerly supplied water for a small creamery, and spring 91-6-10C1S formerly supplied both water and power for a brewery and a feed mill. Both of these springs are used for stock supplies at the present time. The remainder of the springs that are utilized in the county provide water for stock supplies.

Seeps, or places where ground water moves to the surface slowly over a large area and not in a restricted channel as at a spring, are relatively inconspicuous. However, they are subject to the same controlling factors as springs. Seeps are common in the southwestern part of Clayton County along the contact of the Iowan drift with the Kansan drift. Ground water is discharged from the Silurian formations, Galena dolomite, and St. Peter sandstone in Clayton County by direct seepage into the streams that dissect the aquifers. Some discharge from the St. Peter sandstone is by indirect seepage up through the Platteville limestone and Decorah shale in the lower reach of the Turkey River.

Springs and seeps from the formations overlying the St. Peter sandstone furnish the water that makes up the base flow of the Turkey River. The base flow of a stream is the flow that is derived entirely from ground-water discharge. During protracted periods of no precipitation, not only is there no overland runoff, but also no ground-water recharge. Hence, the regional water table continually lowers, which results in a continually diminishing ground-water discharge; and consequently, a continually diminishing base flow. Therefore, the depletion of base flow of a stream is in reality the depletion of ground water that discharges into that stream.

A base-flow depletion curve of a stream can be constructed by analyzing long-term stream flow records (Wisler and Brater, p. 24). Such a curve for the Turkey River has been constructed and plotted on figure 3. Although this depletion curve is applicable for any period of time, it has been arbitrarily appended to the hydrograph shown in figure 3 in order to illustrate its application. The depletion curve indicates the amount of ground water that would have been discharged into the Turkey River at any time between mid-May through September of 1951, if no precipitation had occurred during this period. Because it did rain during this period, ground-water discharge was maintained well above the limiting values set by the depletion curve.

During a period of above-average precipitation, such as 1951, the regional water table is high and ground-water discharge is initially high and remains fairly high; i.e, the initial value of base flow falls along the upper part of the depletion curve (fig. 3). During periods of below-average precipitation, the initial base-flow value will fall along the lower part of the curve. Thus, the depletion curve indicates that during periods of average to above average precipitation several hundred cubic feet per second of ground water is discharged from the ground-water reservoir into the Turkey River system above the town of Garber. Moreover, the curve indicates that during prolonged periods of no precipitation ground-water discharge would be maintained at above 50 cfs (about 33 mgd) for several months. This postulation was verified during the prolonged drouth of the 1930's, when the flow of the Turkey River at Garber did not fall below 55 cfs (35 mgd), which is the lowest average daily flow (during non-ice interference periods) on record (Crawford, 1942, p. 40).

Not all of the ground-water discharge to the Turkey River originates from the aquifers in Clayton County, because the Turkey and Volga Rivers drain a large area outside the county. (The total drainage area of Turkey River is 1,684 square miles, but the drainage area in Clayton County only is about 630 square miles.) Because not all the streams in the headwater area are incised on bedrock, and because, where the streams do flow on bedrock, the aquifers are not incised as deeply as they are in Clayton County, at least one third of the base flow of the Turkey River is believed to originate in Clayton County. Thus, a reasonable estimate of the ground water discharged by seepage and spring flow from the aquifers overlying the St. Peter sandstone in Clayton County is at least 10-15 mgd during periods of drouth and several times this amount during periods of near-normal precipitation. Most of this discharge presumably is from the Galena dolomite.

*Subsurface Outflow.* Subsurface outflow is the major form of discharge from the aquifers underlying the St. Peter sandstone. Not enough data are available to determine the direction of flow, but water levels in the several wells finished in the Jordan sandstone indicate that the water in the Jordan sandstone moves in an easterly direction in the eastern part of the county. Presumably a ground-water divide exists somewhere in the county, because water levels in wells to the west and south of Clayton County indicate that the water in the Jordan sandstone in this region moves in a southwesterly direction. Part of the discharge from the St. Peter sandstone is believed to be by subsurface outflow toward the west and southwest.

*Transpiration.* Transpiration is the process whereby water is taken up by plants from the soil and rock materials and discharged to the atmosphere. For the most part, transpiration depletes soil moisture, but locally plant roots take water directly from the capillary zone or the water table. The rate of transpiration is dependent upon temperature, sunlight, available moisture, relative humidity, and air movement as well as type and stage of plant growth. Thus, transpiration is virtually restricted to daylight hours.

Few of the plant types in Clayton County take water from the zone of saturation, but by withdrawing soil moisture plants prevent or greatly reduce movement of water to the water table. Moreover, where the capillary fringe extends upward into the soil, withdrawal of water from the soil may cause upward movement of water from the water table. Plants that depend on ground water for their water supply are known as phreatophytes. Alfalfa, which is a common crop in Clayton County, is a phreatophyte in that its roots may extend to and extract water directly from the zone of saturation. Meinzer (1927, p. 54) cites reports of the roots of older alfalfa plants being traced to depths of 65 feet. In Clayton County, however, ground-water discharge by phreatophytes is probably important only in the Iowan drift area where the water table is high.

The depletion of soil moisture by the transpiration of field crops in the county, however, is important because it greatly reduces potential recharge to the ground-water reservoir. The following figures (Wisler and Brater, 1949, p. 166) show the amount of water used per acre during a growing season by several different crops.

| | |
|---|---|
| Corn | 263,520-408,000 gallons of water per acre |
| Alfalfa | 148,000-374,000 gallons of water per acre |
| Wheat | 211,800-329,400 gallons of water per acre |
| Oats | 207,000-375,600 gallons of water per acre |

Although the rate and amount of transpiration varies considerably, even the lower values given here show that plants discharge a tremendous amount of water to the atmosphere. In fact, this loss by transpiration has a significant effect on recharge to the ground-water reservoir. As an average of about 22 inches, or 600,000 gallons per acre, of precipitation falls during the growing season, about one-half of the potential recharge to the water-table by local precipitation is lost by transpiration.

*Evaporation.* Except in clay soils where deep cracks form upon drying and permit evaporation from a considerable depth, ground-water discharge by evaporation occurs only where the water table is at, or very near, the land surface. Because the depth to the water table in most parts of the county is greater than the depth to which evaporation is effective, evaporation is a significant factor in ground-water discharge only in the bottomlands of Clayton County.

### Artificial Discharge

In Clayton County artificial discharge, such as occurs where water flows or is pumped from wells or where fields have been artificially drained, is considerably less than that from springs and seeps. Locally, however, heavy withdrawals of ground water may exceed the recharge and thus cause a progressive lowering of the water table. Such a change in the ratio of discharge to recharge disrupts the previously established equilibrium, and ground water is taken from storage. Equilibrium will be reestablished only if recharge and discharge are again brought into balance. A new balance may result if the steepened hydraulic gradient induces greater recharge or the lowered water table decreases the natural discharge.

Artificial discharge also occurs where fields have been artifcially drained. Draining fields by tiling is limited mainly to the poorly drained southwestern area covered by Iowan till. Tiling speeds the discharge of soil water, and possibly ground water during wet seasons, but probably much of the water would have been discharged by natural means at a later time. The actual relation between tiling and ground-water storage in Clayton County is not understood fully, but the effect is considered to be minor. Elsewhere in Iowa, tiles are most effective in the spring after the soil thaws and before vegetation develops, and this coincides with highest yearly water levels in shallow wells. Thus, tiling seems in large part to remove water that would be rejected by already full ground-water reservoirs or would soon be discharged naturally because of the high stages.

## RECOVERY OF GROUND WATER

### Construction of Wells

Several types of wells have ben used in Clayton County, including dug, driven, and drilled wells. Dug wells were more common in earlier days, but the principal type now in use is the drilled well.

Most of the existing dug wells are in the area underlain by Iowan till. They are commonly shallow, approximately 3 feet in diameter, and constructed almost entirely in soft, unconsolidated material. A dug well is practical only where the water table is near the surface, and the depth of the well generally is limited by the depth to the first water-bearing bed. Most of the wells are cased with native rock, but some are cased with brick or concrete block. In many places in Clayton County, wells have been dug to bedrock and later drilled into bedrock, because of the need for a greater water supply and the savings in drilling and casing costs.

Drive-point wells are used in eastern Clayton County along the flood plains and terraces of the Mississippi, the Turkey, and Volga Rivers, where water-bearing sands and gravels occur at depths of 10 and 25 feet. The drive-point, sometimes referred to as a sand-point, consists of a pipe with a pointed screen that can be driven into the ground. The screen must be reinforced to withstand the driving force. Drive-point wells are satisfactory where water-bearing sand and gravel occur at shallow depth, and the water level is within 25 feet of the land surface. This type of well is generally fitted with a suction pump; the working cylinder and piston may be at the top as in a pitcher pump, or the cylinder may be placed below ground in a pit to permit drawing water from a depth greater than 25 feet. In selecting slot openings for drive points, it is desirable to have the openings large enough to pass at least 50 percent of the finer sand initially in order that the coarser sand and gravel will collect around the point. The major advantages of this method of well construction are the ease and economy of installation.

Drilled wells are by far the most common type of well used in Clayton County, and more than 90 percent of the wells canvassed were of this type. The type of drilling machine in common use in this county is the portable cable-tool, or percussion, type drilling rig, which is particularly adapted for drilling in both unconsolidated and consolidated rock. A cable-tool rig consists of a mast or A-frame, drawworks, cable, drilling tools, bailer, and power unit. A walking beam alternately lifts and drops the bit, causing it to break or crush the rock at the bottom of the hole. The crushed rock is removed by a bailer. Blank casing is installed to prevent the caving of unconsolidated material into the well and perforated casing or a well screen is installed opposite the water-bearing material if it tends to cave. Wells drilled into bedrock are also cased where shale or soft limestone tends to slump into the well or to add objectionable sediments to the water. The Maquoketa shale, Decorah shale, and Platteville limestone commonly are cased off.

The starting diameter of a cable-tool well is determined by the number of shale beds that must be cased off and the quantity of water to be pumped. The yield of a well is not directly proportional to the diameter of the well, but with larger diameters it is possible to install pumps having a larger capacity. Most of the farm wells are 5 to 6 inches in diameter, whereas municipal and industrial wells are 6 to 20 inches in diameter at the surface (table 6).

### Methods of Lift and Types of Pumps

In the past, the predominant type of pump in use for domestic and stock water supplies was the lift, or cylinder pump operated by windmill, and later powered by gasoline or electric pump jack. Now, electrically powered jet pumps and submersible turbine pumps are being installed in many new wells. A few of the shallow lift pumps are operated by hand. Where larger quantities of water are needed, as for municipal and creamery supplies, turbine and submersible pumps powered by electric motors are used.

## QUALITY OF GROUND WATER

Information on the chemical characteristics of water supplies is necessary in planning the location of some industries and for the economical and satisfactory treatment of water for domestic and municipal supplies. If the chemical properties of waters are known, the most suitable equipment for water treatment and accurate cost analyses can be included in the plans of a water plant. Moreover, knowledge of the stratigraphic distribution of the chemical constituents in the ground-water reservoir facilitates the planning and installation of properly constructed wells, which will prevent interaquifer contamination.

The chemical character of ground water commonly differs not only from aquifer to aquifer, but also from place to place within an aquifer. Information on the vertical and horizontal distribution of various types of water factilitates the prediction of the chemical character of the water that will be derived from a given aquifer at a particular place. Moreover, it may prevent costly drilling where the desired quality of water does not occur at a reasonable depth.

The minerals and gases present in ground water are those which were taken up by the water as it passed first through the air and then through the various layers of soil and rock before reaching the point of withdrawal or discharge. Differences in the amount of minerals and gases dissolved or suspended in the water are governed by the chemical composition of the rock material through which the water moved, temperature, pressure, reactions between the water and rock material, and the length of time that the water was in contact with these various materials.

The general mineral characteristics of water from 41 different wells and 10 springs in Clayton County are tabulated in table 4. These water samples are considered to be representative of water from each of the water-bearing formations in the county. The analytical determinations were made in the Water Laboratory of the State Department of Health at Iowa City, Iowa.

### Chemical Constituents and Physical Properties in Relation to Use

Mineral substances in large amounts are objectionable in any water, and some constituents are undesirable even in small amounts. Mineral constituents commonly found dissolved in ground water and some data on their source and significance to the user of the water are summarized in table 3. Of these the dominant ionic constituents are calcium, magnesium, sodium, potassium, bicarbonate, sulfate, and chloride. Calcium, magnesium, sodium, and potassium are positive ions called cations. Bicarbonate, sulfate, and chloride are negative ions called anions. In water analyses these constituents are generally determined as parts per million cations and anions.

In order to express the ionic balance of a water sample, the quantities of constituents are expressed in equivalents per million as in figure 13. These are obtained by dividing the parts per million by the combining weight of the constituents. Parts per million may be converted to grains per gallon by dividing the values by 17.12.

*Dissolved solids.* Theoretically, dissolved solids are considered to be the anhydrous residues of the dissolved substances in water. However, they are not a measure of the total weight of dissolved material as they occur in solution. For example, in the determination a sample is evaporated to dryness at a temperature that converts bicarbonate to carbonate. Water containing less than 500 ppm of dissolved solids generally is satisfactory for domestic

## TABLE 3. CHEMICAL CONSTITUENTS COMMONLY FOUND IN GROUND WATER

| Constituent | Source or cause | Effect on usability of water |
|---|---|---|
| Silica ($SiO_2$)............ | Practically all rocks and soils. Usually in small amounts up to about 25 ppm. In alkaline water, up to 100 ppm may be found. | Forms hard scale in pipes and boilers. Carried over in steam of high-pressure boilers to form deposits on blades of steam turbines. |
| Iron (Fe).............. | The common iron-bearing minerals present in nearly all formations. Usually less than 1 ppm in alkaline surface water. Higher amounts occur in acid waters from mine drainage or other sources. | Objectionable for food and beverage processing. More than 0.3 ppm iron causes brown stains on porcelain and fabrics. |
| Manganese (Mn)........ | Manganese-bearing minerals. Usually less than 1 ppm in alkaline surface waters. Large quantities often associated with high iron content and with acid waters. | Same objectionable features as iron. Federal drinking water standards state that iron and manganese together should not exceed 0.3 ppm. |
| Calcium (Ca) and Magnesium (Mg)....... | Practically all rocks and soils, but especially from limestone, dolomite, gypsum, and gypsiferous shale. | Cause most of the hardness and scale-forming properties of water. Comsume much soap. Removed by water-softening processes. |
| Sodium (Na) and Potassium (K).......... | Ancient brines, sea water, industrial brines, and sewage. Also dissolved from feldspar, clay and other common minerals. | Gives salty taste to water when present in large amounts with chloride. Sodium salts may cause foaming in steam boilers. |
| Bicarbonate ($HCO_3$) and Carbonate ($CO_3$).... | Action of carbon dioxide in water on carbonate minerals. | Bicarbonate and carbonate produce alkalinity. Bicarbonates of calcium and magnesium decompose in boiling water with formation of scale and release of carbon dioxide gas. |
| Sulfate ($SO_4$)........... | Rocks and soils containing iron sulfide, gypsum, and other sulfate minerals. Common in industrial wastes and in waters from coal mining operations. | Sulfate in water containing calcium forms hard scale in steam boilers. In larger amounts, sulfate in combination with other ions may gve a bitter taste to water. Federal drinking water standards recommend that sulfate content should not exceed 250 ppm. |
| Chloride (Cl)........... | Small to large amounts in all soils and rocks, natural and artificial brines, and sea water. | Large amounts in combination with sodium give a salty taste to water. Objectionable in some industrial uses. Federal drinking water standards recommend that the chloride content should not exceed 250 ppm. |
| Fluoride (F)............ | Various minerals of widespread occurrence. Present in brines from oil wells and in industrial wastes from processing of insecticides, disinfectants, and preservatives. | Fluoride in drinking water reduces the incidence of tooth decay when the water is consumed during the period of calcification of enamel. However, it may cause mottling of the teeth, depending on the concentration of the fluoride, the age of the child, and the amount of drinking water consumed. (Maier, 1950) |
| Nitrate ($NO_3$).......... | Decayed organic matter, sewage, and nitrate in the soil. | High values of nitrate may suggest organic pollution. Waters of high nitrate content should not be used for baby feeding. (Maxey, 1950) |

and most industrial purposes, except for local difficulties resulting from the hardness or exceptional concentrations of minor constituents such as iron or manganese. Water containing as much as 1,000 ppm of dissolved solids is acceptable for domestic purposes if no better water is available (U. S. Public Health Service, 1946).

On the basis of 48 samples collected from various untreated municipal, domestic, and industrial ground-water supplies, the

## TABLE 4. CHEMICAL ANALYSES OF GROUND

Dissolved constituents and hardness given in parts per million.

Well and spring numbers indicate location; numbering system described in figure 2. Locations plotted on plate 2.

| Well or spring number | Owner | Depth (feet) | Principal water-bearing unit | Date of collection | Temperature (°F) |
|---|---|---|---|---|---|
| 90-5-2C1 | Edgewood City Well 4 | 269 | Formations of Silurian age | 8-16-52 | 51 |
| 91-2-16A1 | Millville Creamery | 130 | St. Peter sandstone | 8-22-51 | 54 |
| 91-2-28L1 | Rae Anderegg | 565 | Galena dolomite | 4-29-59 | ...... |
| 91-3-2A1 | H. Willman Store | 28 | Recent alluvium | 2- 3-54 | ...... |
| 91-5-30R1 | Carl Kramer | 162 | Formations of Silurian age | 11- 2-51 | ...... |
| 91-5-35N1 | Edgewood City Well 3 | 248 | do | 8- 6-52 | 51 |
| 91-6-10C1S | Carl Kleinlein | Spring | do | 7-23-51 | 49 |
| 91-6-19P1S | John Lee | do | do | 7-28-51 | 49 |
| 91-6-22C1 | Strawberry Point Creamery 1 | 165 | do | 11- 2-51 | ...... |
| 91-6-22C3 | Strawberry Point Creamery 3 | 215 | do | 5-20-54 | 54 |
| 91-6-22D1 | Elmer Baldridge | 12 | Glacial drift | 2- 1-54 | 48 |
| 91-6-22G1 | Strawberry Point City Well 1 | 160 | Formations of Silurian age | 9-19-34 | ...... |
| 92-2-5R1 | Charles Cain | 30 | Recent alluvium | 8-14-52 | 53 |
| 92-2-17H1 | Guttenberg City Well | 26 | do | 8-26-37 | 54 |
| 92-2-17L1 | Guttenberg City Well 2 | 435 | Jordan sandstone | 8-22-51 | 51 |
| | | | | 9- 4-51[1] | ...... |
| 92-2-17L2 | Guttenberg City Well 1 | 450 | do | 8-25-37 | 52 |
| 92-5-9L1S | George Stahl | Spring | Galena dolomite | 7-25-51 | 50 |
| 92-5-17A1 | Elizabeth Debes | 30 | Recent alluvium | 2- 3-54 | 45 |
| 92-6-3N1 | Volga Town Well | 225 | Galena dolomite | 5-25-59 | 51 |
| 92-6-10C1 | F. G. Cummings | 18 | Recent alluvium | 2- 3-54 | 49 |
| 92-6-14G1S | Stanley Sargent | Spring | Maquoketa shale | 7-24-51 | 52 |
| 93-2-7G1S | Concrete Materials and Construction Div | do | Platteville limestone | 7-23-54 | 54 |
| 93-3-2R1S | City of Clayton | do | Galena dolomite | 2- 4-54 | 54 |
| 93-3-18J1 | Garnavillo City Well | 385 | St. Peter sandstone | 7-18-51 | ...... |
| 93-3-18K1 | Garnavillo City Well | 365 | do | 9-14-34 | ...... |
| 93-4-7A1 | Clayton County Home | 780 | Jordan sandstone | 10-17-44 | 52 |
| 93-4-16B1 | Hugo Kalke | 152 | Galena dolomite | 4-30-59 | ...... |
| 93-5-2R1 | John Hagensick | 96 | do | 5- 1-59 | ...... |
| 93-5-23E1 | Elkader City Well 3 | 515 | Jordan sandstone | 7-19-51 | 52 |
| 93-5-23E2 | Elkader City Well 2 | 432 | St. Peter sandstone | 9-15-34 | ...... |
| 93-6-20H2 | Melvin Gregerson | 158 | Formations of Silurian age | 9- 4-51 | 51 |
| 94-4-18F1 | Farmersburg City Well | 705 | Jordan sandstone | 5-19-54 | 51 |
| 94-5-25M1 | St. Olaf Town Well 1 | 330 | St. Peter sandstone | 8-29-51 | 50 |
| 94-5-26H1 | St. Olaf Town Well 2 | 378 | do | 1- 4-52 | 51 |
| 94-5-31R1S | Ray Ehlers—Big Spring | Spring | Galena dolomite | 9- 4-51 | 47 |
| 94-6-21F1S | Emil Maur | do | Maquoketa shale | 9- 6-51 | 57 |
| 95-3-15K1 | Marquette City Well 2 | 442 | Dresbach group | 8-22-51 | ...... |
| 95-3-15K2 | Marquette City Well 1 | 585 | do | 9-23-50 | 52 |
| 95-3-16L1 | Marquette Stockyard Well | 450 | do | 9-23-50 | 52 |
| 95-3-22Q1 | McGregor City Well 2 | 1,006 | do | 1-18-40 | 52 |
| | | | | 5-10-51[2] | 52 |
| 95-3-22Q2 | McGregor City Well 4 | 502 | do | 10-14-45 | 53 |
| 95-3-22R1 | McGregor City Well 5 | 645 | do | 5- 6-49 | 52 |
| 95-3-22R1 | McGregor City Well 5 | 481[3] | Dresbach group | 12- 8-49 | 52 |
| | | | | 9-22-50 | 52 |
| | | | | 9-22-50[4] | 52 |
| 95-3-22R1 | McGregor City Well 5 | 479[5] | do | 5-27-51 | 51 |
| | | | | 7-18-51 | 52 |
| | | | | 8- 6-52 | 52 |
| | | | | 2- 2-54 | 52 |
| | | | | 4- 5-55 | 52 |
| 95-3-22R2 | McGregor City Well 6 | 116 | St. Lawrence formation | 2- 2-54 | 50 |
| | | | | 4- 5-55 | 50 |
| 95-3-35P1 | Pikes Peak State Park | 630 | Jordan sandstone | 7-21-37 | 54 |
| 95-4-15M1S | F. V. Lestina | Spring | Galena dolomite | 8-18-38 | 49 |
| 95-4-21A1S | Ben Lestina | Spring | Galena dolomite | 7-24-51 | 49 |
| 95-4-31D1 | W. H. Johanningmeier | 335 | St. Peter sandstone | 8-23-51 | 50 |
| 95-5-5R1 | Luana City Well | 339 | Galena dolomite | 2- 2-54 | ...... |
| 95-5-11K1 | Monona City Well 1 | 815 | Jordan sandstone | 7-18-51 | 52 |
| 95-5-11K2 | Monona City Well 2 | 814 | do | 3-24-37 | 52 |
| 96-6-32L1 | Postville Packing Company | 930 | do | 8-22-51 | 50 |

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[1] Water treated by Guttenberg Municipal softening system.

[2] Sample collected through a 2-inch discharge pipe from a depth of 1,004 feet.

[3] Well plugged back to 481 feet on October 3, 1949.

[4] Sample collected through a garden hose from a depth of 470 feet.

[5] Well plugged back to 479 feet on May 26, 1951.

## WATER IN CLAYTON COUNTY, IOWA

**Principal water-bearing unit is given, but some water commonly is derived *also from other formations in the uncased portion of the well.***

**pH: Determination commonly made several days after collection of sample and may not be identical with determination made at the well.**

| Iron (Fe) | Manganese (Mn) | Calcium (Ca) | Magnesium (Mg) | Sodium (Na) and potassium (K) | Bicarbonate (HCO₃) | Sulfate (SO₄) | Chloride (Cl) | Fluoride (F) | Nitrate (NO₃) | Dissolved solids | pH | Hardness (as CaCO₃) | | | Specific conductance (micromhos at 25°C) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | Total | Carbonate | Non-carbonate | |
| 0.96 | 0 | 72 | 22 | 7.5 | 283 | 10 | 2.0 | .3 | 0.0 | 288 | 8.0 | 270 | 252 | 18 | 470 |
| .0 | .0 | 97 | 49 | 9.1 | 454 | 60 | 5.5 | .1 | .4 | 493 | 7.9 | 444 | 372 | 72 | 717 |
| .08 | ...... | 79 | 38 | 6.9 | 398 | 40 | 2.0 | .2 | 1.3 | 392 | 7.5 | 354 | 326 | 28 | 650 |
| .02 | .0 | 126 | 35 | 9.5 | 495 | 26 | 9.0 | .1 | 16 | 492 | 7.3 | 459 | 406 | 53 | 695 |
| 4.8 | .0 | 76 | 22 | 13 | 350 | 14 | 2.0 | .3 | .0 | 317 | 7.8 | 280 | 280 | 0 | 546 |
| .48 | .0 | 75 | 24 | 7.3 | 322 | 19 | 5.0 | .3 | .0 | 311 | 7.8 | 286 | 264 | 22 | 444 |
| .0 | .0 | 36 | 16 | 5.8 | 164 | 21 | 4.0 | .2 | 8.0 | 218 | 7.6 | 156 | 134 | 22 | 317 |
| .06 | .0 | 44 | 23 | 9.7 | 210 | 14 | 5.0 | .1 | 24 | 257 | 7.6 | 204 | 172 | 32 | 375 |
| .0 | .0 | 63 | 22 | 11 | 278 | 26 | 6.0 | .2 | 4.0 | 278 | 7.8 | 248 | 228 | 20 | 502 |
| .0 | .2 | 56 | 28 | 6.2 | 271 | 21 | 7.0 | .1 | 5.3 | 319 | 7.9 | 255 | 222 | 33 | 403 |
| .20 | .0 | 73 | 16 | 18 | 200 | 64 | 8.0 | .1 | 37 | 299 | 8.0 | 248 | 164 | 84 | 453 |
| .0 | .0 | 58 | 21 | 8.7 | 278 | 14 | 3.0 | .0 | .8 | 247 | 7.4 | 231 | 228 | 3 | ...... |
| 16 | 1.2 | 76 | 22 | 4.3 | 286 | 31 | 3.0 | .3 | .0 | 427 | 7.8 | 280 | 234 | 46 | 428 |
| .0 | .1 | 76 | 23 | 20 | 276 | 45 | 27 | .0 | 44 | 431 | 7.3 | 284 | 226 | 58 | ...... |
| .0 | .0 | 70 | 35 | 18 | 368 | 35 | 19 | .1 | .31 | 377 | 7.9 | 319 | 302 | 17 | 598 |
| .0 | .0 | 6.5 | 16 | 23 | 32 | 38 | 18 | .1 | 2.2 | 128 | 9.7 | 82 | 58 | 24 | 236 |
| 1.2 | .2 | 91 | 34 | 10 | 392 | 31 | 22 | .0 | .44 | 429 | 7.1 | 367 | 321 | 46 | ...... |
| .0 | .0 | 76 | 36 | 8.1 | 364 | 33 | 5.0 | .2 | 5.3 | 395 | 7.3 | 338 | 298 | 40 | 584 |
| .5 | .0 | 73 | 29 | 4.5 | 305 | 30 | 6.0 | .2 | 21 | 284 | 7.8 | 302 | 250 | 52 | 474 |
| .02 | .05 | 67 | 21 | 5.9 | 268 | 41 | 5.0 | .5 | 2.7 | 294 | 7.8 | 254 | 220 | 34 | 480 |
| .02 | .05 | 86 | 28 | 4.8 | 334 | 31 | 4.0 | .1 | 18 | 351 | 7.6 | 330 | 274 | 56 | 521 |
| .0 | .0 | 37 | 13 | 7.8 | 93 | 18 | 8.0 | .2 | 57 | 217 | 7.3 | 146 | 76 | 70 | 308 |
| | | | | | | | | | | | | | | | |
| .0 | .0 | 81 | 44 | 4.8 | 415 | 27 | 1.5 | .1 | .0 | 300 | 7.6 | 383 | 340 | 43 | 680 |
| .02 | .0 | 75 | 38 | 4.6 | 329 | 27 | 7.0 | .1 | 16 | 311 | 8.0 | 344 | 294 | 50 | 521 |
| .0 | .0 | 70 | 29 | 12 | 312 | 29 | 12 | .3 | .0 | 328 | 7.8 | 294 | 256 | 38 | 537 |
| .0 | .0 | 80 | 35 | 10 | 354 | 31 | 38 | .0 | 1.2 | 478 | 7.1 | 344 | 290 | 54 | ...... |
| .6 | .0 | 78 | 35 | 13 | 355 | 40 | 6.5 | .3 | .18 | 329 | 7.4 | 339 | 291 | 48 | ...... |
| .54 | .05 | 87 | 48 | 9.3 | 400 | 47 | 13 | .2 | 31 | 477 | 7.3 | 415 | 328 | 87 | 740 |
| .02 | .05 | 96 | 27 | 6.0 | 366 | 28 | 8.5 | .2 | 35 | 413 | 7.3 | 351 | 300 | 51 | 700 |
| .2 | .0 | 69 | 31 | 12 | 307 | 64 | 5.0 | .5 | .0 | 343 | 7.5 | 301 | 252 | 49 | 563 |
| .3 | .0 | 69 | 32 | 12 | 330 | 61 | 4.0 | .0 | .0 | 340 | 7.3 | 305 | 270 | 35 | ...... |
| .2 | .0 | 74 | 36 | 7.5 | 378 | 31 | 7.0 | .0 | 7.7 | 370 | 7.5 | 333 | 310 | 23 | 579 |
| .10 | .0 | 73 | 30 | 5.8 | 327 | 22 | 2.0 | .2 | 1.8 | 314 | 7.8 | 306 | 268 | 38 | 474 |
| .0 | .0 | 86 | 36 | 14 | 366 | 51 | 22 | .4 | 1.06 | 474 | 7.0 | 363 | 300 | 63 | 644 |
| .22 | .0 | 60 | 27 | 9.1 | 293 | 28 | 1.0 | .5 | .0 | 283 | 7.7 | 261 | 240 | 21 | 462 |
| .1 | .0 | 73 | 31 | 9.7 | 349 | 31 | 6.0 | .1 | 13 | 354 | 7.3 | 310 | 286 | 24 | 565 |
| .05 | .0 | 60 | 35 | 5.2 | 212 | 99 | 2.5 | .3 | 3.1 | 328 | 8.4 | 294 | 198 | 96 | 434 |
| 1.1 | .0 | 70 | 25 | 49 | 305 | 53 | 54 | .1 | .0 | 415 | 7.9 | 278 | 250 | 28 | 661 |
| .1 | .0 | 72 | 30 | 65 | 298 | 64 | 76 | .1 | .0 | 509 | 7.8 | 303 | 244 | 59 | 713 |
| .2 | .0 | 69 | 32 | 44 | 312 | 54 | 51 | .1 | .0 | 424 | 7.9 | 305 | 256 | 49 | 713 |
| 1.5 | .0 | 138 | 59 | 733 | 300 | 475 | 1020 | .8 | .0 | 2,664 | 7.5 | 587 | 246 | 341 | 4,030 |
| 2.1 | .0 | 153 | 68 | 824 | 303 | 564 | 1173 | .7 | .0 | 3,044 | 7.5 | 662 | 248 | 414 | 4,810 |
| .55 | .0 | 103 | 42 | 325 | 321 | 225 | 454 | .7 | .4 | 1,350 | 7.5 | 431 | 263 | 168 | 2,880 |
| .3 | .0 | 117 | 48 | 511 | 300 | 319 | 747 | .7 | .0 | 2,066 | 7.3 | 490 | 246 | 244 | 3,060 |
| .6 | .0 | 102 | 40 | 319 | 317 | 214 | 440 | .6 | 0.0 | 1,335 | 7.5 | 419 | 260 | 159 | 2,260 |
| .3 | .0 | 99 | 44 | 344 | 303 | 240 | 515 | .6 | .0 | 1,449 | 7.6 | 428 | 248 | 180 | 1,743 |
| .8 | .0 | 118 | 50 | 526 | 293 | 325 | 792 | .6 | .0 | 2,003 | 7.5 | 500 | 240 | 260 | 3,120 |
| .5 | .0 | 95 | 39 | 312 | 310 | 224 | 445 | .6 | .0 | 1,297 | 7.7 | 398 | 254 | 144 | 1,820 |
| 1.0 | .03 | 97 | 39 | 312 | 320 | 212 | 439 | .6 | .0 | 1,298 | 7.5 | 403 | 262 | 141 | 2,100 |
| 1.2 | .0 | 90 | 38 | 256 | 310 | 172 | 348 | .7 | .0 | 1,096 | 7.9 | 381 | 254 | 127 | 1,920 |
| 1.6 | .0 | 90 | 37 | 210 | 312 | 160 | 284 | .5 | .0 | 960 | 7.7 | 377 | 256 | 121 | 1,300 |
| 4.8 | .1 | 81 | 34 | 149 | 315 | 123 | 208 | .5 | .0 | 773 | 7.7 | 342 | 258 | 84 | 1,336 |
| .02 | .0 | 84 | 33 | 30 | 339 | 45 | 38 | .1 | 15 | 423 | 7.7 | 345 | 278 | 67 | 613 |
| .04 | .03 | 80 | 33 | 33 | 339 | 44 | 46 | .1 | 2.7 | 428 | 7.5 | 336 | 278 | 58 | 755 |
| .7 | .08 | 87 | 27 | 5.4 | 307 | 54 | 4.0 | .0 | .44 | 369 | 7.1 | 328 | 252 | 76 | ...... |
| .0 | .0 | 76 | 33 | 4.4 | 373 | 12 | 6.0 | .0 | 13 | 354 | 7.1 | 326 | 306 | 20 | ...... |
| .0 | .0 | 74 | 35 | 7.8 | 371 | 14 | 5.0 | .2 | 5.3 | 350 | 7.6 | 329 | 304 | 25 | 569 |
| .2 | .0 | 69 | 30 | 7.1 | 310 | 31 | 5.0 | .0 | 7.3 | 321 | 7.7 | 297 | 254 | 43 | 467 |
| .02 | .0 | 84 | 36 | 6.3 | 334 | 58 | 13 | .3 | .0 | 332 | 7.7 | 358 | 274 | 84 | 548 |
| .0 | .0 | 59 | 27 | 8.1 | 261 | 42 | 4.0 | .2 | .0 | 265 | 7.6 | 258 | 214 | 44 | 462 |
| .4 | .04 | 64 | 19 | 12 | 256 | 40 | 10 | .0 | .2 | 252 | 7.1 | 238 | 210 | 28 | ...... |
| .2 | .0 | 103 | 42 | 18 | 512 | 29 | 4.0 | .5 | .31 | 461 | 7.6 | 431 | 420 | 11 | 738 |

potable ground water in Clayton County ranges from 217 to 509 ppm dissolved solids (table 4). Excluded from this tabulation are water samples from McGregor wells 2, 4, and 5, where the well field was contaminated by highly mineralized water from the Mt. Simon sandstone. Of the 48 samples, 12 contained less than 300 ppm dissolved solids, 22 contained between 300 and 400 ppm, and 14 contained more than 400 ppm.

*Hardness.* Hardness is the property of water attributable to the presence of alkaline earth elements. Calcium and magnesium are the principal alkaline earths in natural waters, although strontium and barium may be present in small quantities. Hardness manifests itself in the amount of soap that is necessary to produce a lather because of the reaction of the soap with calcium and magnesium ions. It is usually expressed in terms of an equivalent amount of calcium carbonate.

The acceptable hardness of water depends upon the intended use of the water. Hardness of water used for ordinary domestic purposes does not become particularly objectionable up to about 100 ppm (Hem, 1959, p. 147). Hardness tolerances of water for industrial uses vary from one industry to another. A range of from less than 10 ppm to several hundred for process waters has been reported by the California State Water Pollution Control Board (1952, p. 267).

The hardness of the potable ground water samples in Clayton County ranges from 146 to 459 ppm; the average hardness is about 300 ppm. Guttenberg is the only town with a municipal water-softening unit; table 4 includes analyses of both the treated and untreated water. Many domestic water softeners are in use in individual homes within the county.

*Specific Conductance.* All aqueous solutions have the ability to conduct electrical currents. The measure of this ability is known as the specific conductance or conductivity of the solution. Specific conductance is the reciprocal of specific resistance and is expressed in mhos (micromhos). It furnishes an approximation of the ionic strength of a solution, within wide limits, although it does not indicate the relative amounts of different constituents.

### Chemical Characteristics of Water in Relation to Stratigraphy

The chemical characteristics of water from aquifers are dependent on the chemical composition of the mineral grains comprising the soils and rock strata, the length of time the water is in contact with the mineral grains, the hydrostatic head relations between aquifers, and the degree to which mineralized water trapped during deposition has been flushed out of the aquifer. A discussion of these factors is beyond the scope of this report. Briefly, however, the following generalities are valid: water from the shallower aquifers is usually less mineralized than water from the deeper aquifers; water from the recharge area of an aquifer is usually less mineralized than water from the discharge area; and, excluding those areas where extensive inter-aquifer movement of water occurs, most aquifers tend to yield a distinctive type of water. Ground water in Clayton County does not deviate greatly from these generalizations (tables 4a and b). The general quality of water from the various aquifers in Clayton County is shown in figures 13 and 14.

The hardness of water from the various aquifers in the county ranges from an average of 270 ppm in the formations of Silurian age to an average of 580 ppm in the lower part of the Dresbach (table 4a). The hardness of water increases with depth, the seemingly aberrant averages for the Jordan and St. Peter sandstones notwithstanding. Most of the analyses of water from the St. Peter sandstone are of water from wells that are located in the recharge area of the aquifer, where the chemical

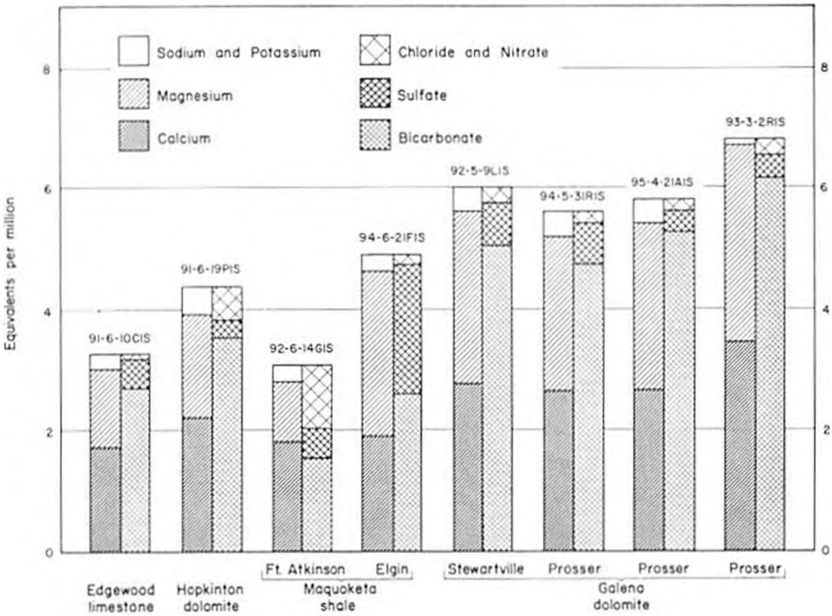

Figure 13.—Graphic representation of analyses of water samples from selected springs.

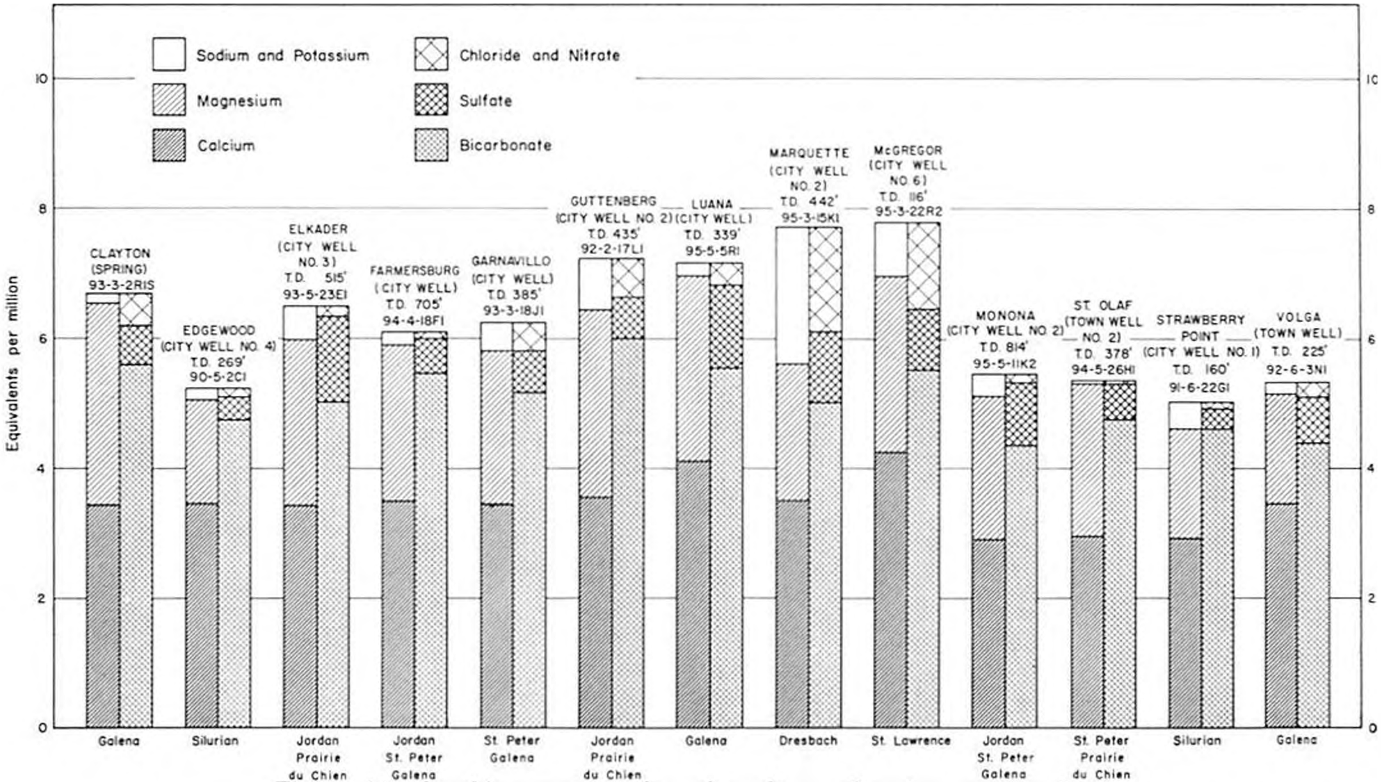

Figure 14.—Graphic representation of analyses of water samples from municipal supplies derived from different aquifers.

**Table 4a.—Range in Hardness, in ppm, of Water From Water-bearing Units in Clayton County**

| Water-bearing unit | Depth (feet) | Number of samples | Hardness of water | | |
|---|---|---|---|---|---|
| | | | Maximum | Minimum | Average |
| Glacial drift and alluvium | <30 | 6 | 459 | 248 | 315 |
| Formations of Silurian age | 158-269 | 7 | 333 | 231 | 270 |
| Galena dolomite | Springs | 5 | 344 | 310 | 330 |
| | 96-565 | 5 | 415 | 251 | 345 |
| St. Peter sandstone | 130-432 | 7 | 441 | 261 | 330 |
| Jordan sandstone[1] | 435-930 | 9 | 431 | 238 | 320 |
| Dresbach group[2] | 442-585 | 3[3] | 305 | 278 | 295 |
| | 645-1006 | 3[3] | 662 | 490 | 580 |

**Table 4b—Range in Dissolved-solids Content, in ppm, of Water from Water-bearing Units in Clayton County**

| Water-bearing unit | Depth (feet) | Number of samples | Dissolved solids content of water | | |
|---|---|---|---|---|---|
| | | | Maximum | Minimum | Average |
| Glacial drift and alluvium | <30 | 6 | 492 | 284 | 380 |
| Formations of Silurian age | 158-269 | 7 | 376 | 247 | 305 |
| Galena dolomite | Springs | 5 | 395 | 311 | 350 |
| | 96-565 | 5 | 477 | 291 | 380 |
| St. Peter sandstone | 130-432 | 7 | 493 | 283 | 390 |
| Jordan sandstone[1] | 435-930 | 9 | 461 | 252 | 350 |
| Dresbach group[2] | 442-585 | 3[3] | 509 | 415 | 450 |
| | 645-1006 | 3[3] | 3044 | 2066 | 2600 |

[1] Some wells are also open to St. Peter sandstone.

[2] All wells are also open to the Jordan sandstone and the St. Lawrence formation.

[3] Analysis of water from McGregor City well 4 and extra analyses of City well 5 not included.

constituents are at a minimum concentration. Thus, the average is weighted more in the direction of the minimum and is not believed to be valid for the aquifer. Water from the Jordan and upper part of the Dresbach in many places is a mixture with water from the overlying aquifers, thus the chemical constituents are certain to be diluted. The increasing hardness with depth is best reflected in the maximum column of table 4a.

The dissolved solids content ranges from an average of 305 ppm in the aquifer of Silurian age to an average of 2,600 ppm in the lower part of the Dresbach (table 4b). Mineralization of the water increases with depth, as reflected in the maximum concentration column of table 4b. The average concentration of dissolved solids is not believed to be representative for the St. Peter and Jordan sandstones, because of the reasons stated in the discussion on hardness of the water.

A major change in water quality occurs between the Galesville and Mt. Simon sandstone of the Dresbach group. The water from the Galesville and younger rocks is of the calcium magnesium bicarbonate type whereas that from the Mt. Simon is of the sodium chloride type. Moreover, the water from the Mt. Simon is much more mineralized than is the water from the younger rocks. Perhaps the connate saline water in the Mt. Simon sandstone was incompletely flushed out by fresh water. Whether this condition exists throughout Clayton County is not known, because the only wells drilled to the Dresbach group in Clayton County are at McGregor and Marquette. However, the water in the Mt. Simon sandstone at Cedar Rapids, Iowa, about 50 miles south-southwest of Clayton County, is known to be highly mineralized.

### Temperature

Information on water temperature is necessary for industries and others that require water for cooling or processing purposes. Increasing use of air-conditioning by business establishments and homes also requires a knowledge of water temperature. The use of ground water for cooling purposes has two particularly great advantages over the use of surface water. Ground water is usually sediment free, therefore settling basins are not required as they are for surface water. More important, ground water has a uniformly low temperature throughout the year, therefore cooling towers are not required. The temperature of ground water from aquifers deeper than 50 feet usually varies no more than a degree or two during the year; whereas the temperature of surface water varies as much as 50° F.

The temperature of ground water in Clayton County ranges from an average of 49°F. in the drift and alluvial aquifers to an average of 52°F. in the Jordan sandstone and the Dresbach group (table 4c). The computation of the average figures is subject to the same limitations and conditions that were discussed in the preceding section. Thus, the average temperature of water from the Jordan and Dresbach sandstones as shown in table 4c, probably is somewhat lower than the actual temperature. Water from the shallow aquifers exhibits seasonal variations in temperature. The minimum temperatures of water from the drift and alluvium and from the springs (table 4c) were recorded during the winter and early spring, whereas the maximum temperatures were recorded during the summer. Normally the average temperature of water from shallow aquifers is about the same as the average annual air temperature of the area. Because the average temperature of the water samples collected from shallow aquifers in

Clayton County is 2 or 3 degrees higher than the average air temperature, it is believed that the discrepancy may be due to the sampling procedure. Many more samples need to be collected before a valid average temperature can be established.

Table 4c—Range in Temperature of Water-bearing Units in Clayton County

| Water-bearing unit | Depth (feet) | Number of samples | Temperature (°F) | | |
|---|---|---|---|---|---|
| | | | Maximum | Minimum | Average |
| Glacial drift and alluvium | <30 | 7 | 54 | 45 | 49 |
| Formations of Silurian age and Galena dolomite | Springs | 7 | 51 | 47 | 49 |
| Formations of Silurian age | 100–269 | 6 | 54 | 51 | 51 |
| St. Peter sandstone | 130–378 | 4 | 54 | 50 | 51 |
| Jordan sandstone[1] | 435–930 | 9 | 51 | 50 | 52 |
| Dresbach group[2] | 442–1006 | 14 | 53 | 51 | 52 |

[1] Some wells are also open to St. Peter sandstone.

[2] All wells are also open to the Jordan sandstone and the St. Lawrence formation.

### Sanitary Conditions

The analyses reported in table 4 show only the mineral content and properties of the water and do not indicate the sanitary condition. A relatively large amount of nitrate in water is an indication that the water may contain organic wastes, but a sanitary analysis, plus information on well construction and location, is necessary to establish with certainty that the water is polluted.

Most ground water is nearly free of contamination by harmful bacteria. However, the water from dug wells is likely to be contaminated if they are not effectively sealed off at the surface so as to prevent the entrance of surface water, which commonly contains harmful bacteria. The water from drilled wells that are cased generally is not subject to surface contamination because the casing extends deep enough to exclude surface drainage. Occasionally, however, leaks in the casing or an inadequate seal about the casing may endanger the supply. Another possible source of contamination is the direct inflow of pollution to water-bearing beds through sinkholes in limestone terrane.

Domestic and public water supplies should be located and constructed so that the supply of water is wholesome and safe at all times. Wells should not be located near possible sources of pollution such as cesspools, privies, septic tanks, sinkholes, or barnyards. Every well, regardless of type, should be constructed so as to prevent surface seepage from entering the well.

Although well pits prevent freezing of pipes and pumps in winter, the unsanitary water that accumulates on the floor of these pits very commonly is a source of pollution if it overflows into the casing. A pit should be provided with drains that will function at all times to prevent an accumulation of excess water.

## UTILIZATION OF GROUND WATER

A small amount of water is pumped from the Mississippi River for use by some industries located along its banks, but nearly all the other water used in the county is obtained from ground-water sources.

An estimated 2 mgd (million gallons per day) of ground water is pumped for domestic and stock supplies; and about 1 mgd of ground water is pumped by the few municipal wells, which supply a small urban population and a few small industries. Industries having their own wells are few in number and pump only about 200,000 gpd (gallons per day). Irrigation is limited to minor garden and lawn sprinkling. Locations of wells visited during this investigation are shown on plate 2, and the use of water from these wells is given in table 6.

### Public Supplies

Thirteen towns in Clayton County have municipal water supplies and 12 of them depend upon wells. The other towns in the county have no public supply, and privately owned wells supply their water needs.

A brief description of the water-supply installations for each town together with the consumption is given on the following pages. Chemical analyses of the public-water supplies are illustrated in figure 14, and available data on the wells are summarized in table 6. The geologic logs of some of these wells are given at the end of this report.

*Clayton.* This is the only town in Clayton County which obtains its water supply from springs. Water from two springs (93-3-2R1S) located about 75 feet above the Mississippi River and flowing from the Galena dolomite is diverted into a storage tank at the head of the principal street. Fom this tank the water is distributed by a main extending about half a mile down the street. In earlier days, the system was used largely for fire protection; but at the present time nearly all the houses along the principal street are connected to the main. Houses off the main street are served by hydrants. The springs have an estimated average combined flow of about 100 gpm and supply a population of 136.

*Edgewood.* The water-supply system of the town was installed in 1922. By 1928, the town had two closely spaced 8-inch wells which obtained water from the dolomite of Silurian age; well 1, now abandoned, was 261 feet deep and completely penetrated the rocks of Silurian age; whereas well 2 (91-5-35P1) was 126 feet deep and extended into only the upper part of the rocks of Silurian age. In 1934 well 2 was deepened to a total of 1150 feet, into the Jordan sandstone, but because 70 feet of drilling tools was lost in the bottom of the hole, the effective depth really is 1080 feet. The hole is cased with 432 feet of 6-inch casing that extends approximately 10 feet into the Elgin limestone member of the Maquoketa shale. When first completed, the well had a nonpumping level of 76 feet and, according to the driller, yielded 80 gpm for 45 minutes; the amount of drawdown was not known. All the aquifers above the Jordan sandstone were tested during the deepening of this well, but none has a specific capacity (yield in gpm divided by drawdown of water level) greater than 0.5 gpm per foot. This well was abandoned in 1946.

In 1946, well 3 (91-5-35N1) was completed in the Elgin limestone member of the Maquoketa shale at a total depth of 450 feet. The well was cased with 16-inch iron pipe to 99 feet, and lined with a 12-inch liner from 248 to 375 feet; the remainder of the hole was open. The water level prior to pumping was 77 feet; but after the well had been pumped for 24 hours at a rate of 210 gpm, the water level had declined to 115 feet. The well was plugged back to 248 feet in 1956, because shale caved into the bottom of the hole, and it now is used for standby purposes only.

Well 4 was drilled by the town of Edgewood in 1952. This well (90-5-2C1) is in Delaware County but is inside the town's limits. The new well is 269 feet deep and completely penetrates the Silurian rocks. The hole is cased with 10-inch pipe to 84 feet, and 10-inch open hole extends to the total depth. The original static water level was 77 feet, and after the well was pumped for 8 hours at the rate of 94 gpm the water level was 182 feet. The temperature of the water is 50°F. An estimated 35,000 gpd is pumped from this well into a 70,000-gallon reservoir. The supply goes into the distribution system without treatment. The population of 767 is supplied an average of about 46 gpd per person.

*Elkader.* The Elkader water-supply system was installed in 1895-96. Wells 1 and 2, drilled about 25 feet apart along the bank of the Turkey River, were 184 and 182 feet deep and tapped the St. Peter sandstone. The initial water level was 20 feet above the curb (altitude 734 feet) and the combined flow was 35 gpm. About 1912, they were pumped regularly at a reported rate of 500 gpm, and they continued to flow when not pumped. In 1927, well 3 (93-5-23E1) was drilled to an initial depth of 659 feet. Most of the water was derived from the Jordan sandstone between the depths of 490 and 530 feet and from the Prairie du Chien formation between the depths of 350 and 400 feet. Some water also came from the base of the St. Peter sandstone, and some came from the St. Lawrence formation at a depth of 550 feet. The water level in 1927 was about 20 feet above the curb (altitude 732 feet) and the discharge was 190 gpm. The combined flow of wells 1 and 2 had declined to 24 gpm at that time.

In 1933-34, well 1 was plugged with clay and abandoned and well 2 (93-5-23E2) was deepened to 432 feet, into the upper part of the Prairie du Chien formation. Well 3 (93-5-23E1) was deepened to 1426 feet and cased with iron pipe to 216 feet. In deepening this hole, the pressure head had declined to about 8 feet below the surface. The loss of head reportedly occurred in the Dresbach group. In an attempt to regain the flow, the well was dynamited between the 345- and 525-foot levels. This resulted in bridging the hole. The well was then cleaned out to 515 feet and the flow of water was restored. The well was pumped an average of 9 hours a day at 200 gpm. Somewhat later the combined flow of wells 2 and 3 was reported at 77 gpm.

At the present time well 3 is the primary source of supply, and untreated water is pumped to a 57,000-gallon low-level tank and a 173,000-gallon reservoir. The average daily pumpage is about 180,000 gpd for a population of 1,526 or an average of about 118 gpd per person.

*Farmersburg.* The public water-supply system at this town was installed in 1939 and the well was drilled the same year. This well (94-4-18F1) reached the Jordan sandstone at 670 feet and has a total depth of 705 feet; the hole was cased to 85 feet with 8-inch steel pipe into the Galena dolomite. The well is reported to have encountered some water at a depth of 125 feet in the Prosser limestone member of the Galena dolomite, and the reported static water level of 111 feet below the surface is the same as that measured for the water from the St. Peter sandstone, which occurs between 315 and 360 feet. The specific capacity of the combined Galena dolomite and St. Peter sandstone was less than 0.2 gpm per foot of drawdown. The water level is reported to have declined to 240 feet when the Root Valley sandstone member of the Prairie du Chien formation was penetrated between 455 and 480 feet. The final static water level was 231 feet below land surface when the well was completed in the Jordan sandstone. A pumping test indicated a specific capacity of about 14 gpm per foot of drawdown after pumping at rates of 40 to 80 gpm for about 5 hours.

The chemical quality of the water from well 94-4-18F1 is shown in table 4. Although the water is derived mostly from the St. Peter and the Jordan sandstones it includes some from overlying formations. The water obtained from the completed well is harder and contains larger quantities of iron than does water from wells drilled into the Jordan sandstone in other areas.

The water used for public supply is not treated, and is pumped once a day into a 52,000-gallon reservoir. No records are available of daily pumpage, but the demand is estimated to average about 30,000 gpd. This supplies a town of 250, or an average of about 120 gpd per person.

*Garnavillo.* Prior to 1924, Garnavillo obtained its public supply from two wells about 150 feet deep. Because the yield of these wells was inadequate, a third well (93-3-18K1) was drilled to a total depth of 365 feet, probably to the St. Peter sandstone. In 1949, a new well (93-3-18J1) was drilled; it penetrated 25 feet of the St. Peter sandstone, was 385 feet deep, and was cased with 10-inch pipe set at 60 feet below the top of the Galena dolomite. Shortly after completion of the well, the static water level was reported to be 70 feet below land surface. Because the drawdown was reported to be 63 feet after pumping several hours at the rate of 76 gpm, the specific capacity of the well probably is slightly less than 1 gpm per foot of drawdown.

In 1955, the production from well 93-3-18J1 had decreased to less than 50 gpm. Therefore, in 1956 a well (93-3-19D1) was drilled to a depth of 815 feet, into the St. Lawrence formation. The hole was cased with 12-inch pipe from the surface to 400 feet, or about 25 feet into the Prairie du Chien formation, and was pressure grouted with 185 sacks of cement. The original static level was 312 feet below land surface. As pumping at the rate of 420 gpm caused a drawdown of 16 feet, the specific capacity of the well is slightly more than 26 gpm per foot of drawdown.

During 1956, the town pumped a total of 15,155,000 gallons of water, slightly more than 8 million gallons of which was pumped from well 93-3-18J1. Since 1956, well 93-3-19D1 has supplied the town needs and the older well is used as a standby. From September 1956 to June 1957 this well produced 14,083,000 gallons of water, or an average of about 51,000 gpd. The 1960 census reported a population of 662 which indicates an average daily use of approximately 77 gpd per person. The water is not treated, and the system includes a 30,000-gallon steel standpipe reservoir.

*Guttenberg.* Prior to 1937, a dug well (92-2-17H1) reported to be 26 feet deep, 26 inches in diameter and cased with concrete, served as the source for the public water supply of this town. This well was located about 10 feet from the Mississippi River and the relatively high nitrate content of the water indicated the well was receiving some seepage from the stream. In 1937 the well was reported to have a nonpumping water level 4 feet below the surface of the ground and to yield about 200 gpm with a 20-foot drawdown.

Two wells were drilled into the Jordan sandstone in 1937. Well 1 (92-2-17L2) was drilled to a total depth of 450 feet and was cased into the Prairie du Chien formation with 8-inch pipe from the surface to 127 feet. At the time of completion, the static water level was 26 feet, and during an 8-hour test 440 gpm was obtained with a drawdown of 64 feet. Well 2 (92-2-17L1) is 435 feet deep. Twelve-inch surface casing was set at 56 feet and the completed well was cased from the surface to 99 feet with 8-inch pipe. The diameter of the well was considerably enlarged by discharging explosives at a depth of 420 feet. The static water level was 23 feet, and was tested at 490 gpm for 4 hours with 19 feet of drawdown. Most of the supply now is obtained from well 2, and well 1 is used only when additional water is needed.

During the period of July 1956 through March 1957 the town pumped 28,349,000 gallons, or about 105,000 gpd. This indicates a per capita consumption of about 50 gpd. Several industries in the town use a small part of this total. A food processing plant uses an average of about 800,000 gallons per year, a metal fabricating plant about 650,000 gallons per year, a creamery about 800,000 gallons per year, and a plant where button blanks are cut from clam shells about 350,000 gallons per year.

The water is hard and a treatment plant was constructed in 1939. Treatment consists of aeration, addition of lime and alum, coagulation, re-carbonation, and rapid sand filtration. During summer months, when water usage is high, some untreated water is pumped into the mains. The system includes a 65,000-gallon low-level reservoir and a 132,000-gallon high-level reservoir.

*Luana.* The original public water supply for Luana was from a well drilled in 1934 to a depth of 412 feet, presumably into the St. Peter sandstone. The initial static water level was reported as 138 feet, although when measured in 1957, the static water level was 85 feet below land surface. Apparently the well would not supply enough water and a new well was drilled in 1941. This well (95-5-5R1) is 339 feet deep and just reached the top of the Decorah shale. The well is cased with 6-inch pipe to 63 feet, in the Elgin limestone member of the Maquoketa shale. The static water level was 165 feet and the yield was reported as 50 gpm with very little drawdown. The well yielded about 23,000 gpd until 1957, when the yield from the well declined. Although the well was acidized, its yield was not increased. A third well (95-5-9E1) was drilled in 1958 to a depth of 347 feet. This well is cased with 8-inch pipe to 131 feet, about 30 feet into the Galena dolomite. The initial static water level was reported as 106 feet below ground surface, almost 60 feet less than the other well (95-5-5R1). The well produced 210 gpm with a drawdown of only 7 feet. No production figures for this well are available but presumably this well now furnishes the town supply. The town has a population of 276 people and the 1957 consumption of about 23,000 gpd would indicate a per capita usage of about 83 gpd per person. The water is pumped without treatment into two reservoirs of 10,000- and 30,000-gallon capacity.

*Marquette.* The records on the well (95-3-15K2) drilled for the public supply at this town in 1896 are not entirely clear. Seemingly, however, the well was 585 feet deep, and originally the water level was 17 feet above the surface. By 1904 the head had declined so that the well did not flow, but after recasing, the static level returned to 10 feet above the surface. The water level was 18 feet below the surface in 1944. Another well (95-3-15K1) was drilled in 1950 to a depth of 442 feet, into the Dresbach group, and was cased to a depth of 150 feet, just above the base of the St. Lawrence formation. The driller reported essentially no water to a depth of 150 feet. Water from the interval between 150 and 325 feet had a static level of 20 feet below land surface; water flowed from the interval between 326 and 442 feet. The natural flow in 1950 was about 75 gpm, and 110 gpm were obtained with a drawdown of 12 feet after 3.5 hours of pumping.

On the basis of pumping rates and water levels reported by the driller, the coefficient of transmissibility for the units open in this well, the Franconia sandstone and the Dresbach group, is calculated approximately as 10,000 to 20,000 gpd per foot.

The water is not treated, and about 50,000 gpd is pumped to supply the population of 572. This is an average of 87 gpd per person. The distribution system includes a 65,000-gallon reservoir.

*McGregor.* Several public-supply wells have been drilled for the town of McGregor. The first of these wells was drilled about 1876 to a depth of 500 feet in an attempt to obtain a flowing well. The site was about 60 feet above the lower levels of the town and the static water level was just below land surface. Well 2 (95-3-22Q1) was drilled in 1877 to a depth of 1,006 feet and cased with 4-inch copper tubing to a depth of 40 feet. The original intent was to have a flowing well with water of such mineral content as to be used for medicinal purposes. The original flow was 630 gpm, but the development of a health center never materialized and the water was too highly mineralized for a public supply. Salt water was reported to occur in a 4-foot bed of white sand at a depth of 520 feet in this well. The water was used as a fountain in the City Park until the well was plugged in May 1951, to prevent further contamination of the present city supply. The flow at that time was estimated to be 75 to 100 gpm.

Well 3 (95-3-22Q3) was drilled in 1890 to a depth of 520 feet and cased with 215 feet of 3-inch pipe. Water was reported to come from a depth of about 303 feet; although the initial water level was 20 feet above the surface, the flow had ceased by 1895.

Well 4 (95-3-22Q2) was drilled in 1898 to a depth of 502 feet and cased with 12-inch pipe to 70 feet and 9-inch pipe to 200 feet. At the time of drilling the water level was 1 foot above the surface, but after 6 months the water level had declined to below the curb and in 1949 was 8 feet below the surface. The well was pumped at about 400 gpm, but no record of the drawdown at that pumping rate is available.

Late in 1948, well 5 (95-3-22R1) was drilled into the Dresbach group at a depth of 645 feet. The diameter of the hole was 15 inches to a depth of 282 feet and 10 inches from 282 feet to 645 feet, with 10-inch casing from the surface to 282 feet. The water level was reported to be 18.5 feet above the surface, and the flow about 200 gpm; pumping at 325 gpm lowered the water level to 12 feet below the surface. Although the yield of the well was sufficient, the water was too highly mineralized for most uses. Tests made with the Iowa Geological Survey geophysical logging equipment in August 1949 indicated that water entered the well from the Galesville sandstone of the Dresbach group between 280 and 410 feet and the Mt. Simon sandstone between 530 and 645 feet. The well at this time had a natural flow of 225 gpm made up of a flow of approximately 125 gpm from the Mt. Simon sandstone and 100 gpm from the Galesville sandstone. No water seemed to enter the well from the Eau Claire sandstone between 410 feet and 530 feet. As chemical analyses of water from nearby wells indicated that much of the mineralized water was obtained from the Mt. Simon sandstone, the well was back filled with sand and gravel to a depth of about 490 feet in September 1949 and cemented to 481 feet in October 1949. Subsequently this plug was found to be inadequate and a lead seal was placed between 481 and 479 feet in May 1951. At this time, well 2 (95-3-22Q1), the deep flowing well, was plugged to prevent the mineralized water from reaching the Galesville sandstone. Since the amount of mineralized water reaching the Galesville was reduced, the quality of water from this aquifer has steadily improved (fig. 15).

In March 1952, well 6 (95-3-22R2) was drilled to a total depth of 116 feet and completed in the St. Lawrence formation. Ten-inch casing was set at 90 feet and cemented in the St. Lawrence formation. When drilling was completed, this well had a static water level of 15 feet, and pumping at 394 gpm lowered the water level to 33 feet. This well now provides the entire city supply, although well 5 (95-3-22R-1) is still flowing and is available in an emergency.

In 1956 the city pumped 44,472,800 gallons of water, an average of about 122,000 gpd to supply a population of 1,040, an average of about 117 gpd per person. The water is not treated, although chlorine has been used in the past. The distribution system includes a 275,000-gallon reservoir.

*Monona.* The water supply for this town was originally obtained from a spring and a well drilled in the St. Peter sandstone at a reported depth of 459 feet. Field reports by the Iowa Geological Survey in 1935 include mention of two abandoned wells, each 415 feet deep. One well was abandoned in 1920, and had a water level of 161 feet in 1935. The second well had been deepened to 465 feet but was abandoned in 1932. It had a static water level of about 200 feet and a pumping level of about 400 feet when discharging 40 gpm. In 1922, well 1 (95-5-11K1) was

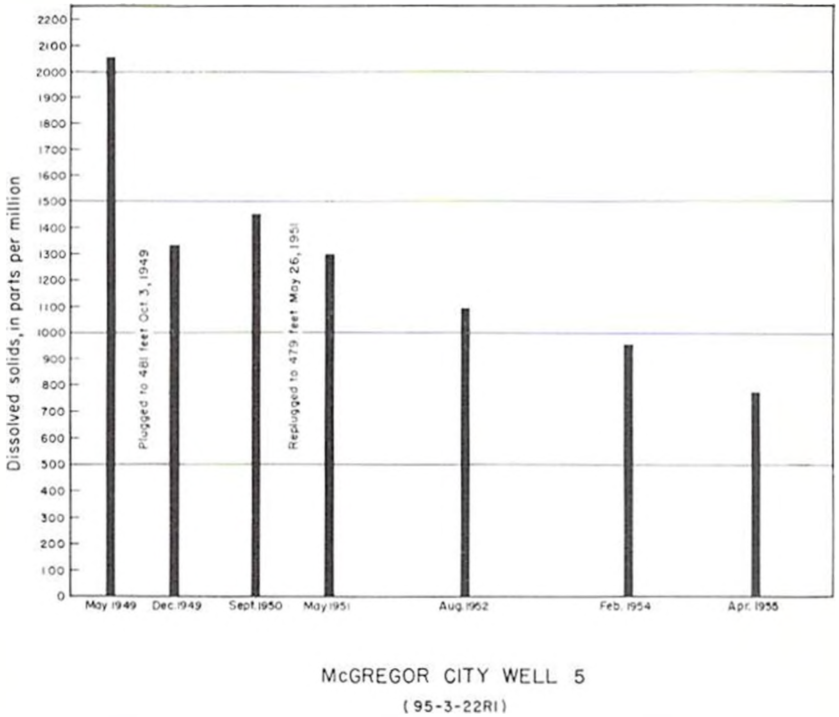

Figure 15.—Graph showing the decrease in dissolved solids content of water from well 95-3-22R1 at McGregor after well was plugged back to shut out mineralized water from deeper aquifers.

drilled through the Jordan sandstone to a total depth of 815 feet. In 1936, because the well yielded contaminated water, it was repaired and recased with 8-inch iron pipe to a depth of 631 feet. In 1935, the static water level was reported to be 415 feet below land surface, and in 1937 it was at 437 feet with a reported pumping capacity of 75 gpm. The resulting drawdown at that pumping rate is not known.

In 1932, well 2 (95-5-11K2) was drilled about 50 feet from well 1 to a depth of 814 feet. The well is cased with 10-inch casing from the surface to 408 feet, probably into the St. Peter sandstone. The static water level was 427 feet, and pumping at the rate of 327 gpm caused a drawdown of 83 feet. This well now supplies most of the water used, with well 1 available in emergency.

The town of Monona pumped 23,714,000 gallons of water in 1955, an average of almost 65,000 gpd. This quantity supplies a population of 1,346, which indicates a per capita consumption of about 49 gpd. Of this total, the Chicago, Milwaukee, St. Paul and Pacific Railroad uses an estimated 7,000 gpd. The water is not treated, and the system includes a 60,000-gallon reservoir for maintaining pressure in the public system and a separate reservoir for the railroad supply.

*St. Olaf.* Prior to 1928, St. Olaf obtained its water supply from a dug well 8 feet in diameter and lined with stone. The well was in the alluvium along Roberts Creek, which runs through the town. The system was expanded in 1927, and well 1 (94-5-25M1) was drilled to a depth of 330 feet. The water level was reported to be 191 feet below the surface. No other records are available on this well, but evidently it passed through the St. Peter sandstone and into the Prairie du Chien formation. The well was abandoned in 1951 because the water was bacterially contaminated.

Well 2 (94-5-26H1) was drilled in 1951 to a depth of 378 feet, and cased with 8-inch iron pipe to 302 feet. The well is open to the St. Peter sandstone and nearly 40 feet of the underlying Prairie du Chien formation. The initial static water level was 187 feet below land surface, and pumping at 55 gpm caused a drawdown of 37 feet.

No record is kept of the amount of water pumped, but it is estimated to be about 18,000 gpd to supply a population of 169. This is an average of about 106 gpd per person. The water is chlorinated and pumped directly into the mains or to a 51,000-gallon reservoir.

*Strawberry Point.* The public-supply system at this town was installed in 1900. Very little information is available on the wells, except that city well 1 (91-6-22G1) was 160 feet deep and obtained water from the Hopkinton dolomite. In 1936, city well 2 (91-6-22G2) was drilled to a depth of 492 feet and completed in the Galena dolomite. Casing was set into the Silurian rocks at 161 feet. Below this, open hole extended to 229 feet, where 141 feet of 10-inch liner was set opposite the upper part of the Maquoketa shale; open hole continued from 370 to 492 feet. At the time of completion the static water level was 130 feet below land surface, and pumping at an average rate of 400 gpm caused a drawdown of 30 feet, which indicates a specific capacity of slightly more than 13 gpm per foot of drawdown. At this time it was determined that all the production was from the aquifer of Silurian age. The well was repaired in 1944 after blue, clayey material was found in the water. At that time the static water level was reported to be 128 feet, and the well was pumped at 438 gpm with a drawdown of 30 feet.

City well 3 (91-6-22K1), drilled in 1955, was completed to a depth of 259 feet and finished in the Edgewood limestone. The well was cased with 8-inch casing into the Kankakee limestone at 157 feet. The static water level was 130 feet below the surface, and pumping at a rate of 280 gpm lowered the water level 30 feet.

The town of Strawberry Point pumped 72,722,000 gallons of water in 1956, an average daily pumpage of approximately 199,000 gpd to supply a population of 1,303. This is an average of about 152 gpd per person. Well 2 furnished 67,870,000 gallons of the total pumpage. In 1957, well 2 began yielding an objectionable amount of sediment under sustained heavy pumping, therefore well 4 (91-6-22N1) was drilled to the top of the Maquoketa shale at 240 feet. Ten-inch casing was set in the Kankakee limestone at 135 feet. The static water level in well 4 is 96 feet, and pumping at a rate of 420 gpm causes a drawdown of only 14 feet. This indicates a specific capacity of 30 gpm per foot of drawdown. No pumping records on the 1957 well are available, but it is assumed this well will furnish the main supply for the town, and the older wells will be used only in emergency.

The distribution system of the town includes an 80,000-gallon elevated steel tank, and the water is pumped either into the reservoir or the mains without treatment.

*Volga.* The public water-supply system for this town of 361 persons was established in 1957, when a well (92-6-3N1) was completed at a depth of 225 feet. It is cased with 8-inch pipe to the top of the Galena dolomite at a depth of 53 feet; the rest of the hole is open to the Galena dolomite. The initial water level was 41 feet, and the drawdown in water level was 15 feet when the well was pumped at a rate of 150 gpm.

During 1958, this well produced 9,057,800 gallons of water, an average of almost 25,000 gpd. Based on a population of 361, the average daily per capita use is about 69 gallons. A creamery uses an average of about 10,000 gpd. The water is chlorinated before being pumped to a 42,000-gallon supply tank.

### Domestic and Stock Supplies

Nearly all rural residents of Clayton County, as well as the residents of small towns that lack a municipal supply, obtain water for domestic and stock supplies from wells. Because of the great topographic relief, well depths differ markedly from place to place in the county. The average depth is approximately 200 feet, but some farm wells are more than 800 feet deep. The majority of the wells are drilled and are 6 inches or less in diameter.

Flowing artesian wells have been drilled on a few farms in the northeastern part of the county. Only a very few of the many springs in the county have been developed for use as stock supplies; a few undeveloped springs also are used. The chemical analyses of water from a number of springs are shown in table 4 and graphic representations of the analyses are shown in figure 13.

Most rural wells are pumped only when water is needed and the discharge rate commonly is only a few gallons per minute. On many farms the older windmill and pump jack systems are being dismantled and electric pressure systems are being installed for more efficient use of the water. Farms, unless very large, generally are supplied by a single well. A count of the number of farms indicates that there are about 3,000 domestic and stock wells in the county. This number includes wells used principally for domestic purposes in towns that lack municipal supplies. If the average farm family uses about 600 gpd, the average pumpage from domestic and stock wells in the county is about 2 mgd.

### Industrial Supplies

The 15 creameries in Clayton County are the main users of ground water for industrial purposes. All the creameries use water only for part of each day and some for only 3 days each week. Although the exact amount of water used per day by each creamery is not known, the average is about 10,000 gpd, or a total of 150,000 gpd. Other industries having their own ground-water supply include a tool manufacturing establishment at Guttenberg and poultry processing establishments throughout the county. The total industrial pumpage is estimated to be about 200,000 gpd.

Some industries make use of municipal supplies. The two bottling plants for soft beverages, one at Garnavillo and the other at Elkader, and the food processing plant at Guttenberg are supplied with water by the municipal system of the city in which each is located. Municipal water supplies are also used by several ice plants. The sand mine at Clayton obtains water directly from the Mississippi River for washing sand; this water is untreated and is used once only, after which it is returned to the river.

# GEOLOGIC FORMATIONS AND THEIR WATER-BEARING CHARACTERISTICS

## PRE-CAMBRIAN ROCKS

No wells in Clayton County have been drilled deep enough to reach the Pre-Cambrian rocks. However, several wells in adjacent counties have reached these rocks, and the great variance in the altitude of the Pre-Cambrian surface in these several wells indicates that the top of the Pre-Cambrian is an erosional surface of great relief. Although they are known to consist principally of igneous and metamorphic rocks, the uppermost of the Pre-Cambrian rocks consist, in places, of sedimentary strata. At Lansing, Iowa, about 13 miles north of the Clayton County line, a soft, silty red shale was reached at a depth of only 675 feet. Beneath 25 feet of this shale is 12 feet of medium- to fine-grained sandstone, and at 712 feet, crystalline rock was reached. The age of these sediments is not known definitely, but in Iowa the red shale and sandstone that underlie strata of known Late Cambrian age commonly have been assigned to Pre-Cambrian systems (Trowbridge and Atwater, 1934, p. 29).

Because the Pre-Cambrian sedimentary and crystalline rocks do not yield water in adjacent counties, they are believed unlikely to yield water in Clayton County.

## CAMBRIAN SYSTEM

### *St. Croixan Series*

#### Dresbach Group

*Stratigraphy.* The Dresbach group was named by Winchell (1886) to include a thick sandstone section that contains some shale and sandstone now assigned to the lower part of the Franconia sandstone. The term Dresbach now is generally applied to all Upper Cambrian beds below the base of the Franconia sandstone, and includes, in ascending order, the Mt. Simon, Eau Claire, and Galesville sandstones (Raasch, 1935). Although the Dresbach group is not exposed in Clayton County, these sandstones can be differentiated in the subsurface. The Mt. Simon, as indicated by samples from McGregor city well 5 (95-3-22R1), consists of coarse, clear to pink and gray, angular to rounded, partly frosted quartz grains, with some gray to green micaceous shale. Although only 115 feet of the Mt. Simon was penetrated, the probable thickness is in the order of hundreds of feet. The

Eau Claire sandstone is made up of gray, partly fissle, silty shale and some siltstone with dolomitic cement. The Eau Claire here is about 120 feet thick. The upppermost formation, the Galesville, is composed of white to gray, medium to coarse, frosted sand grains that generally are rounded. The thickness is about 140 feet.

*Water supply.* The Marquette city wells 1 and 2 (95-3-K2 and K1), the Chicago, Milwaukee, St. Paul and Pacific Railroad wells (95-3-16L2 and L3) at Marquette, and the McGregor city wells 2, 4, and 5 (95-3-22Q1, Q2, and R1) all obtain water from the Dresbach group. McGregor city well 2 (95-3-22Q1) at a total depth of 1,006 feet may have reached rock below the Dresbach group, but this is doubtful as the Pre-Cambrian surface is believed to slope steeply to the south and west from the comparatively shallow depth at Lansing.

Water from the lower formation of the Dresbach group is much more mineralized than that from the upper formation (fig. 16). The sample from the McGregor city well 2 (95-3-22Q1), which was collected from a depth of 1,004 feet and so can be considered representative of water from the Mt. Simon, had a high dissolved-solids content; whereas the sample collected at the land surface, which represents a mixture from all formations of the Dresbach group had a markedly lower dissolved-solids content. Similarly, the dissolved-solids content of the water sample collected from the McGregor city well 5 (95-3-22R1) at a depth of 470 feet was substantially higher than that of the sample collected at the surface. The sample collected at 470 feet was water from the Mt. Simon that was not completely sealed off by a plug set at 481 feet; whereas the sample collected at the surface was made up of the combined flow from the Mt. Simon and Galesville. Samples collected from this well since the water from the Mt. Simon was successfully sealed off in May 1951 are representative of water from the Galesville only, and all show a marked decrease in dissolved-solids content (table 4).

A rather undesirable characteristic of water from the Dresbach group in this area is hydrogen sulfide gas which gives the water an odor of "rotten eggs." The gas, however, can be removed easily by aeration.

All the wells mentioned above had initial flows of about 200 gpm, but these flows have since diminished. Those wells still in use are pumped with only a moderate drawdown. The temperature of the water from the Dresbach group does not vary notice-

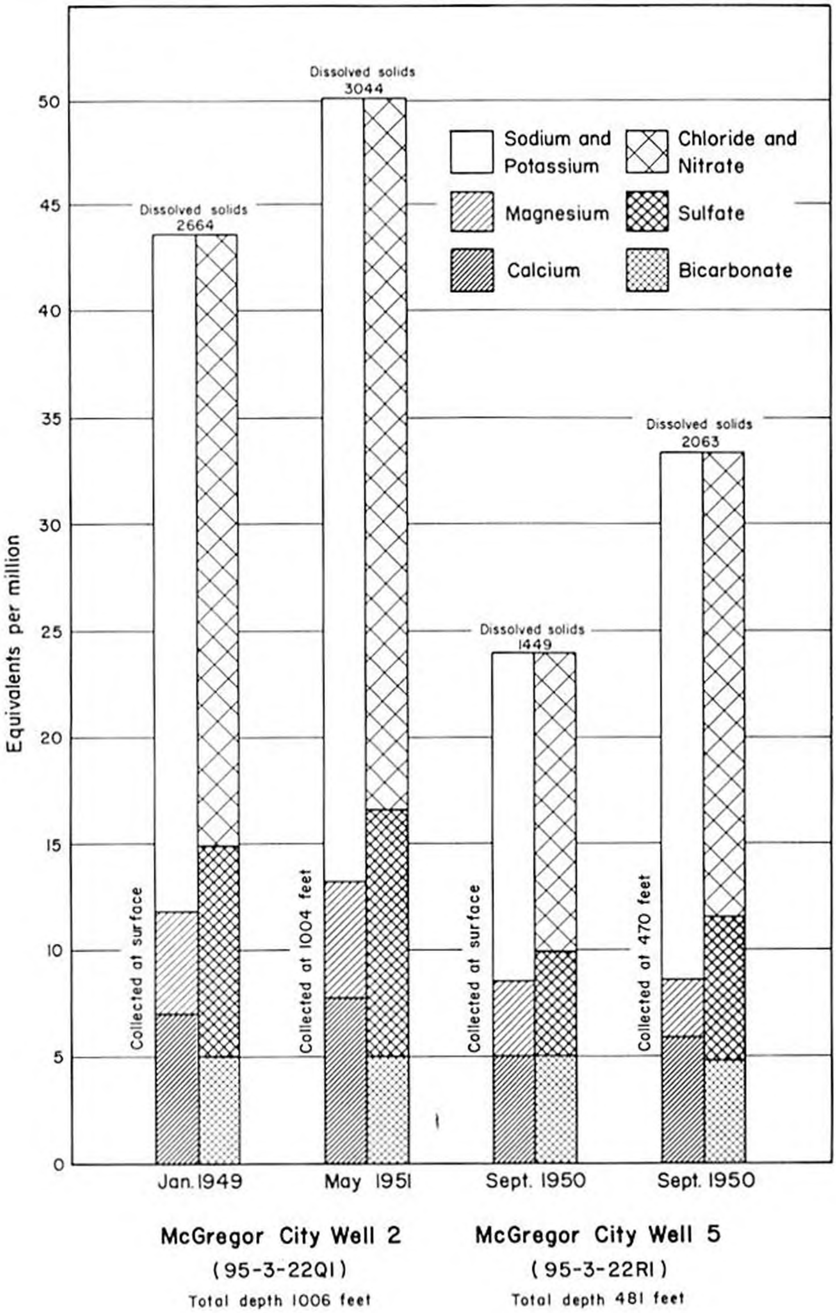

Figure 16.—Graphic representation of chemical analyses of water from wells 95-3-22Q1 and 95-3-22R1 at McGregor illustrating the increase of mineralization with depth.

ably with depth; a temperature of 52°F. has been recorded for water from both the Mt. Simon and the Galesville.

### Franconia Sandstone

*Stratigraphy.* The name Franconia was first applied by Berkey (1897, p. 377), and is now used for beds underlying the St. Lawrence formation and overlying the Dresbach group. This formation includes in ascending order the Ironton, Goodenough (Taylor Falls), Hudson, and Bad Axe members (Raasch, 1935). As these members are differentiated in surface exposures on the basis of fossils, subdivision of the formation in the subsurface is difficult. In Clayton County, where the Franconia is known only in the subsurface, it consists of glauconitic, dolomitic siltstone and shale interbedded with glauconitic sandstone. The Ironton member is recognized, however, as the coarse-grained, somewhat more dolomitic, lower sandstone. In the Marquette area the total thickness of the Franconia sandstone is about 130 feet.

*Water supply.* The siltstone and shale in the upper part of this formation probably yield little water to wells. Although several wells that draw water from the underlying Dresbach group are open to much of the Franconia sandstone, no wells in Clayton County tap only the Franconia. The basal Ironton member probably yields some water to the wells that are bottomed in the Dresbach.

### St. Lawrence Formation

*Stratigraphy.* The name St. Lawrence was originally applied by Winchell (1874, p. 152-155) to the dolomitic limestones exposed along the Minnesota River near St. Lawrence, Minn., where the dolomitic beds are underlain by glauconitic sandstone and overlain by siltstone. Later Winchell (1876, p. 153-155) described the St. Lawrence as consisting of 200 feet of "dolomitic limestone" with some distinctly arenaceous layers and stained with green sand, overlain by the Jordan sandstone and underlain by the St. Croix sandstone. The Mendota limestone of Irving (1875, p. 441-442) and the Black Earth dolomite of Ulrich (1916, p. 477) seem to be the same dolomitic unit (Trowbridge and Atwater, 1934, p. 55; Raasch, 1935, p. 311). In Clayton County, the formation consists almost wholly of coarsely crystalline, gray, silty dolomite containing some glauconite. The various members have not been differentiated in the subsurface.

The St. Lawrence formation has been recognized in well cuttings in Illinois and is exposed in northeastern Iowa and in adjacent parts of Wisconsin and Minnesota. The thickness of this formation in Clayton County probably is somewhat more than 170 feet. This thickness was found in the Marquette city well 2 (95-3-15K1) where the St. Lawrence locally forms the bedrock, and the top, thus, is probably an erosional surface.

*Water supply.* The upper part of this formation yields water from fractures or solution openings which connect with the overlying Jordan sandstone. Many wells in the county drilled to the Jordan sandstone also penetrate the upper part of the St. Lawrence and probably draw some water from this unit. McGregor city well 6 (95-3-22R2) draws its water from a large channel or fracture in the St. Lawrence, but probably most of this water is moving into the St. Lawrence formation from the overlying Jordan sandstone. The discussion of the character of water from the St. Lawrence formation, therefore, is included with the discussion of the Jordan sandstone.

### Jordan Sandstone

*Stratigraphy.* The Jordan sandstone was named by Winchell (1872; 1874; p. 147-152) for exposures in and near Jordan, Minn. As used in this report it includes the beds of sandstone and very sandy dolomite lying below the Oneota dolomite member of the Prairie du Chien formation and above the dolomite of the St. Lawrence formation. According to Trowbridge and Atwater (1934, p. 27-79), the Jordan sandstone is equivalent to the Madison sandstone of Irving (1875, p. 442).

The formation is composed of loosely cemented, medium to coarse, buff to white, well-sorted, sand grains having a frosted surface. The sand grains are somewhat larger than in the younger St. Peter sandstone and in the Root Valley sandstone member of the Prairie du Chien formation, but this difference is not diagnostic enough to identify the formation when the stratigraphic relations are unknown. The thickness of the Jordan sandstone in Clayton County is variable, ranging from 40 feet in the Elkader city well (93-5-23E1) to 120 feet in the Clayton County Home well (93-4-7A1) north of Elkader.

Because of the high relief of the land surface and the slight southwesterly dip of the beds, the depth to the Jordan sandstone varies greatly throughout the county. The depth necessary to reach the Jordan can be determined approximately by examining the logs of wells included with this report or the geologic section of Clayton County (pl. 3).

*Water supply.* Because wells drilled into the Jordan sandstone in Clayton County are not cased completely, water from other formations also may enter the wells. Thus, the quality of water differs in wells tapping the Jordan (fig. 17). The variations in dissolved solids content and hardness are shown in tables 4a and b; temperature data are shown in table 4c.

Municipal wells tapping the Jordan sandstone yield as much as 490 gpm (table 6). The specific capacity of these wells, however, range from about 4 to 20 gpm per foot of drawdown. Municipalities and industries in the county extract approximately ½ mgd from the Jordan sandstone in Clayton County.

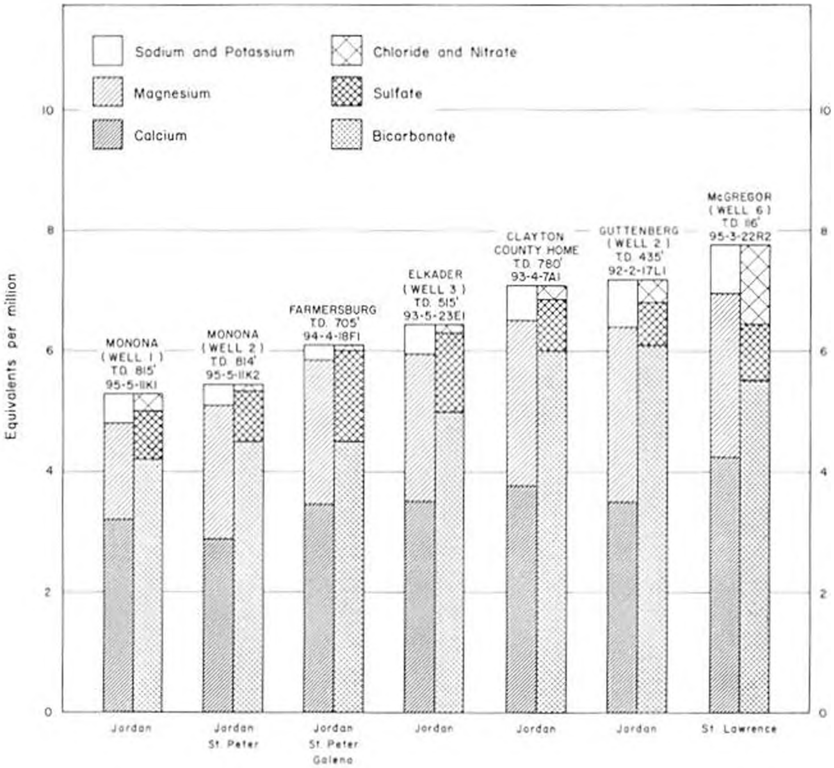

Figure 17.—Graphic representation of analyses of water from the Jordan sandstone. Other water-bearing units also open to wells are indicated.

Not enough data are available to determine all the recharge and discharge areas of the Jordan sandstone in Clayton County. Presumably, however, some recharge enters the county by subsurface inflow from the northwest, because the pressure head of the water in the Jordan sandstone is much higher in the Postville Packing Company well (96-6-32L1) than in the wells at Monona (95-5-11K1), Farmersburg (94-4-18F1), Elkader (93-5-23E1), and the Clayton County Home (93-4-7A1) (table 6). No data is available to indicate whether subsurface inflow enters the county from the west or south. At least one component of ground-water movement is toward the Mississippi River, because the pressure head of water from the Jordan sandstone is lower in the wells at Guttenberg (92-2-17L1) and Pikes Peak State Park (95-3-35P1) than in any of the other wells in the county. Consequently, at least some ground-water discharge from the Jordan sandstone is to the east by subsurface outflow. In addition, some discharge is believed to occur in the outcrop area of the Jordan Sandstone along Bloody Run Creek and along the Mississippi River.

## ORDOVICIAN SYSTEM

### *Beekmantownian Series*

#### **Prairie du Chien Formation**

*Stratigraphy.* The term Prairie du Chien was applied by Bain (1906, p. 18) to dolomitic and sandy beds exposed in the vicinity of Prairie du Chien, Wis. This formation overlies the Jordan sandstone and underlies the St. Peter sandstone. In ascending order, it includes the Oneota dolomite, the Root Valley sandstone, and the Willow River dolomite members.

The Oneota dolomite member was described by McGee (1891, p. 331-332) from exposures along the Oneota River in Allamakee County, Iowa. It was described as an arenaceous dolomite that for the most part is coarsely saccharoidal and in many places is cavernous and vesicular. As seen in Clayton County, this member is a drab-gray to buff, cherty dolomite, somewhat sandy, and with many vuggy cavities and pores (pl. 6A). The maximum thickness of the Oneota dolomite member is 215 feet in wells in this county; approximately 160 feet is exposed in a quarry (95-3-16M1Q) near Marquette, Iowa.

The sandstone between the Oneota and Willow River dolomites along the Willow River at New Richmond, Wis., originally was named New Richmond by Wooster (1882, p. 106, 123-129). However, the member was renamed the Root Valley sandstone by Stauffer and Thiel (1941, p. 61), and that name was adopted by the Iowa Geological Survey. The Root Valley sandstone member is a white to light brown, fine-grained sandstone that probably

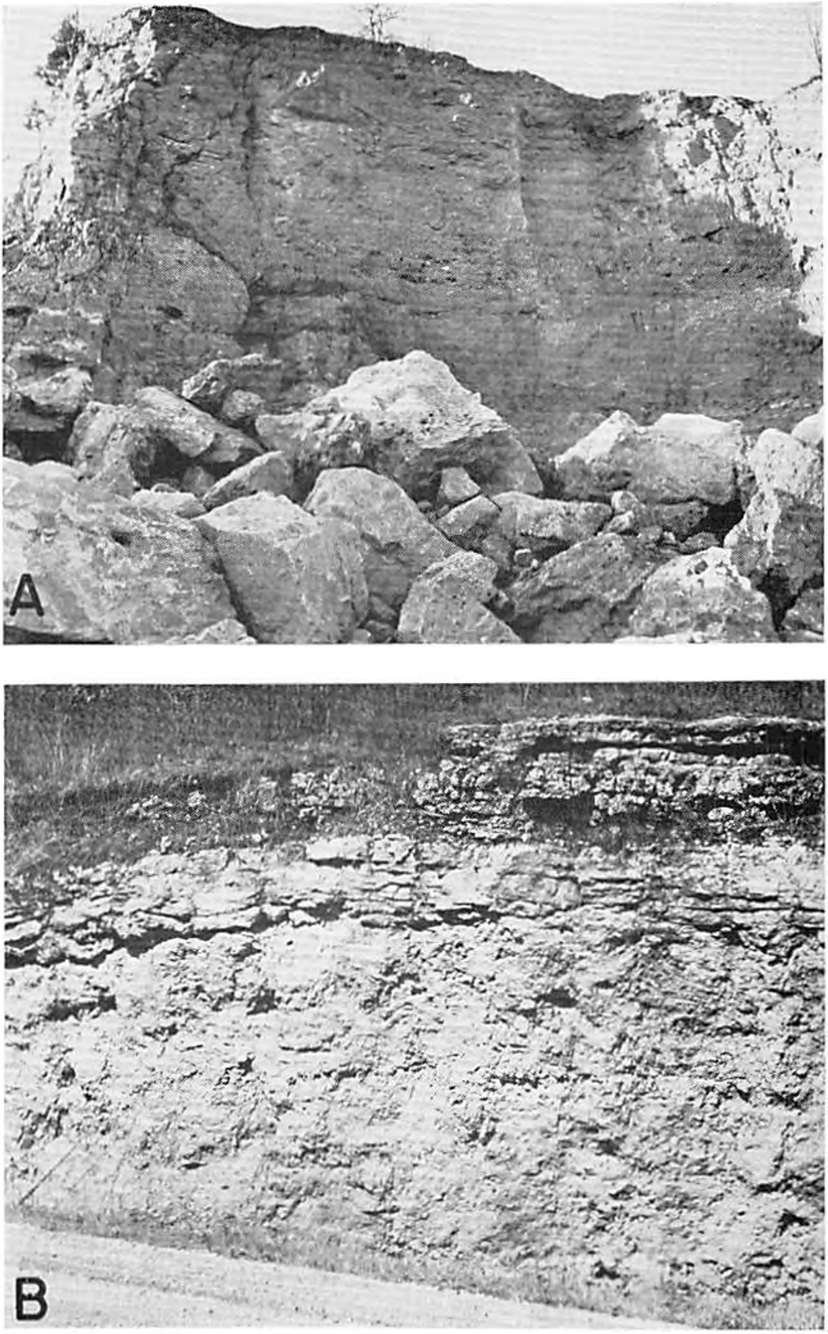

PLATE 6.—*A*, Exposure of the Oneota dolomite member of the Prairie du Chien formation in a quarry (95-3-16M1Q) near Marquette, showing the porous character of the rock; *B*, Exposure of the Willow River dolomite member of the Prairie du Chien formation in a road cut (95-3-9A1E) northwest of Marquette, showing the thin-bedded upper portion overlying the reeflike lower beds of the member.

grades locally into sandy dolomite. The thickness of this unit is as much as 25 feet. In drill cuttings from the Root Valley member, sandstone is intermixed with dolomite. Moreover, because it is poorly exposed in the county, the lithology of the Root Valley is incompletely known. In the few localities where the sandstone is exposed, the sand resembles that of the Jordan sandstone, but it is somewhat finer grained.

The dolomite unit above the Root Valley sandstone member and below the St. Peter sandstone was named Shakopee dolomite by Winchell (1874, p. 138-147). Wooster (1882, p. 106), however, applied the name Willow River to the upper dolomite unit of the Prairie du Chien that cropped out along the Willow River, Wis., and that name was tentatively adopted by Trowbridge and Atwater (1934, p. 65-73). Powers (1935, p. 171) proposed the name Willow River dolomite member for the upper dolomite of the Prairie du Chien formation, and this usage is followed by the Iowa Geological Survey. The Willow River dolomite member is well exposed in a road cut (95-3-9A1E) northwest of Marquette, Iowa (pl. 6B). In Clayton County, this member is composed of gray to buff, sandy dolomite with some oolitic and tripolitic chert. As shown in the logs of selected wells in this report, the thickness of the Willow River dolomite member is as much as 95 feet.

*Water Supply.* The Prairie du Chien formation does not yield large supplies of water to wells in this area. Those wells that are drilled to the St. Peter sandstone are generally completed in the Willow River dolomite member, where some water may come into the wells along fractures, but this water is probably derived from the St. Peter sandstone. Wells finished in the Jordan sandstone are usually left uncased through the Prairie du Chien formation, and some water could come from this zone. The Elkader city well 3 intercepted a large fissure in the lower Prairie du Chien formation and obtains some water from this formation as well as the Jordan sandstone.

### *Chazyan Series*

#### St. Peter Sandstone

*Stratigraphy.* The St. Peter sandstone was named for exposures along the Minnesota River (formerly St. Peters River) in southern Minnesota by Owen (1847, p. 169-170) and has been recognized widely since that time. In Clayton County, it unconformably overlies the Prairie du Chien formation and is overlain by the Glenwood shale member of the Platteville limestone

(Trowbridge, 1917, p. 177-182). Although the St. Peter sandstone is very uniform over wide areas in the upper Mississippi River basin, variations due to exposure and weathering of the iron-bearing minerals characterize the formation in Clayton County. In this county is is composed of medium- to fine-grained, pure white to buff-colored sandstone made up of frosted and well-rounded, well-sorted grains of quartz. Locally, as at Pikes Peak State Park near McGregor, the formation is prominently iron-stained and strongly cemented by iron oxides. Some of the iron stains are a vivid red. Northwest of Marquette, Iowa, in a road-cut (95-3-9A1E) the same type of iron-stained sand is interbedded with shale which yields conodonts that are typical of Lower Ordovician rocks. These conodonts may indicate that the St. Peter sandstone is more closely associated with the Prairie du Chien formation than was previously believed.

The St. Peter sandstone is exposed along the Mississippi River north from Guttenberg and along Sny Magill and Bloody Run Creeks (plate 1). Probably the best of the exposures are near McGregor (95-3-29J1E and 95-3-34A1Q). Additional exposures are described in tables 7 and 8. As seen in the sand mine (93-2-7G1Q) three-fourths of a mile south of Clayton on the Mississippi River, the St. Peter sandstone contains not only considerable clay material that binds the sand grains, but also thin lenses of laminated, dolomitic shale that occur near the base of the formation. The shale lenses appear to be localized in occurrence, because they were encountered in only a few of the wells in the county.

Because the St. Peter sandstone lies unconformably upon the Prairie du Chien formation, its thickness differs greatly from place to place in Clayton County. The maximum known thickness is 112 feet, which was recorded in the drilling of the Clayton County Home well (93-4-7A1); the minimum known thickness is 30 feet, which was recorded in the drilling of Elkader city well 3 (93-5-23E1). The St. Peter sandstone underlies all the county except the few square miles in the northeastern part where it has been removed by erosion. The configuration and altitude of the top of the formation is shown in figure 18.

*Water supply.* The St. Peter sandstone is the principal aquifer for farm wells in those lowland areas where the deeply dissected valley systems of the Turkey and Volga Rivers have drained the overlying aquifers, and in the dissected upland areas near the headwaters of the creeks that drain directly into the Mississippi River. Although the St. Peter sandstone yields enough water for

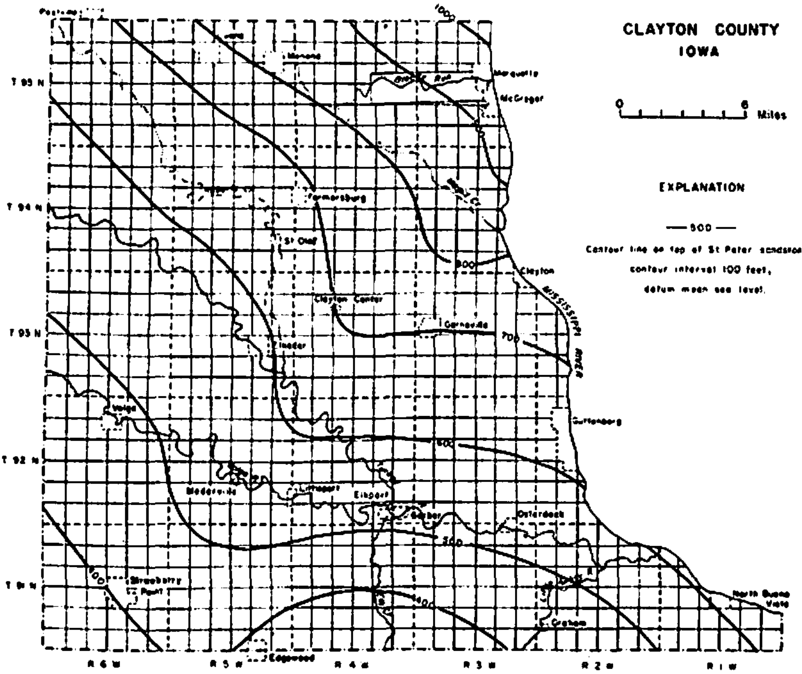

Figure 18.—Map of Clayton County showing the general configuration and altitude of the top of the St. Peter sandstone.

domestic and stock requirements, only locally does it yield enough water for municipal or industrial requirements. The towns of St. Olaf and Garnavillo and the creameries at Millville and St. Olaf pump relatively large amounts of water without excessive drawdown from wells that tap the St. Peter sandstone. The towns of Farmersburg, Monona, Elkader, Guttenberg, and Edgewood and the Clayton County Home had to continue drilling to the Jordan sandstone, because the St. Peter sandstone did not yield enough water for municipal requirements. The low yields throughout most of the county is an indication of the formation's low transmissibility, which is attributed to interstitial clay minerals and localized lenses of shale that occur in the formation and to the great difference in its thickness.

Figure 19 is a piezometric map of the St. Peter sandstone, prepared from water-level data that were obtained when wells were drilled into or through the St. Peter sandstone. The map, therefore, depicts the general configuration and approximate altitude of the pressure-surface before artificial discharge was initiated. However, the configuration of the pressure-surface at the present time is presumably not greatly different, because only small quantities of water are withdrawn from the aquifer so that cones of depression are not extensively developed, and because seasonal fluctuations of the pressure-surface are very slight as indicated by the following water level measurements in well 95-4-22L1 (depth to water in feet below land surface).

| 1957 | | 1958 | | 1959 | |
|---|---|---|---|---|---|
| Date | Water level | Date | Water level | Date | Water level |
| 10-4 | 24.45 | 1-30 | 24.85 | 1-12 | 25.20 |
| 11-25 | 24.43 | 3-4 | 24.87 | 5-26 | 24.66 |
| 12-27 | 24.30 | 3-31 | 25.01 | 7-16 | 23.45 |
| | | 5-2 | 24.25 | 9-3 | 23.79 |
| | | 5-21 | 24.58 | 12-9 | 24.00 |
| | | 6-11 | 24.75 | | |
| | | 7-16 | 24.84 | | |
| | | 8-12 | 25.32 | | |
| | | 9-12 | 24.90 | | |
| | | 10-10 | 25.10 | | |
| | | 11-7 | 24.98 | | |
| | | 12-12 | 24.98 | | |

The contour lines on the piezometric map (fig. 19) indicate not only the approximate altitude to which water will rise in wells drilled into the St. Peter sandstone, but also the direction of ground-water movement within the aquifer. Water in the aquifer moves at right angles to the contour lines and from areas of high head toward areas of low head. The map shows that recharge to the St. Peter sandstone occurs by (1) subsurface inflow from the north and south, and (2) by seepage from the Galena dolomite in the east central part of the county, where the hydrostatic head of the Galena dolomite is higher than that of the St. Peter sandstone.

Discharge from the aquifer is partly toward the Mississippi River and partly toward the west and southwest. The discharge toward the Mississippi River occurs (1) within the outcrop areas of the St. Peter sandstone by direct seepage into Bloody Run Creek, Sny Magill Creek, and the Mississippi River in the Guttenberg area, and (2) in the lower Turkey River Valley by indirect seepage up through the Platteville limestone and Decorah shale. Some water is discharged by subsurface outflow to the west and southwest, as indicated by the ground-water divide at Elkport. Additional evidence comes from water-level measurements in

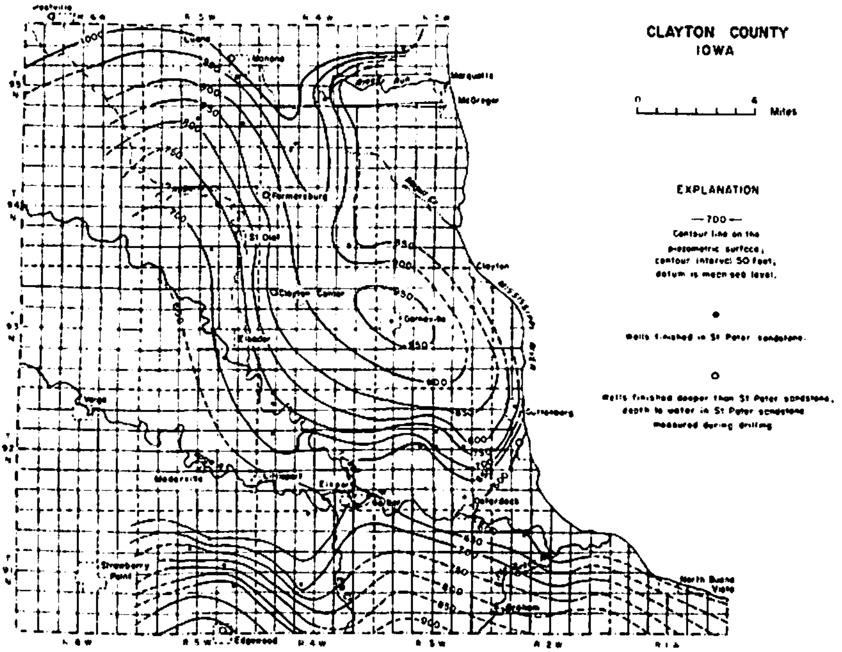

Figure 19.—Map of Clayton County showing the general configuration and altitude of the pressure surface of water in the St. Peter sandstone. The pressure surface shown is based on original static water levels in wells drilled into or through the St. Peter sandstone (see table 6) and, therefore, represents a restored pressure surface.

wells drilled to the St. Peter sandstone in the counties to the west and southwest, which indicate that the regional piezometric surface of the St. Peter sandstone slopes in a generally west-southwest direction.

Analyses of water from the St. Peter sandstone are given in table 4, some of these analyses are graphically illustrated in figure 20. Temperature data of water from the St. Peter sandstone are given in table 4c. The differences in the chemical quality of water from the St. Peter sandstone are attributed to mixing of water from the St. Peter with water from overlying formations.

## *Mohawkian Series*

### Platteville Limestone

*Stratigraphy.* The Platteville limestone, as originally described by Bain (1905, p. 18), included the Decorah shale but later was separated from it because of differences in the faunas. The formation consists of four members which, in ascending order, are the Glenwood shale, Pecatonica dolomite, McGregor

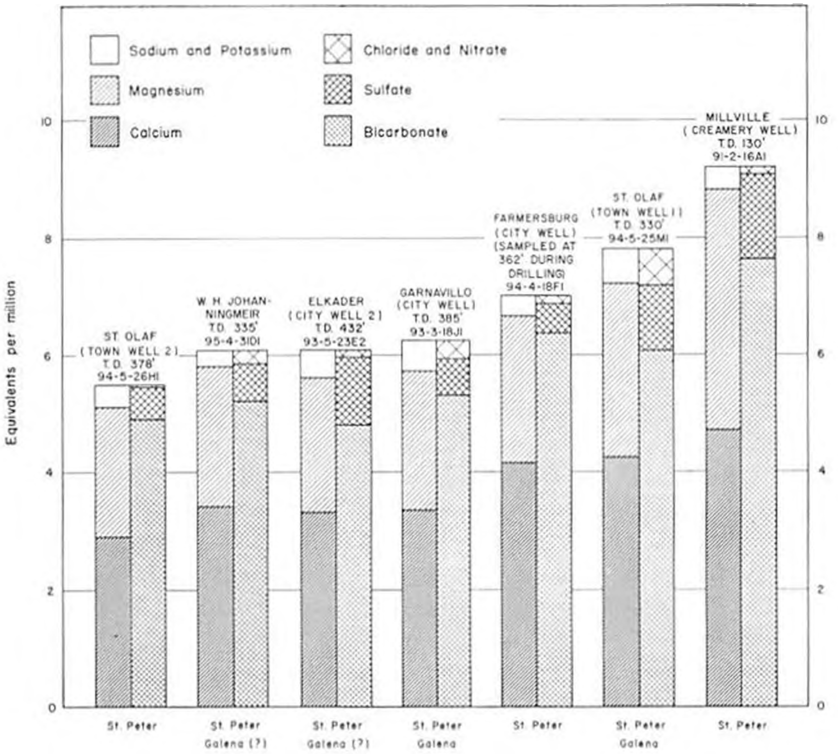

Figure 20.—Graphic representation of chemical analyses of water from the St. Peter sandstone. Other water-bearing units also open to wells also indicated.

member, and the Spechts Ferry member (Kay, 1935b, p. 286-287). The Quimbys Mill member (Agnew and Heyl, 1946, p. 1585-1587), which occurs between the McGregor and Spechts Ferry members, has been recognized in Wisconsin. In Clayton County, however, the Quimbys Mill member is lacking (personal communication from A. F. Agnew, October 13, 1951).

The Glenwood (Calvin 1906b, p. 60-61) is a thin green shale which overlies the St. Peter sandstone. The thickness of this member ranges from 0-25 feet in Clayton County. Although the unit crops out only in a few places, it is well exposed at the St. Peter mine (93-2-7G1Q) south of Clayton, Iowa, where it is only 3 feet thick (table 7), and in a stream cut west of McGregor (95-3-29J1E), where it is only 5 feet thick (table 8).

The Pecatonica dolomite member (Hershey, 1894, p. 175) consists of grayish-brown, mottled, massively bedded dolomite, which contains phosphatic pellets in the lower part. It differs markedly from the overlying thin-bedded McGregor member (pl. 7). The thickness ranges from 0 to 16 feet in Clayton County; where exposed in many quarries and road cuts (tables 7 and 8), the thickness ranges from 12 to 16 feet.

The name McGregor was applied by Kay (1935b, p. 286-287) to beds exposed in a stream cut (95-3-29J1E) about 1.5 miles west of McGregor, Iowa. Characteristically the McGregor member is a thin-bedded limestone, which commonly contains shaly partings and numerous well-preserved fossils. The thickness of this member is greater than that of the Pecatonia, ranging from 0 to 35 feet. The character of this member is well illustrated at a number of quarries and exposures.

Kay (1928, p. 16) originally defined the Spechts Ferry member as the basal member of the Decorah shale but later, because of the faunal relationships, he (1931, p. 370) redefined it as the top member of the Platteville limestone. This member consists of interbedded gray to green shale and very fossiliferous dolomite. The thickness in Clayton County ranges from 0 to 18 feet. This member is not well exposed generally, but good exposures occur at a stream cut (95-3-29J1E), a road cut (95-3-34G1E), and a quarry (92-2-20G1Q), where the Spechts Ferry member is 9 feet, 5 feet, and 7 feet thick, respectively. Plate 7 shows the unit and its contacts with the overlying and underlying units. A special

Plate 7.—Exposure of the Guttenberg limestone member of the Decorah shale (A) and of the Spechts Ferry (B), McGregor (C), and Pecatonica dolomite (D) members of the Platteville limestone in a quarry (92-2-20G1Q) south of Guttenberg.

feature of this member is a persistent thin layer of white, clay metabentonite within about a foot of the base.

*Water supply.* The Platteville limestone yields little water to wells in Clayton County. Generally it is cased off in deep wells to prevent caving of the shale into the well. A few springs flow from the McGregor and the Pecatonica dolomite members, but their flow is small.

### Decorah Shale

*Stratigraphy.* The Decorah shale was named by Calvin (1906b, p. 60-61, 84-87) for exposures within the city of Decorah, Iowa, and consists of two members: the Guttenberg limestone, or "oilrock", and the overlying Ion (Kay, 1928, p. 16).

The Guttenberg limestone member, the type section of which is at Guttenberg, Iowa, consists mainly of distinctive thin-bedded, gray to brown, dense limestone and dolomite, with some imbedded dolomite grains and thin reddish-brown shale partings (pl. 7). Its thickness ranges from 0 to 27 feet across the county.

The Ion member consists of very fossiliferous, interbedded greenish-gray calcareous shale and limestone having a thickness of from 0 to 23 feet. It is well exposed south of Guttenberg along U. S. Highway 52 at a road cut (92-2-33D1E) and at a quarry southwest of Guttenberg (92-2-19R1Q). The Guttenberg limestone member is exposed in the same road cut and in stream and road cuts (95-3-29J1E) and (95-3-34G1E), as well as quarry (92-2-20G1Q).

*Prasopora simulatrix,* a gumdrop-shaped bryozoan occurs characteristically near the top of the Decorah shale, and the brachiopods *Alyptorthis bellarugosa* and *"Dalmanella" rogata* are abundant in the middle and lower parts of the formation.

*Water supply.* The Decorah shale, like the Platteville limestone, yields little water in Clayton County. It is cased off in most deep wells to prevent the shale and thin limestone layers from caving.

### Galena Dolomite

*Stratigraphy.* The Galena dolomite was named by Hall (1851, p. 146-148) and in its type section at Galena, Ill., includes 250 to 300 feet of dolomite and limestone. This formation consists, in ascending order, of the Prosser limestone, Stewartville dolomite, and Dubuque dolomite members. In Minnesota, only the Prosser limestone and Stewartville dolomite members are included in the Galena dolomite; the upper member, the Dubuque dolomite, is included with the overlying beds of the Maquoketa shale (Stauffer and Thiel, 1941, p. 90).

In Clayton County, the Prosser limestone member (Ulrich, 1911, p. 368-369) is composed of a hard, compact dolomite, with limestone beds near the base and considerable chert throughout the member. The lower part of the Prosser is especially cherty and also contains the lower *Receptaculites* zone. The maximum thickness of this member in Clayton County is 132 feet, as indicated by well records and exposures.

The Stewartville dolomite member was defined by Ulrich (1911, p. 368-369) and has a maximum thickness of 77 feet in Clayton County. In surface exposures it is characterized by the weathered, pitted, thickly bedded, porous, brown dolomite, and by the occurrence of the upper *Receptaculites* zone at its base.

In subsurface work, however, the Stewartville dolomite member is difficult to distinguish from the underlying Prosser member, because the dolomite cuttings appear similar and the upper *Receptaculites* zone is rarely noted in drill cuttings. Thus, in subsurface work, the contact between the two members is arbitrarily placed at the transition from non-cherty to cherty dolomite, although this transition occurs within the Prosser limestone member (as defined in surface work). Hence, if the members were redefined so that the contact could be established at the transition from non-cherty to cherty dolomite, the surface and subsurface work would be more conformable.

The Dubuque dolomite member (Sardeson, 1907, p. 193) as redefined by Kay (1935a, p. 563) has a maximum thickness of 50 feet in Clayton County; it consists of thin-bedded dolomite and limestone, interbedded with thin, brown shale. The Dubuque can be distinguished from the underlying Stewartville by the differences in their lithology (pl. 8A and B) and by the presence in the Dubuque of *Lingula iowensis* Owen.

*Water supply.* As in most carbonate rock, the yield of water from the Galena dolomite is dependent on the fractures and solution cavities that are present. This is a variable factor, but apparently the fracture systems in the Galena are better developed in the areas where the Galena is exposed or under a thin cover of the Maquoketa shale. In the southern part of the county, where the Galena dolomite is overlain by the Maquoketa shale and Silurian dolomite, the formation is very tight and will yield only small quantities of water; whereas in the northern part of the county, particularly at Luana, it is possible to draw rather large

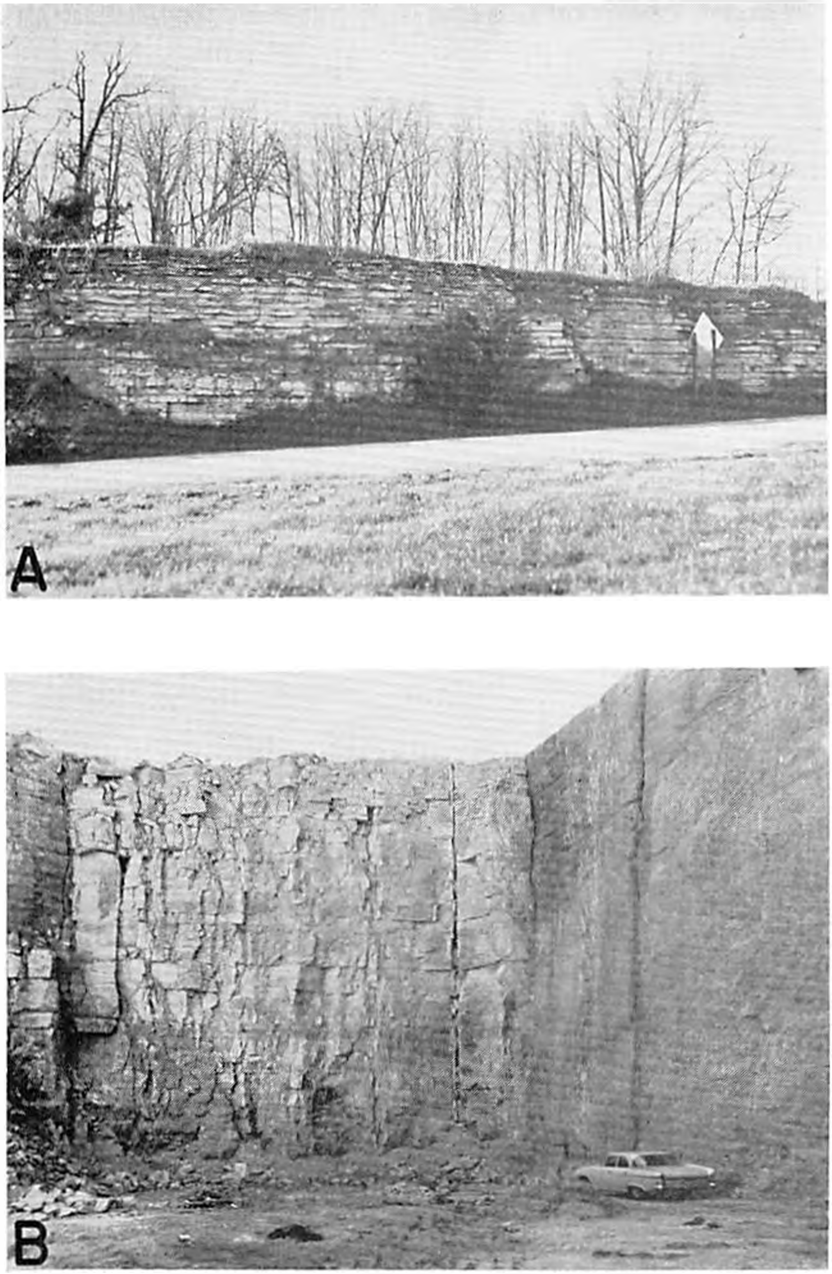

Plate 8.—*A*, Exposure of the Dubuque dolomite member of the Galena dolomite in a road cut (93-5-12K1E) on State Highway 13 north of Elkader, showing the thin beds of dolomite with shale partings which are characteristic of this member; *B*, Exposure of the Stewartville dolomite member in a quarry (93-5-12K2Q) north of Elkader, showing the massive character of this member.

supplies from this formation without excessive drawdowns. The Galena dolomite is the principal aquifer for domestic and stock supplies in the upland areas north of the Turkey River. It is an important aquifer also in the upper reaches of the Turkey and Volga valleys, particularly in the area surrounding the town of Volga (table 6). Also, numerous springs flow from this formation. The largest spring in the county, Big Spring (94-5-31R1S), discharges from the Galena dolomite.

Figure 21 is a map of the generalized piezometric surface of the Galena dolomite based on water-level measurements made when wells were drilled into or through the Galena dolomite. The configuration of the piezometric surface, unlike that of the St. Peter sandstone, is subject to seasonal changes owing to seasonal variations in local precipitation. The decreasing rate of flow from springs in the Galena dolomite during dry periods is an indication that the piezometric surface is declining in the recharge areas, whereas the increasing rate of flow during wet

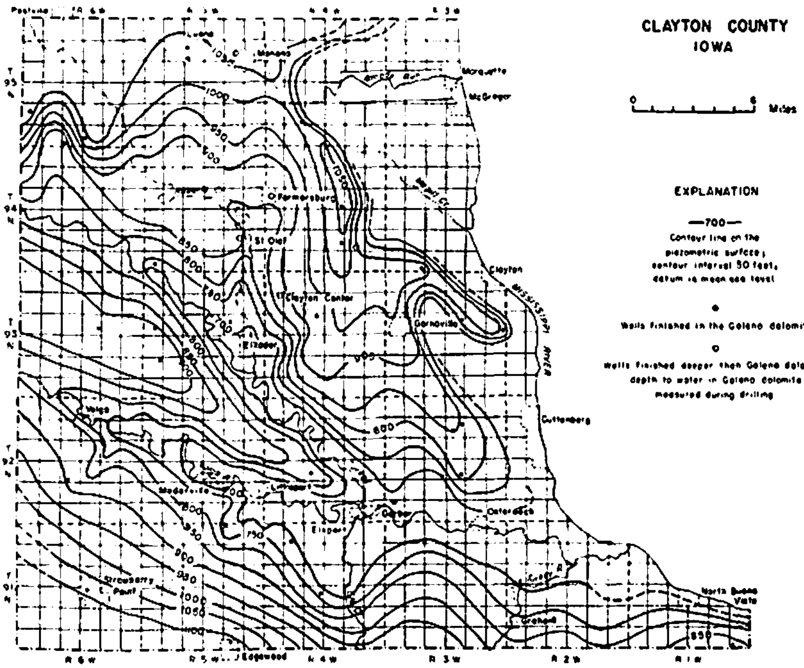

Figure 21.—Map of Clayton County showing the general configuration and altitude of the pressure surface of water in the Galena dolomite. The pressure surface shown is based on original static water levels in wells drilled into or through the Galena dolomite (see table 6) and, therefore, represents a restored pressure surface.

periods denotes a rising piezometric surface. However, because recharge by direct infiltration of precipitation occurs only on the interstream upland between Sny Magill Creek and Turkey River, any major fluctuations of hydrostatic pressures in the aquifer is restricted to this area. The piezometric map of the aquifer in general, therefore, is considered to closely approximate the actual hydrostatic pressures in the aquifer, and the contour lines indicate the approximate altitude to which water will rise in wells drilled into the Galena dolomite.

Recharge to the aquifer in Clayton County is partly by subsurface inflow from the north and south, partly by direct infiltration of precipitation in the interstream outcrop areas, and partly by seepage from overlying formations in the interstream areas (fig. 21). Much of the recharge in the interstream area between Sny Magill Creek and Turkey River is aided by the numerous sinkholes in the area.

Natural discharge from the aquifer in the county is toward the Mississippi River, partly by springs and partly by direct seepage into the Turkey and Volga Rivers and other smaller streams that flow into the Mississippi River. Approximately ¾ of the estimated 11 mgd total spring flow in the county during periods of average precipitation is discharged by the springs in the Galena dolomite. The amount of discharge by seepage is not accurately known, but the water discharged by seepage and most of the springs provides the major contribution to the base flow of the Turkey and Volga Rivers (see section on ground-water discharge).

The sanitary quality of water from the Galena dolomite is quite poor in many places, because of the rapid infiltration of contaminated surface water into sinkholes and the rapid flow of this water through large solution channels. The chemical quality of water is shown in figure 22. The dissolved solids content and hardness of the water are shown in table 4a and 4b; temperature data are shown in table 4c.

## *Cincinnatian Series*

### Maquoketa Shale

*Stratigraphy.* The Maquoketa shale was named from exposures of shale along the Little Maquoketa River in Dubuque County, Iowa (White, 1870, p. 180-182). In Clayton County it comprises four members, the Elgin limestone, Clermont shale, Ft. Atkinson dolomite, and the Brainard shale, in ascending order.

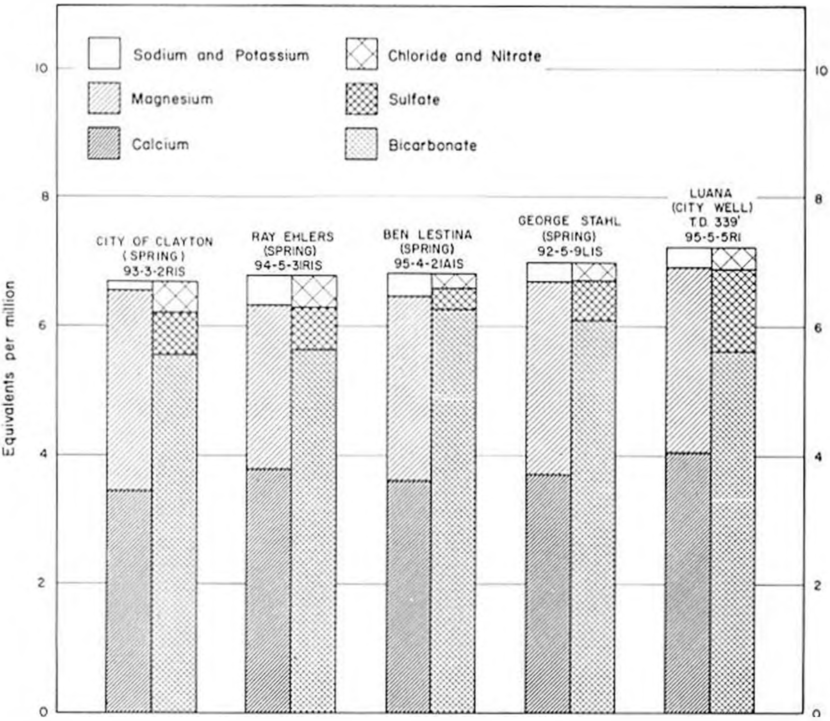

Figure 22.—Graphic representation of chemical analyses of water from the Galena dolomite.

These members were all named by Calvin (1906b, p. 60, 98) and redescribed in detail by Ladd (1929, p. 309-440).

The Elgin limestone member in Clayton County consists of clayey gray to buff dolomite and shale. It is slightly darker and more clayey to the south and it contains chert to the north. Where not eroded, the minimum observed thickness of the Elgin is 38 feet, which was measured in a stream cut (91-4-14E1E) south of Garber; whereas in a well at Postville the thickness is 110 feet. The Elgin thins toward the south and east.

The Clermont shale member consists of bluish-green shale throughout Clayton County. Although its thickness ranges from 0 to 40 feet, it is about 14-feet thick in the few exposures seen in the county. An excellent exposure can be seen northwest of Gunder (94-6-4C1E), and another in the stream cut previously mentioned for the Elgin limestone member (91-4-14E1E).

Where identified in wells in the county the Ft. Atkinson dolomite member consists of 20 to 40 feet of cherty dolomite. Some good exposures of this unit can be seen at the same localities that were cited for the Clermont shale member.

The Brainard shale member is poorly exposed in Clayton County because it erodes so easily. The only location where this member is completely exposed is in the stream cut south of Garber (91-4-14E1E). Thicknesses of 100 to 126 feet have been recorded in the drilling of wells. The member consists of grayish-green blocky shale.

*Water supply.* Several wells in the northwestern part of the County tap the Maquoketa shale, and some springs flow from the middle or upper members. Ordinarily the formation is usually cased off in deep wells.

## SILURIAN SYSTEM

### *Alexandrian Series*

#### **Edgewood Limestone**

*Stratigraphy.* Savage (1909, p. 517-518) designated the limestone beds of Silurian age at Edgewood, Pike County, Mo., as the Edgewood limestone. Equivalent beds in Iowa, considered to represent a different depositional basin, were named the Winston limestone (Savage, 1914, p. 34-37), but subsequently this term was abandoned (Savage, 1926; Scobey, 1935).

In Clayton County, the Edgewood limestone is composed of yellow to gray, sandy, thin-bedded dolomite with scattered nodules of chert. The thickness varies widely, becoming thicker as the underlying Brainard shale member of the Maquoketa shale thins. In Clayton County, the thickness of the formation ranges from 0 to 35 feet. The Edgewood and younger Silurian formations underlie only the southern and west-central parts of the county.

*Water Supply.* Because the underlying impermeable Brainard shale member prevents downward movement of water, the base of the Edgewood limestone is marked by countless springs and seeps. Although nearly all the wells tapping the Silurian rocks in this county were drilled to the easily recognized top of the Maquoketa shale, little water seems to be obtained from the Edgewood limestone except from occasional crevices.

#### **Kankakee Limestone**

*Stratigraphy.* The Kankakee limestone was named by Savage (1916, p. 305-324) to include the upper part of the Alexandrian series in Illinois and Missouri. Equivalent beds in Iowa were first termed the Waucoma limestone (Savage, 1914, p. 35-36), but later assigned to the Kankakee (Savage, 1926; Scobey, 1935).

The Kankakee limestone in Clayton County is composed of yellow to buff dolomite interbedded with bands of chert. The chert, which comprises 20 to 40 percent of the formation, occurs in thin, irregular layers that gives the formation a characteristic banded appearance (pl. 9). The top of the Kankakee limestone is defined as the uppermost definite chert layer that occurs in the dolomite section. Thus, in surface work, the contact between the Kankakee limestone and the overlying Hopkinton dolomite is precisely located, although the base of the Hopkinton contains scattered, nodular chert. In subsurface work, however, the layered chert in the Kankakee limestone cannot be distinguished from the nodular chert in the Hopkinton dolomite; therefore, the contact between the two formations is impossible to establish with any degree of accuracy. Thus, the thickness assigned to the Kankakee limestone on the basis of subsurface work is open to considerable doubt. The maximum thickness measured in surface exposures is 31 feet (table 7), but nowhere was a complete section with both upper and lower stratigraphic boundaries observed. The maximum thickness based on subsurface work is 140 feet (see table of logs). Thus, the actual thickness of the formation is greater than 31 feet and probably considerably less than 140 feet. Obviously, wherever the Kankakee limestone is

PLATE 9.—EXPOSURE OF THE KANKAKEE LIMESTONE IN A QUARRY (93-6-36P1Q)) NORTHEAST OF VOLGA, SHOWING THE THIN-BEDDED AND NODULAR WHITE CHERT THAT IS CHARACTERISTIC OF THIS FORMATION.

assigned too great a thickness, the overlying Hopkinton dolomite will be concomitantly thinner. However, the maximum total thickness of both units is about 190 feet (table 2).

*Water suppply.* The Kankakee limestone is not a very productive aquifer in Clayton County. Because it is not cased off in any of the wells that penetrate the complete Silurian section, some water from this formation may enter wells. However, the main sources of water seems to be the overlying Hopkinton dolomite.

The Kankakee limestone and overlying Hopkinton dolomite contain a great many sinkholes in the southern part of Clayton County. The sinkholes are a major factor in the drainage of that part of the area where these limestones are covered by Iowan drift, so that much of the water which would otherwise run off is carried underground. Some of this water may leave the county by subsurface outflow to the south and southwest, but most of it probably is discharged by the countless springs that issue from the Silurian rocks.

### *Niagaran Series*

#### Hopkinton Dolomite

*Stratigraphy.* The Hopkinton dolomite was named by Calvin (1906a, p. 572-574). It consists of the massive dolomite between the base of the Niagaran series and the top of the beds containing the brachiopod *Pentamerus.*

The Hopkinton dolomite is not well exposed in Clayton County, although 20 feet is exposed at a quarry (91-6-18Q1Q) for crushed rock and agricultural lime. The formation is a massive, yellow to buff, medium-to coarse-grained dolomite, which contains some nodular chert, particularly near the base. The maximum thickness is believed to be about 125 feet although, as indicated in the description of the Kankakee limestone, it may be somewhat less.

*Water supply.* The Hopkinton dolomite supplies many farm wells in the southwestern part of Clayton County and also the city and creamery wells at Strawberry Point. Most of the wells drilled into this dolomite, however, also penetrate the Kankakee and Edgewood limestones, so that some of the water may be obtained from these formations. The chemical quality of water from the Silurian formations is presented in table 4 and graphically shown in figure 23. Differences in the hardness and dissolved solids content of water from the Silurian formations are shown in tables 4a and 4b; temperature data is presented in table 4c.

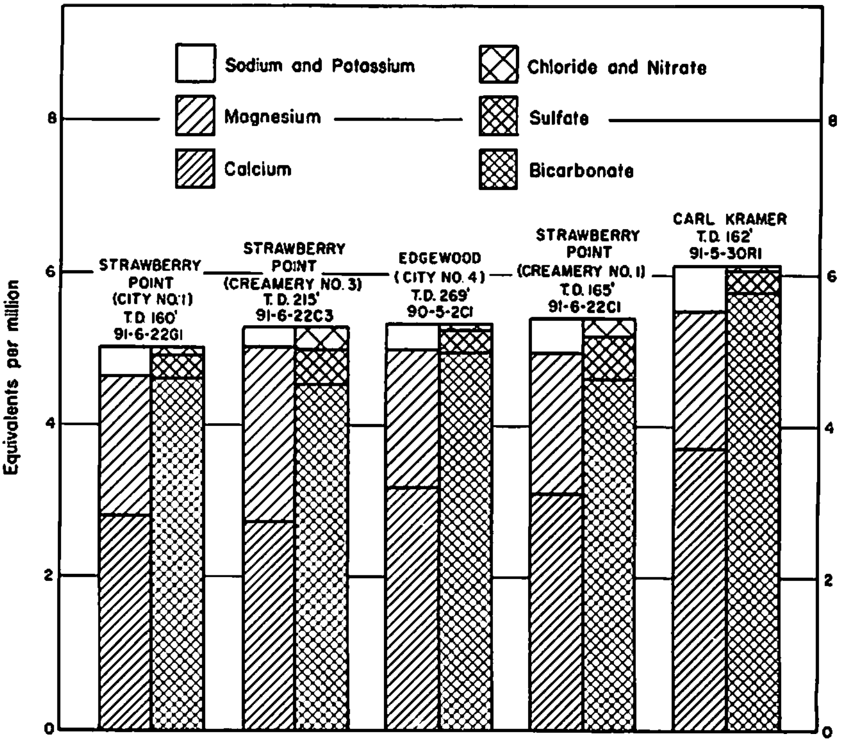

Figure 23.—Graphic representation of chemical analyses of water from the Silurian formations.

## QUATERNARY SYSTEM

### *Pleistocene Series*

### Glacial Deposits

*Stratigraphy.* The bedrock throughout much of Clayton County is covered by deposits of glacial till which consists of yellow, buff, brown, and gray, unstratified pebbly clay. These deposits were left by the three continental glaciers that invaded this area during the Pleistocene epoch. In addition, melt water from the glaciers deposited sand, gravel, silt, and clay in the valleys as valley trains. The silt fraction of the valley trains served as the source material for the wind-blown deposits called loess, which accumulated on the upland surfaces. Between the periods of glaciation, the tills and associated deposits were subjected to weathering and erosion, the degree of weathering depending largely upon the length of time between ice invasions.

A detailed study of the Pleistocene deposits in Iowa has been in progress for many years. The nomenclature used by Kay and Apfel (1929) and Kay and Graham (1943) in their review of the general features of these deposits is followed in this report.

The name of the stage applies equally to the continental ice sheet, to the mantle of till deposited by the ice sheet, and to the contemporary deposits of stratified drift. The total thickness of the glacial deposits ranges from less than a foot to as much as 130 feet. The greater thicknesses are in that part of the county covered by the Iowan ice sheet of the Wisconsin stage of glaciation.

The deposits of the Nebraskan ice sheet, which completely covered the county, have been almost completely removed by erosion; only scattered quartzose residuum remains on a few high surfaces outside the Kansan boundary (fig. 24) and, locally, thin remnants underlie the Kansan drift. Deposits of the Kansan glacier cover a large part of Clayton County (fig. 24). Where not protected by overlying deposits of the Iowan the Kansan till has been deeply weathered and largely removed by erosion; nowhere in the county is it much more than 20 feet thick. Iowan till underlies only the southwestern part of the county (fig. 24) and is the only till sheet that conceals the bedrock topography of the county. The Iowan till is mostly gray, whereas the older Kansan till is mostly brown.

Deposits of gravel, sand, and silt, formerly termed the Buchanan gravels (Calvin, 1896, p. 58-60), are present at scattered localities in Clayton County. These deposits are interpreted to be Kansan outwash that was deeply weathered during post-Kansan time. They are characteristically red and iron stained and locally are as much as 10 feet thick. Two good exposures of these gravels are south of Elkader in the NE¼NE¼ sec. 34, T. 93 N., R. 5 W., and north of Elkader in the NW¼NW¼ sec. 35, T. 94 N., R. 5 W.

Deposits of loess cover much of the county, but studies of these sediments are not as yet sufficiently advanced to positively distinguish loess other than that clearly assignable to the Wisconsin stage. The loess is well exposed in sec. 35, T. 94 N., R. 5 W., where it overlies "Buchanan" gravels.

Terraces along the Mississippi River and the major streams in Clayton County show that the streams at one time had a much larger volume and carried a far greater load of sediments than they do now. Although the formation of the terraces was, without doubt, related to the glaciation in the area, the terraces have

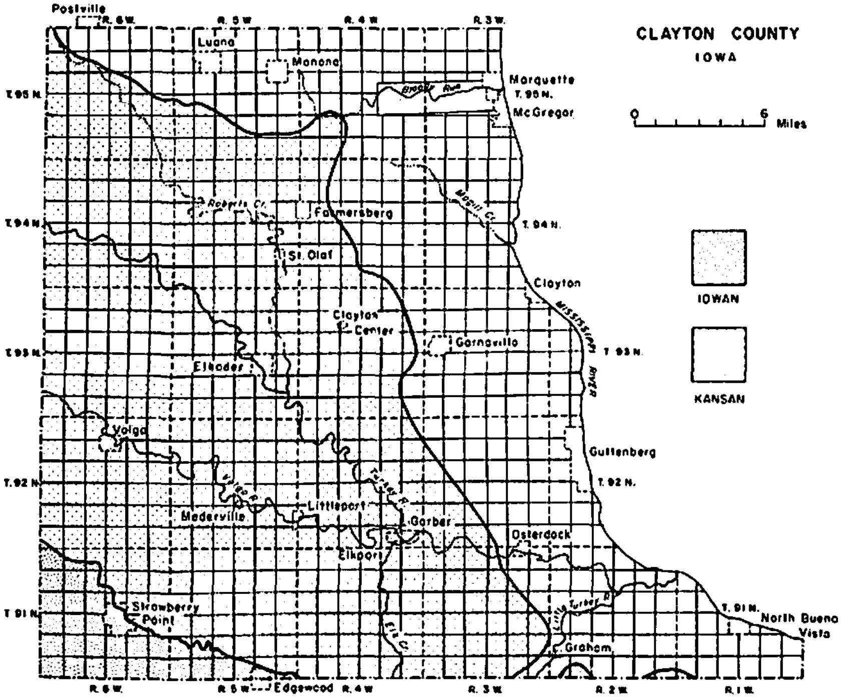

Figure 24.—Map showing the present distribution of the Kansan and Iowa drifts.

not been definitely correlated with the stages of the Pleistocene. The town of Osborne in the SE¼SW¼ sec. 9, T. 92 N., R. 5 W., is built upon one of the terraces along the Volga River.

Alluvial deposits that underlie the flood plains of the rivers, particularly the Mississippi River, are at least in part of Wisconsin age. The water supply from alluvium is discussed under Recent deposits, because there is no way of differentiating the ages of these deposits.

Pleistocene deposits are well exposed northwest of Gunder. The water-laid sand beneath the till in the following section is crossbedded and shows marked involutions that seemingly were caused by pressure as glacial ice moved over it.

*Pleistocene deposits in the SW¼NW¼ sec. 4, T. 94 N., R. 6 W., near Gunder, Iowa*

| *Unit* | *Description* | *Thickness* (feet) |
|---|---|---|
| 10. | Loess, dark-brown, oxidized, leached, silty and clayey | 1 |
| 9. | Loess, medium- to dark-brown, oxidized, leached, clayey | 9 |
| 8. | Till, medium-brown, oxidized, leached, silty | 4 |
| 7. | Till, dark-brown, oxidized, leached, silty, sandy | 2 |
| 6. | Till, buff to medium-brown, oxidized, unleached, silty and sandy | 15.7 |
| 5. | Sand and silts, medium- to dark-brown, oxidized, unleached, waterlaid, poorly sorted, well-cemented | 1.3 |
| 4. | Sand, buff, oxidized, unleached, medium-fine, dominantly quartz, crossbedded | 1 |
| 3. | Sand, as above, intermixed with waterlaid clay | 1 |
| 2. | Sand, buff, oxidized, unleached, coarse to fine, dominant quartz | 1 |
| 1. | Silt, buff to gray, oxidized, unleached, micaceous | 3 |
| | Total | 39 |

In this section the till is of Kansan age and the underlying sand and silt is pre-Kansan. The loess overlying the till undoubtedly is of early Wisconsin age.

*Water supply.* The development of water from the Pleistocene deposits in Clayton County is restricted to the Iowan drift area. The Kansan drift does not yield water in its outcrop area, because the drift is generally too thin and too dissected to hold water.

Englacial sand deposits within the Iowa drift and interglacial sand and gravel deposits between the Iowan and Kansan drifts yield small quantities of water to several dug wells and a few drilled wells. Because these deposits occur as thin, discontinuous lenses and stringers, they are difficult to locate and they are unable to yield enough water to satisfy modern demands. However, if the requirements for water are low, these sandy zones within and at the base of the Iowan drift yield a fairly constant supply. Wells like the Elmer Baldridge well (91-6-22D1) have obtained a small but constant yield from the Iowan drift for many years.

### Recent Deposits

*Stratigraphy.* Deposits of Recent age, excepting soils, are restricted to the valleys of the major streams of the county and are called alluvium. They consist of silt, clay, sand, and gravel beneath the flood plains of the rivers in the county. As indicated in the discussion on the glacial deposits, the alluvium probably is in part of Wisconsin age. The locations of some sand and gravel deposits in the county are shown in figure 6.

*Water supply.* The city of Guttenberg initially obtained its water supply from a large-diameter dug well finished at a depth of 26 feet in the alluvium of the Mississippi River flood plain. This well was capable of yielding 200 gpm with a 20-foot drawdown in water level. The well was abandoned because the water had a high nitrate content.

The alluvial aquifers are not extensively developed as a source of water supply in the county. A few wells, such as the F. G. Cummings well (92-6-10C1) and the Willman Store well (91-3-2A1) obtain small quantities of water from the alluvium along the Volga and Turkey Rivers. The alluvium along the interior streams are not thick enough or extensive enough to yield more than small to moderate quantities of water. The Mississippi River alluvium, however, probably could yield moderate to large quantities of water. The city of Dubuque, about 10 miles downstream from the county line, pumps an average of approximately 6 mgd from the Mississippi River alluvium.

Chemical analyses of water from some of the alluvial aquifers is presented in table 4 and graphically shown in figure 25. Temperature data on this water are shown in table 4c.

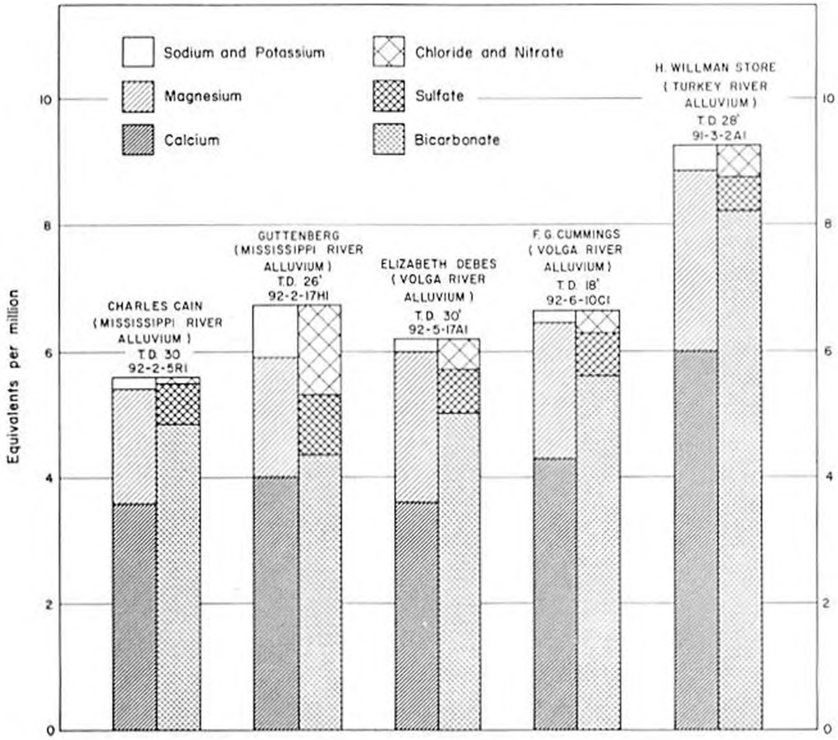

Figure 25.—Graphic representation of chemical analyses of water from the alluvium.

## SUMMARY AND CONCLUSIONS

The Silurian formations and Galena dolomite supply moderate quantities of water to many farm wells throughout the county. Only locally, such as at Strawberry Point, Volga, and Luana, do these aquifers yield large quantities of water. The yields of wells may be increased by acidizing the wells.

Comparison of the estimates of natural and artificial discharge indicates that additional water could be developed from these aquifers without critically depleting these reservoirs. Because their recharge and discharge areas are within close proximity of each other, and because their major form of recharge is by local precipitation, the hydrostatic pressures within the aquifers respond rather quickly to variations in local precipitation. During periods of drought, when the total discharge temporarily exceeds the recharge to these aquifers, spring flows diminish and water levels drop in wells. Because of this, wells drilled into the Silurian formations and Galena dolomite should completely penetrate the entire aquifer. The water from wells that are in close proximity to sinkholes are subject to contamination and should, therefore, be analyzed for bacteria.

The St. Peter sandstone supplies sufficient water for domestic and stock supplies in the eastern half of the county. Only locally does this aquifer supply large quantities of water for municipal or industrial purposes. The variation in water yield is attributed to variations in the permeability and thickness of the formation. Data on the St. Peter sandstone in the western tier of townships are not available.

Slightly more than ½ mgd of water is pumped by municipalities and a few industries from the deep aquifers in Clayton County. Most of this water is withdrawn from the Jordan sandstone and underlying St. Lawrence formation and a lesser amount from the Galesville sandstone of the Dresbach group. Both these aquifers are known to yield abundant supplies of water to wells in the eastern half of the county. Data from adjacent Fayette County indicate that additional supplies could be developed from the Jordan sandstone in the western part of the county, although wells would be deeper and static water levels probably lower.

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## TABLE 5. RECORDS OF SELECTED SPRINGS IN CLAYTON COUNTY

Spring number: Springs are numbered according to numbering system shown in figure 2.

Date: Date when yield and temperature were determined.

Yield: Determined by use of V-notch weir (a), measured cross section of channel and velocity (b), or estimation (c).

| Spring number | Owner | Geologic source | Topographic situation | Date | Yield (Gallons per minute) | Temperature (°F) | Use of water | Remarks |
|---|---|---|---|---|---|---|---|---|
| 91-4-9H1S | John Wiley | Maquoketa shale | Valley side | 8-15-51 | 5$^{c}$ | ... | Stock | |
| 91-4-14M1S | Roy Appleton | do | do | 8- 3-51 | 8$^{c}$ | 49 | do | |
| 91-4-26E1S | C. Gleason | Edgewood limestone | do | 8-28-51 | 4$^{a}$ | 49 | do | |
| 91-4-26M1S | C. Gleason | do | do | 8-28-51 | 5$^{c}$ | ... | do | |
| 91-5-27C1S | Bassett Brothers | Kankakee limestone | do | 7-10-51 | 10$^{c}$ | ... | do | |
| 91-6-3R1S | E. Zwanziger | do | do | 6-26-51 | 5$^{c}$ | ... | do | |
| 91-6-10C1S | Carl Kleinlein | Edgewood limestone | do | 6-18-51 | 400$^{b}$ | 49 | do | Analysis of water given in table 4. |
| 91-6-12C1S | J. R. Alderson | do | do | 6- 3-51 | 150$^{b}$ | 49 | Domestic and stock | |
| 91-6-17P1S | Newberry Estate | Hopkinton dolomite | Rolling plain | 7- 5-51 | 7$^{c}$ | 48 | Stock | |
| 91-6-19P1S | John Lee | do | Valley side | 7- 7-51 | 50$^{a}$ | 49 | do | Analysis of water given in table 4. |
| 91-6-19P2S | John Lee | do | do | 7- 7-51 | 19$^{a}$ | 49 | do | |
| 92-3-30A1S | Rudolph Rentschler | Galena dolomite | do | 8- 6-51 | 8$^{c}$ | ... | do | |
| 92-4-7B1S | E. H. Klink | do | do | 9- 3-51 | 75$^{b}$ | 49 | do | |
| 92-4-18E1S | Leroy Klink | do | do | 9- 3-51 | 15$^{c}$ | ... | do | |
| 92-4-25R1S | Eunice Thein | Galena dolomite | Valley side | 7-27-51 | 10$^{c}$ | ... | ... | |
| 92-5-9L1S | George Stahl | do | do | 7-25-51 | 200$^{a}$ | 50 | ... | Analysis of water given in table 4. |
| 92-5-21E1S | Myrtle Kramer | do | Valley floor | 7-12-51 | 250$^{b}$ | 49 | Trout pond | |
| 92-5-27R1S | Otto Hakert | Edgewood limestone | Valley side | 8- 3-51 | 7$^{c}$ | ... | Stock | |
| 92-5-27Q1S | Otto Hakert | do | do | 8- 3-51 | 5$^{c}$ | ... | do | |
| 92-5-31E1S | Herman Kruse | do | do | 8- 3-51 | 10$^{c}$ | ... | do | |
| 92-5-34G1S | J. W. Stocks | Maquoketa shale | do | 8- 5-51 | 8$^{c}$ | ... | do | |
| 92-5-35D1S | R. E. Liddy | do | do | 8- 5-51 | 20$^{c}$ | ... | do | |
| 92-6-3L1S | L. C. Richards | do | do | 9- 4-51 | 25$^{c}$ | 50 | ... | |
| 92-6-14G1S | Stanley Sargent | do | Valley floor | 7-24-51 | 5$^{a}$ | 52 | Stock | Analysis of water given in table 4. |
| 92-6-16R1S | Harry Roeder | Edgewood limestone | Valley side | 7-24-51 | 8$^{c}$ | ... | do | |
| 92-6-20G1S | Walter Manson | do | do | 7- 6-51 | 150$^{b}$ | 49 | do | |
| 92-6-20N1S | George Andreae | do | do | 7- 6-51 | 10$^{c}$ | ... | do | |
| 92-6-20P1S | Walter Manson | do | do | 7- 6-51 | 30$^{c}$ | 49 | do | |
| 92-6-21A1S | Roy Klingman | do | do | 7- 6-51 | 15$^{c}$ | ... | do | |
| 92-6-21C1S | Harry Roeder | do | do | 7- 6-51 | 8$^{c}$ | ... | do | |
| 92-6-26J1S | Mary O'Brien | do | do | 7- 3-51 | 20$^{a}$ | 48 | do | |
| 92-6-29B1S | Sig Koehler | Edgewood limestone | Valley side | 7-22-51 | 8$^{c}$ | ... | Stock | |
| 92-6-32K1S | Martin Baumgartner | do | do | 8-28-51 | 300$^{b}$ | 49 | do | |
| 92-6-32K2S | Martin Baumgartner | do | do | 8-28-51 | 18$^{c}$ | 49 | do | |
| 93-2-7G1S | Concrete Materials and Construction Division | Platteville limestone | do | 9-12-54 | 7$^{c}$ | 54 | Private drinking | Analysis of water given in table 4. |
| 93-2-30P1S | Wm. and John Link | Galena dolomite | do | 8- 6-51 | 5$^{c}$ | ... | Stock | |

| | | | | |
|---|---|---|---|---|
| 93-3-2R1S...... | City of Clayton........ | do | do | 2- 4-54 |
| 93-3-22J1S..... | G. W. Hunt........... | Decorah shale | do | 7-12-51 |
| 93-3-22L1S..... | G. W. Hunt........... | do | do | 7-12-51 |
| 93-3-23N1S..... | Jac. Jaeger............ | Galena dolomite | do | 7-12-51 |
| 93-3-26C1S..... | L. O. Hall............. | Decorah shale | do | 7-21-51 |
| 93-3-26D1S..... | L. O. Hall............. | do | do | 7-21-51 |
| 93-3-26G1S..... | L. O. Hall............. | do | do | 7-21-51 |
| 93-3-27A1S..... | Jac. Jaeger............ | Platteville limestone | do | 7-21-51 |
| 93-4-12C1S..... | Lester Kromer.......... | Galena dolomite | Rolling plain | 7- 5-51 |
| 93-6-31P1S..... | T. and R. Leahy....... | Maquoketa shale | Valley floor | 7- 5-51 |
| 94-4-2M1S..... | O. J. Schoulte.......... | Galena dolomite | Rolling plain | 10-13-54 |
| 94-4-8Q1S...... | Fritz Mueller.......... | Galena dolomite | Rolling plain | 10-13-54 |
| 94-4-9B1S...... | Serenus Eilers.......... | do | do | 10-13-54 |
| 94-4-12B1S..... | Casper Schoulte........ | do | do | 10-13-54 |
| 94-4-17B1S..... | Arno Henning.......... | do | do | 10-13-54 |
| 94-5-4Q1S...... | Roy Saacke............ | Maquoketa shale | do | 10-13-54 |
| *94-5-5L1S*...... | *A. H. Olsen*............ | *do* | *Valley floor* | *7-15-51* |
| 94-5-12J1S..... | John Bossard.......... | Galena dolomite | Rolling plain | 10-12-54 |
| 94-5-13P1S..... | Oscar Thompson....... | do | do | 10-12-54 |
| 94-5-31R1S..... | Ray Ehlers (Big Spring) | do | Valley side | 7-28-51 |
| *94-6-12K1S*..... | *A. A. Gulsvig*.......... | Maquoketa shale | do | 7-15-51 |
| 94-6-21P1S..... | Emil Maur............ | do | do | 7-15-51 |
| 95-3-35E1S..... | Pikes Peak State Park.. | Galena dolomite | do | 7-24-51 |
| 95-4-1B1S...... | Frank Sanger.......... | do | do | 10-14-54 |
| 95-4-2E1S...... | Ray Grady............ | do | do | 10-14-54 |
| 95-4-2L1S...... | Frank Blaha.......... | do | do | 10-14-54 |
| 95-4-12A1S..... | Milton Nelson......... | do | do | 10-14-54 |
| *95-4-12R1S*..... | Milton Nelson......... | Galena dolomite | Valley side | *10-14-54* |
| 95-4-15M1S..... | F. V. Lestina.......... | do | ............ | 8-18-38 |
| 95-4-21A1S..... | Ben Lestina.......... | do | Valley side | 7-24-51 |
| 95-4-22E1S..... | Charles Welch......... | Platteville limestone | do | 10-15-54 |
| 95-4-25K1S..... | Emma Yearous......... | Galena dolomite | do | 10-15-54 |
| 95-4-31R1S..... | Gaylord Oelke......... | do | do | 10-15-54 |
| 95-4-33J1S..... | Dale Thompson........ | do | Rolling plain | 10-15-54 |
| 95-4-36B1S..... | Frank Davies......... | do | do | 10-15-54 |
| 95-5-1P1S...... | Elgie Ferguson......... | do | Valley side | 10-15-54 |
| 95-5-2C1S...... | Edmund Ryan......... | do | do | 10-15-54 |
| 95-5-22H1S..... | Raymond Kohler....... | Maquoketa shale | do | 10-15-54 |
| 95-5-26P1S..... | Kenneth Thompson..... | do | Rolling plain | 10-15-54 |
| 95-5-28N1S..... | Carl Johanningmeier.... | do | do | 10-15-54 |

| | | | |
|---|---|---|---|
| 100[c] | 54 | Public drinking | Analysis of water given in table 4. Combined flow of two springs. |
| 8[c] | 49 | Stock | |
| 12[c] | 49 | do | |
| 15[c] | ... | do | |
| 8[c] | ... | do | |
| 12[c] | ... | do | |
| 15[c] | ... | do | |
| 5[c] | ... | do | |
| 8[c] | ... | do | |
| 12[c] | 50 | do | |
| 8[c] | 48 | do | |
| 12[c] | ... | Stock | |
| 10[c] | 48 | do | |
| 5[c] | ... | do | |
| 4[c] | 49 | do | |
| 12[c] | 48 | do | |
| 10[c] | 50 | do | |
| 8[c] | ... | do | |
| 10[c] | 49 | do | |
| 5,000[c] | 47 | Fish hatchery | Analysis of water given in table 4. Owner reports that spring flows an average of 5,000 gpm; immediately following heavy rains, it flows as much as 10,000 gpm. |
| 4[c] | 50 | Stock | |
| 1[a] | 57 | ... | Analysis of water given in table 4. |
| 15[c] | 49 | ... | |
| 22[c] | 49 | Stock | |
| 8[c] | 48 | do | |
| 5[c] | 48 | do | |
| 7[c] | 49 | do | |
| 10[c] | 49 | Stock | |
| 100[c] | 49 | ... | Analysis of water given in table 4. |
| 210[b] | 49 | Stock | Analysis of water given in table 4. |
| 6[c] | 49 | do | |
| 15[c] | 50 | do | |
| 5[c] | 49 | do | |
| 12[c] | 49 | do | |
| 8[c] | 49 | do | |
| 5[c] | ... | do | |
| 4[c] | 50 | do | |
| 18[c] | 49 | do | |
| 10[c] | 49 | do | |
| 3[c] | 49 | do | |

## TABLE 6. RECORDS OF SELECTED

Well number: Wells are numbered according to the numbering system

Type of well: Dg, dug; Dp, drive point; Dr, drilled.

Depth of well: Measured depths given in feet and tenths; reported depths indicated depth.

Type of casing: B, brick; C, copper; I, iron or steel; N, none; R, rock;

Type of pump: J, jet; L, lift; N, none; Ps, pressure system (type of

Type of power: E, electric; G, gasoline engine; H, hand; W, wind and

Altitude: Determined with altimeter or hand level, accurate to within

Water level: Measured levels given in feet and hundredths; reported

Use of water: A, abandoned; D, domestic; Ind, industrial; M, municipal;

| Well number | Owner or tenant | Well construction | | | | | Method of lift | |
|---|---|---|---|---|---|---|---|---|
| | | Type | Depth (feet) | Diameter (inches) | Casing | | Pump | Power |
| | | | | | Type | Depth (feet) | | |
| 90-5-2C1 | Edgewood City Well 4 | Dr | 269 | 10 | I | 84 | T | E |
| 91-1-26K1 | George Kamm | Dr | 265 | ...... | I | ...... | L | W |
| 91-1-36N1 | Jaeger farm | Dr | 245 | ...... | ...... | ...... | ...... | ...... |
| 91-2-8B1 | William Moran | Dr | 370 | 6 | I | ...... | T | E |
| 91-2-9G1 | G. W. Hunt | Dr | 55 | 6 | ...... | ...... | ...... | ...... |
| 91-2-16A1 | Millville Creamery | Dr | 130 | 8 | I | ...... | T | E |
| 91-2-28L1 | Rae Anderegg | Dr | 565 | 5 | | ...... | L | W |
| 91-3-2A1 | H. Willman Store | Dp | 28 | 1¼ | ...... | ...... | Ps | E. |
| 91-3-14E1 | John Moser | Dr | 395 | 5 | I | ...... | Ps | E |
| 91-3-19F1 | Elmer Simmons | Dr | 425 | 6 | I | ...... | L | G |
| 91-4-4B1 | Ted Smock | Dr | 305 | 5 | I | ...... | L | W |
| 91-4-5P1 | Pilkington Farm | Dr | 205 | 5 | I | ...... | L | W |
| 91-4-21H1 | Art Wessell | Dr | 525 | 6 | I | ...... | L | G |
| 91-4-21L1 | Dr. D. W. Newman | Dr | 875 | 6 | I | 274 | L | G |
| 91-5-2D1 | F. E. Nading | Dr | 160 | 6 | I | ...... | ...... | ...... |
| 91-5-4A1 | Gerald Scott | Dr | 65 | 6 | ...... | ...... | ...... | ...... |
| 91-5-6P1 | S. P. Wolfe | Dr | 225 | 5 | I | ...... | L | E |
| 91-5-7F1 | Fannie Kramer | Dr | 200 | 6 | I | ...... | ...... | ...... |
| 91-5-7P1 | Jessen Farm | Dr | 187 | 5 | I | ...... | L | W |
| 91-5-9F1 | Kate Newberry | Dr | 158 | 5 | I | ...... | L | E |
| 91-5-9N1 | Earl Berns | Dg | 24 | 36 | ...... | ...... | ...... | ...... |
| 91-5-9Q1 | Kate Newberry | Dr | 835 | 6 | I | ...... | Ps | E |
| 91-5-10G1 | Sofia Hochaus | Dr | 735 | 6 | ...... | ...... | ...... | ...... |
| 91-5-14L1 | Ernest Rickert | Dr | 815 | 6 | I | ...... | L | E |
| 91-5-14M1 | Lloyd Gates | Dr | 825 | 6 | I | ...... | L | E |
| 91-5-16A1 | Lillian Phelps | Dr | 190 | 6 | I | ...... | ...... | ...... |
| 91-5-16P1 | Walter Klosterman | Dr | 270 | 6 | ...... | ...... | ...... | ...... |
| 91-5-17A1 | Herman Reinhardt | Dr | 200 | 6 | ...... | ...... | L | W |
| 91-5-18F1 | W. S. Pugh | Dr | 200 | 6 | ...... | ...... | ...... | ...... |
| 91-5-19N1 | Will Knight | Dg | 36 | 30 | Cement | ...... | L | H |
| 91-5-19N2 | Will Knight | Dr | 260 | 6 | I | 100 | Ps | E |
| 91-5-20D1 | Leonard Keppler | Dr | 161 | 6 | ...... | ...... | ...... | ...... |
| 91-5-21F1 | G. J. Gill | Dr | 178 | 5 | I | ...... | Ps | E |
| 91-5-22B1 | Leroy Glawe | Dg | 49 | 24 | Cement | ...... | ...... | H |
| 91-5-22G1 | Harlan Weyant | Dr | 193 | 6 | ...... | ...... | ...... | ...... |
| 91-5-23J1 | Ernest Thurn | Dr | 710 | ...... | ...... | ...... | ...... | ...... |
| 91-5-27C1 | Herman Bassett | Dr | 130 | 5 | I | ...... | ...... | ...... |
| 91-5-28F1 | Lowell Rowell | Dg | 32 | 30 | ...... | ...... | L | H |
| 91-5-28G1 | Willard Armer | Dr | 135 | 6 | ...... | ...... | ...... | ...... |
| 91-5-28L1 | Edna Wilson | Dg | 40 | 30 | B | ...... | L | H |
| 91-5-29A1 | Francis Wilson | Dr | 265 | 6 | I | 165 | ...... | ...... |
| 91-5-29C1 | Opitz Brothers | Dr | 160 | 6 | I | 160 | ...... | ...... |
| 91-5-29M1 | H. B. Farrington | Dr | 34 | 6 | ...... | ...... | L | H |
| 91-5-29M2 | H. B. Farrington | Dr | 135 | 6¼ | I | 126 | ...... | ...... |
| 91-5-30R1 | Carl Kramer | Dr | 162 | 5 | I | 131 | L | W |
| 91-5-31F1 | Henry Keppler | Dr | 300 | 6 | ...... | ...... | L | W |
| 91-5-31J1 | Henry Keppler | Dr | 190 | 6 | I | 162 | ...... | ...... |
| 91-5-32P1 | John Downey | Dr | 142 | 6¼ | I | 132 | ...... | ...... |

## WELLS IN CLAYTON COUNTY

shown in figure 2. Locations are shown on plate 2.

given in feet. Parentheses around figure indicates well was plugged back to

T, tile.
pump unknown); T, turbine.
hand.
5 feet.
levels given in feet.
PS, public supply; RR, railroad supply; S, stock.

| Principal water-bearing beds | | | Water-level | | Pumping data | | | |
|---|---|---|---|---|---|---|---|---|
| Character of material | Geologic subdivision | Altitude of land surface (feet) | Distance below land surface (feet) | Date of measurement | Production (gpm) | Drawdown (feet) | Use of water | Remarks |
| Dolomite | Silurian | ........ | 77 | ........ | 91 | 105 | M | Geologic log available*; analysis of water given in table 4. |
| Sandstone | St. Peter | ........ | ........ | ........ | ........ | ........ | D, S | |
| Dolomite | Galena | 940 | 64 | 1954 | ........ | ........ | D, S | Geologic log available* |
| Sandstone | St. Peter | 882 | 270 | 1958 | ........ | ........ | D, S | |
| ........ | Galena(?) | 640 | 16.60 | June 25, 1957 | ........ | ........ | S | |
| Sandstone | St. Peter | 638 | 80 | 1950 | ........ | ........ | Ind | Analysis of water given in table 4; geologic log given in table of logs. |
| Dolomite | Galena | 1,216 | 440 | 1954 | ........ | ........ | D, S | Analysis of water given in table 4; geologic log available*. |
| Sand and gravel | Alluvium | 640 | ........ | ........ | ........ | ........ | D, PS | Analysis of water given in table 4. |
| Sandstone | St. Peter | ........ | ........ | ........ | ........ | ........ | D, S | |
| Sandstone | St. Peter | ........ | ........ | ........ | ........ | ........ | D, S | |
| Sandstone | do | 860 | 215 | ........ | ........ | ........ | D, S | |
| Dolomite | Galena | 740 | 39.30 | June 11, 1957 | ........ | ........ | D, S | Geologic log available.* |
| Dolomite | do | 1,162 | 456 | ........ | 3 | 6 | D, S | |
| Sandstone | St. Peter | 1,167 | 475 | ........ | 55 | None** | D, S | Geologic log given in table of logs. |
| Dolomite | Galena | 860 | 140 | ........ | ........ | ........ | D, S | |
| Dolomite | Maquoketa | ........ | 10.05 | June 14, 1957 | ........ | ........ | D | |
| Dolomite | Silurian | ........ | 180 | ........ | ........ | ........ | D, S | |
| Dolomite | do | ........ | 160 | ........ | ........ | ........ | D, S | |
| Dolomite | do | ........ | ........ | ........ | ........ | ........ | D, S | |
| Dolomite | do | 1,243 | 69 | 1943 | ........ | ........ | D, S | Geologic log available.* |
| Drift | Pleistocene | ........ | 19.27 | June 6, 1957 | ........ | ........ | A | |
| Sandstone | St. Peter | 1,230 | 490 | 1919 | 6 | 20 | D, S | Geologic log available.* |
| Sandstone | do | 1,200 | 550 | ........ | ........ | ........ | D, S | |
| Sandstone | do | 1,200 | 400 | ........ | ........ | ........ | D, S | |
| Sandstone | do | 1,230 | 591 | ........ | ........ | ........ | D, S | |
| Dolomite | Silurian | ........ | 160 | 1956 | ........ | ........ | D, S | |
| Dolomite | do | ........ | 140 | 1956 | ........ | ........ | D, S | |
| Dolomite | Silurian | ........ | 134.83 | June 14, 1957 | ........ | ........ | D, S | |
| Dolomite | do | ........ | 175 | ........ | ........ | ........ | D, S | |
| Drift | Pleistocene | ........ | 28.45 | June 10, 1957 | ........ | ........ | A | |
| Dolomite | Silurian | ........ | 134.40 | June 10, 1957 | 15 | 14.6 | D, S | Temperature 52° F. |
| Dolomite | do | ........ | 139 | 1950 | ........ | ........ | D, S | |
| Dolomite | do | ........ | 58 | ........ | ........ | ........ | D, S | |
| Drift | Pleistocene | ........ | 13.89 | June 5, 1957 | ........ | ........ | D | |
| Dolomite | Silurian | ........ | 153 | 1948 | ........ | ........ | D | |
| Sandstone | St. Peter | 1,180 | 210 | ........ | ........ | ........ | S | |
| Dolomite | Silurian | ........ | 103 | 1933 | ........ | ........ | D, S | |
| Drift | Pleistocene | ........ | 27.03 | June 6, 1957 | ........ | ........ | ........ | |
| Dolomite | Silurian | ........ | 86.98 | June 6, 1957 | ........ | ........ | D, S | |
| Drift | Pleistocene | ........ | 30.95 | June 6, 1957 | ........ | ........ | D | |
| Dolomite | Silurian | ........ | 126 | 1948 | ........ | ........ | D, S | |
| Dolomite | do | ........ | 94 | 1945 | ........ | ........ | D, S | |
| Drift | Pleistocene | ........ | 31.42 | June 6, 1957 | ........ | ........ | A | |
| Dolomite | Silurian | ........ | 95 | 1956 | 30 | 10 | D, S | Temperature 52° F. |
| Dolomite | Silurian | ........ | 68 | 1951 | ........ | ........ | D, S | Analysis of water given in table 4. |
| Dolomite | do | ........ | 106.64 | June 6, 1957 | ........ | ........ | D, S | |
| Dolomite | do | ........ | 95 | 1954 | 20 | None** | D, S | |
| Dolomite | do | ........ | 65 | 1957 | 30 | ........ | D, S | Geologic log available.* |

## TABLE 6. RECORDS OF SELECTED

| Well number | Owner or tenant | Well construction |  |  |  |  | Method of lift |  |
|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  | Casing |  |  |  |
|  |  | Type | Depth (feet) | Diameter (inches) | Type | Depth (feet) | Pump | Power |
| 91-5-33P1 | Vernard Vaske | Dr | 136 | 6 | I | 16 | ...... | ...... |
| 91-5-35L1 | Edgewood Creamery | Dr | 490 | 8 | I | 485 | T | E |
| 91-5-35N1 | Edgewood City Well 3 | Dr | 248 | 16 | I | 99 | T | E |
| 91-5-35P1 | Edgewood City Well 2 | Dr | 1,080 | 6 | I | 432 | T | E |
| 91-6-4F1 | Louis Baumgartner | Dr | 60 | 5 | I | ...... | L | W |
| 91-6-5F1 | C. E. McCarron | Dr | 300 | 6 | I | ...... | L | W |
| 91-6-5H1 | Carl Zwanzigger | Dr | 210 | 6 | ...... | ...... | ...... | ...... |
| 91-6-5M1 | Leta Arnold | Dr | 280 | 6 | ...... | ...... | ...... | ...... |
| 91-6-6G1 | E. R. Schmidt | Dr | 90 | 6 | I | 21 | L | W |
| 91-6-6N1 | Mildred Kaberle | Dr | 100 | 6 | ...... | ...... | ...... | ...... |
| 91-6-7A1 | Fred Nodurft | Dr | 60 | ...... | ...... | ...... | ...... | ...... |
| 91-6-7E1 | Lloyd Pruess | Dr | 100 | 6 | ...... | ...... | ...... | ...... |
| 91-6-8M1 | L. H. Neumann | Dr | 140 | ...... | ...... | ...... | ...... | ...... |
| 91-6-8R1 | Nell Westfall | Dr | 172 | ...... | ...... | ...... | ...... | ...... |
| 91-6-9A1 | Earl West | Dr | 200 | ...... | ...... | ...... | ...... | ...... |
| 91-6-9R1 | Bernal Kehrli | Dr | 156 | 6 | ...... | ...... | T | E |
| 91-6-10K1 | Melvin Scott | Dr | 210 | 6 | ...... | ...... | ...... | ...... |
| 91-6-11C1 | Weldon Anderson | Dr | 328 | 6 | ...... | ...... | ...... | ...... |
| 91-6-13G1 | Hamlett Estate | Dr | 150 | 6 | ...... | ...... | ...... | ...... |
| 91-6-13N1 | William Knight | Dr | 260 | 6 | ...... | ...... | ...... | ...... |
| 91-6-17H1 | Mrs. Alderson | Dr | 510 | 6 | I | 360 | L | E |
| 91-6-18C1 | Walter Fredrick | Dr | 100 | 6 | ...... | ...... | ...... | ...... |
| 91-6-18N1 | E. C. Bunting | Dr | 32.5 | 6 |  | ...... | J | E |
| 91-6-19F1 | Lester Moser | Dr | 94 | 6 | ...... | ...... | ...... | ...... |
| 91-6-20D1 | Bob McKee | Dr | 110 | 6 | ...... | ...... | ...... | ...... |
| 91-6-21A1 | Edwin Kramer | Dr | 174 | 5 | I | ...... | Ps | E |
| 91-6-21B1 | Edwin Kramer | Dg | 25 | 36 | ...... | ...... | L | H |
| 91-6-21Q1 | Christian Otterbeck | Dr | 157 | 5 | I | ...... | Ps | E |
| 91-6-22C1 | Strawberry Point Creamery 1 | Dr | 165 | 6 | I | ...... | T | E |
| 91-6-22C2 | Strawberry Point Creamery 2 | Dr | 510 | 12 | I | 135 | ...... | ...... |
| 91-6-22C3 | Strawberry Point Creamery 3 | Dr | 215 | 12-8 | I | 118 | T | E |
| 91-6-22D1 | Elmer Baldridge | Dg | 12 | 40 | R | 12 | L | H |
| 91-6-22G1 | Strawberry Point City Well 1 | Dr | 160 | 4 | I | ...... | L | E |
| 91-6-22G2 | Strawberry Point City Well 2 | Dr | 492 | 16-10 | I | 161 | T | E |
| 91-6-22G3 | Howard Bowman | Dg | 18 | 36 | R | 18 | L | H |
| 91-6-22H1 | Lance Scully | Dr | (20) | 5 | I | ...... | ...... | ...... |
| 91-6-22K1 | Strawberry Point City Well 3 | Dr | 259 | 8 | I | 157 | T | E |
| 91-6-22N1 | Strawberry Point City Well 4 | Dr | 240 | 16-10 | I | 135 | T | E |
| 91-6-23J1 | Earl Johnson | Dr | 220 | 5½ | ...... | ...... | ...... | ...... |
| 91-6-24Q1 | Meron Axtell | Dr | 65 | 5 | ...... | ...... | ...... | ...... |
| 91-6-25A1 | Earl Knight | Dg | 16.5 | 30 | ...... | ...... | Ps | E |
| 91-6-26E1 | Jim Gibbs | Dr | 26.8 | 6 | ...... | ...... | ...... | ...... |
| 91-6-26Q1 | Arthur Hawkins | Dr | 125 | 6 | ...... | ...... | ...... | ...... |
| 91-6-27L1 | Goodrich Farm | Dr | 215 | 5 | I | ...... | L | W |
| 91-6-28L1 | Henry Knake | Dr | 127 | ...... | ...... | ...... | ...... | ...... |
| 91-6-29E1 | Howard Schofield | Dr | 80 | ...... | ...... | ...... | ...... | ...... |
| 91-6-31B1 | Gustav Kamass | Dr | 175 | 6 | ...... | ...... | ...... | ...... |
| 91-6-32P1 | Harold Carr | Dr | 67.5 | ...... | ...... | ...... | L | H |
| 91-6-33N1 | Edwin Washburn | Dr | 110 | ...... | ...... | ...... | ...... | ...... |
| 91-6-35C1 | Elmer Borcherding | Dr | 118 | 5 | I | ...... | L | E |
| 91-6-35R1 | Frederick Bockenstedt | Dr | 175 | 5 | I | 58 | Ps | E |
| 91-6-36D1 | G. B. Stamp | Dr | 175 | 6 | ...... | ...... | ...... | ...... |
| 92-2-5N1 | Dr. Walters | Dr | 300 | 6 | I | ...... | Ps | E |
| 92-2-5R1 | Charles Cain | Dp | 30 | 1¼ | I | ...... | L | H |
| 92-2-5R2 | D. Shadle | Dr | 55 | 5 | I | ...... | L | H |
| 92-2-8D1 | Tom Pierce | Dr | 370 | 5 | I | ...... | Ps | E |
| 92-2-8M1 | Dr. Goddard | Dr | 270 | 6 | I | 38 | ...... | ...... |

## WELLS IN CLAYTON COUNTY—Continued

| Principal water-bearing beds | | | Water-level | | Pumping data | | | |
|---|---|---|---|---|---|---|---|---|
| Character of material | Geologic subdivision | Altitude of land surface (feet) | Distance below land surface (feet) | Date of measurement | Production (gpm) | Drawdown (feet) | Use of water | Remarks |
| Dolomite | do | ........ | 17 | 1953 | ........ | ........ | D, S | |
| Dolomite | Galena | 1,180 | 65 | 1936 | ........ | ........ | Ind | |
| Dolomite | Silurian | 1,173 | 77 | 1946 | 210 | 38 | M | Geologic log available*; Analysis of water given in table 4. Original depth 450 feet; plugged back to 248 feet. |
| Sandstone | Jordan | 1,165 | 76 | 1935 | 80 | ........ | A | Geologic log available.* Depth to water while drilling thru St. Peter sandstone—80 feet. |
| Dolomite | Silurian | ........ | 55 | ........ | ........ | ........ | D, S | |
| Dolomite | do | ........ | ........ | ........ | ........ | ........ | D, S | |
| Dolomite | do | ........ | 160 | 1952 | ........ | ........ | D, S | |
| Dolomite | do | ........ | 120 | 1955 | ........ | ........ | D, S | |
| Dolomite | do | ........ | 55 | 1950 | 7 | None** | D, S | |
| Dolomite | do | ........ | 65 | ........ | ........ | ........ | D, S | |
| Dolomite | do | ........ | 55 | ........ | ........ | ........ | D, S | |
| Dolomite | do | ........ | 50 | 1956 | ........ | ........ | D, S | |
| Dolomite | do | ........ | 120 | ........ | ........ | ........ | D, S | |
| Dolomite | Silurian | ........ | 165 | ........ | ........ | ........ | D, S | |
| Dolomite | do | ........ | 170 | ........ | ........ | ........ | D, S | |
| Dolomite | do | ........ | 140 | 1957 | ........ | ........ | D, S | |
| Dolomite | do | ........ | 180 | ........ | ........ | ........ | D, S | |
| Dolomite | Galena | ........ | 310 | ........ | ........ | ........ | D, S | |
| Dolomite | Maquoketa(?) | ........ | 130 | ........ | ........ | ........ | D, S | |
| Dolomite | Galena | ........ | 160 | ........ | ........ | ........ | D, S | |
| Dolomite | Silurian | 1,220 | 450 | 1951 | 12 | None** | D, S | |
| Dolomite | do | ........ | 60 | ........ | ........ | ........ | D, S | |
| Drift | Pleistocene | ........ | 21.32 | June 12, 1957 | ........ | ........ | D | |
| Dolomite | Silurian | ........ | 49.30 | June 12, 1957 | ........ | ........ | D, S | |
| ........ | ........ | ........ | 71.23 | June 12, 1957 | ........ | ........ | D, S | |
| Dolomite | Silurian | ........ | 134 | ........ | ........ | ........ | D, S | |
| Drift | Pleistocene | ........ | 5.50 | June 11, 1957 | ........ | ........ | A | |
| Dolomite | Silurian | ........ | 121 | ........ | ........ | ........ | D, S | |
| Dolomite | do | 1,215 | 130 | 1937 | ........ | ........ | A | Analysis of water given in table 4. |
| Dolomite | Galena | 1,212 | 127 | 1954 | 100 | 16 | A | Geologic log available.* |
| Dolomite | Silurian | 1,213 | 129 | 1954 | 300 | 41 | Ind | Geologic log available*; analysis of water given in table 4. |
| Drift | Pleistocene | ........ | 2 | ........ | ........ | ........ | ........ | Analysis of water given in table 4. |
| Dolomite | Silurian | 1,200 | 135 | ........ | ........ | ........ | M | Analysis of water given in table 4. |
| Dolomite | do | 1,219 | 130 | 1936 | 400 | 30 | M | Geologic log available.* |
| Drift | Pleistocene | 1,213 | 5 | ........ | ........ | ........ | A | |
| Drift | do | 1,205 | 6 | Sept. 1951 | ........ | ........ | A | Original depth of well was 90 feet; plugged back to 20 feet. |
| Dolomite | Silurian | ........ | 130 | 1955 | 280 | 30 | M | Geologic log available.* |
| Dolomite | do | ........ | 96 | 1957 | 420 | 14 | M | Geologic log available.* |
| Dolomite | do | ........ | 175 | 1957 | ........ | ........ | D, S | |
| Dolomite | do | ........ | 200 | 1953 | ........ | ........ | D, S | |
| Drift | Pleistocene | ........ | 12.17 | June 10, 1957 | ........ | ........ | D, S | Temperature 49° F. |
| Drift | do | ........ | 4.40 | June 12, 1957 | ........ | ........ | A | Temperature 50° F. |
| Dolomite | Silurian | ........ | 60 | ........ | ........ | ........ | D, S | |
| Dolomite | do | 1,119 | ........ | ........ | ........ | ........ | D, S | Geologic log given in table of logs. |
| Dolomite | do | ........ | 50 | 1956 | ........ | ........ | D, S | |
| Dolomite | do | ........ | 22 | 1952 | ........ | ........ | D, S | |
| Dolomite | do | ........ | 120 | ........ | ........ | ........ | D, S | |
| Dolomite | do | ........ | 48.19 | June 13, 1957 | ........ | ........ | D, S | |
| Dolomite | do | ........ | 60 | ........ | ........ | ........ | D, S | |
| Dolomite | Silurian | ........ | 20 | ........ | ........ | ........ | D, S | |
| Dolomite | do | ........ | ........ | ........ | ........ | ........ | D, S | Geologic log available.* |
| Dolomite | do | ........ | 130 | ........ | ........ | ........ | D, S | |
| Sandstone | St. Peter | 916 | 160 | 1946 | ........ | ........ | A | Geologic log available.* |
| Sand and gravel | Alluvium | ........ | ........ | ........ | ........ | ........ | D | Analysis of water given in table 4. |
| Sandstone | St. Peter | ........ | ........ | ........ | ........ | ........ | D | |
| Sandstone | do | ........ | ........ | ........ | ........ | ........ | D | Geologic log available.* |
| Sandstone | do | ........ | ........ | ........ | ........ | ........ | A | |

## TABLE 6. RECORDS OF SELECTED

| Well number | Owner or tenant | Well construction | | | | | Metho of lift | |
|---|---|---|---|---|---|---|---|---|
| | | Type | Depth (feet) | Diameter (inches) | Casing | | Pump | Power |
| | | | | | Type | Depth (feet) | | |
| 92-2-17H1 | Guttenberg City Well | Dg | 26 | 26 | Concrete | 26 | T | E |
| 92-2-17L1 | Guttenberg City Well 2 | Dr | 435 | 12-8 | I | 99 | T | E |
| 92-2-17L2 | Guttenberg City Well 1 | Dr | 450 | 8 | I | 127 | T | E |
| 92-3-10H1 | Everett Tuecke | Dr | 240 | 5 | I | 38 | L | W |
| 92-3-10L1 | Louie Nieman | Dr | 122 | 6 | I | 23 | L | E |
| 92-3-14Q1 | Anthony Voss | Dr | 422 | 6 | I | 162 | L | E |
| 92-3-15D1 | Ed Schroder | Dr | 449 | 6 | I | 34 | L | E |
| 92-3-15N1 | John Egsleder | Dr | 406 | 6 | I | 77 | L | W |
| 92-3-16P1 | W. H. Kregel | Dr | 395 | 6 | I | 31 | L | E |
| 92-3-21R1 | H. Borcherding | Dr | 249 | 6 | I | 27 | L | E |
| 92-3-22Q1 | Henry Brase | Dr | 240 | 6 | I | 36 | L | W |
| 92-3-32L1 | Morris Rodenberg | Dr | 87 | 6 | ... | ... | ... | ... |
| 92-3-32M1 | Lemar Chettenger | Dr | 65 | 6 | ... | ... | ... | ... |
| 92-3-35G1 | Thomas Moser | Dr | 135 | ... | ... | 101 | T | E |
| 92-3-35R1 | Thomas Moser | Dr | 30 | ... | ... | ... | ... | ... |
| 92-3-36N1 | Lincoln Kraus | Dr | 90 | 6 | ... | ... | ... | ... |
| 92-4-5G1 | Helmuth Latteyer | Dr | 80 | 6 | ... | ... | L | E |
| 92-4-6A1 | L. P. Meyer | Dr | 264 | 6 | I | ... | L | E |
| 92-4-6J1 | Mable Pust | Dr | 260 | 6 | ... | ... | ... | ... |
| 92-4-18A1 | Hy Klink | Dr | 330 | 6 | I | 116 | L | E |
| 92-4-19B1 | Anna Maier | Dr | 89 | 5 | I | ... | L | W |
| 92-4-21L1 | Ruegnite Brothers | Dr | 216 | 6 | I | ... | L | E |
| 92-4-36N1 | C. Vorwald | Dr | 98 | 6 | I | 58 | L | W |
| 92-5-15K1 | Lillian Schulte | Dr | 260 | 6 | I | 20 | L | E |
| 92-5-17A1 | Elizabeth Debes | Dg | 30 | 24 | R | 30 | L | H |
| 92-5-34G1 | James Stock | Dr | 522 | 6 | I | 109 | L | E |
| 92-5-34R1 | Daly Sylvester | Dr | 383 | 6 | I | 58 | L | G |
| 92-5-35N1 | Minnie Nading | Dr | 485 | 6 | I | 60 | L | E |
| 92-6-3N1 | Volga Town Well | Dr | 225 | 8 | I | 53 | T | E |
| 92-6-4L1 | F. Kitterman | Dr | 200 | 6 | ... | ... | ... | ... |
| 92-6-9K1 | Lyle Jennings | Dr | 120 | 6 | ... | ... | ... | ... |
| 92-6-10C1 | F. G. Cummings | Dp | 18 | 1¼ | I | ... | Ps | E |
| 92-6-10D1 | Essnay Hatchery | Dr | 74 | 6 | I | 40 | Ps | E |
| 92-6-14D1 | John Shea | Dr | 125 | 6 | ... | ... | ... | ... |
| 92-6-21J1 | Ray Klingman | Dr | 320 | 6 | ... | ... | Ps | E |
| 92-6-21P1 | Sebald Andrae | Dr | 209 | 6 | I | 135 | L | E |
| 92-6-25C1 | John O'Brien | Dr | 72 | 6 | I | ... | L | E |
| 92-6-30F1 | Dorn Eckhart | Dr | 200 | 6 | ... | ... | ... | ... |
| 92-6-33K1 | Louis Baumgartner | Dg | 33 | ... | ... | ... | ... | ... |
| 92-6-34J1 | Alfred Kramer | Dr | 108 | ... | ... | ... | ... | ... |
| 92-6-36K1 | Walbord Hereford Farm | Dr | 220 | ... | ... | ... | ... | ... |
| 93-2-32G1 | Cluney | Dr | 50 | 5 | I | ... | L | H |
| 93-3-13R1 | Clarence Pins | Dr | 152 | 6 | I | 25 | L | G |
| 93-3-15H1 | Ben Jost | Dr | 131 | 6 | I | 15 | L | E |
| 93-3-18J1 | Garnavillo City Well | Dr | 385 | 10 | I | 60 | T | E |
| 93-3-18K1 | Garnavillo City Well | Dr | 365 | ... | I | ... | ... | ... |
| 93-3-19D1 | Garnavillo City Well | Dr | 815 | 12 | I | 400 | T | E |
| 93-4-7A1 | Clayton County Home | Dr | 780 | 10-6 | I | 495 | T | E |
| 93-4-16B1 | Hugo Kalke | Dr | 152 | 6 | I | 35 | L | E |

WELLS IN CLAYTON COUNTY—Continued

| Principal water-bearing beds | | | Water-level | | Pumping data | | | |
|---|---|---|---|---|---|---|---|---|
| Character of material | Geologic subdivision | Altitude of land surface (feet) | Distance below land surface (feet) | Date of measurement | Production (gpm) | Drawdown (feet) | Use of water | Remarks |
| Sand and gravel | Alluvium | | 4 | | 200 | 20 | A | Analysis of water given in table 4. |
| Sandstone | Jordan | 625 | 23 | 1937 | 490 | 19 | M | Geologic log given in table of logs; analysis of water given in table 4. |
| Sandstone | do | 630 | 26 | 1937 | 440 | 64 | M | Geologic log available*; analysis of water given in table 4. Depth to water while drilling thru St. Peter—29 feet. |
| Dolomite | Galena | 972 | 150 | 1952 | 5 | 17 | D, S | Geologic log available.* |
| Dolomite | do | 891 | 40 | 1950 | | | D, S | |
| Sandstone | St. Peter | 920 | 125 | 1950 | | | D, S | |
| Sandstone | do | 900 | 180 | 1950 | | | D, S | |
| Sandstone | do | 920 | 200 | 1950 | | | D, S | |
| Sandstone | do | 940 | 300 | 1949 | | | D, S | |
| Dolomite | Galena | 895 | 195 | 1949 | | | D, S | |
| Dolomite | do | 934 | 120 | 1950 | | | D, S | |
| Dolomite | Galena(?) | | 66.10 | June 26, 1957 | | | D, S | |
| Dolomite | Galena | | 55 | | | | D, S | |
| Sandstone | St. Peter | 700 | 55 | 1957 | | | D, S | Geologic log available.* |
| Sand and gravel | Alluvium | | 2.65 | June 25, 1957 | | | S | |
| Dolomite | Galena(?) | | 9 | 1955 | | | D, S | |
| Dolomite | Galena | 711 | 20 | | | | D, S | |
| Sandstone | St. Peter | 900 | 140 | | | | D, S | |
| Sandstone | do | 714 | Flowing | June 25, 1957 | | | D, S | Flowing through a 2" pipe. |
| Sandstone | do | 820 | 90 | 1950 | | | D, S | |
| Dolomite | Galena | | | | | | D, S | |
| Dolomite | do | 936 | 150 | 1947 | | | D, S | Geologic log available.* |
| Sandstone | St. Peter | 780 | 90 | 1950 | | | D, S | |
| Dolomite | Galena | | 180 | 1951 | | | D, S | |
| Sand and gravel | Alluvium | 755 | | | | | D, S | Analysis of water given in table 4. |
| Sandstone | St. Peter | 1,060 | 120 | 1947 | | | D, S | |
| Sandstone | do | 800 | 110 | 1949 | | | D, S | |
| Sandstone | St. Peter | 840 | 90 | 1950 | | | D, S | |
| Dolomite | Galena | 828 | 41 | 1957 | 150 | 15 | M | Geologic log given in table of Logs. Analysis of water given in table 4. |
| Dolomite | do | | 20 | 1956 | | | D, S | |
| Dolomite | do | | 30 | 1955 | | | D, S | |
| Sand and gravel | Alluvium | | 8 | 1937 | | | Ind | Analysis of water given in table 4. |
| Dolomite | Galena | | 50 | 1940 | | | Ind | |
| Dolomite | do | 896 | 50 | 1956 | | | D, S | |
| Dolomite | do | | 240 | 1957 | | | D, S | |
| Dolomite | do | 995 | 100 | 1950 | | | D, S | |
| Dolomite | do | | 44 | | | | D, S | |
| Dolomite | do | | 194 | 1957 | | | D, S | |
| Drift | Pleistocene | | 23 | 1955 | | | | |
| Dolomite | Silurian | | 50 | | | | D, S | |
| Dolomite | do | | 60 | 1956 | | | D, S | |
| Sandstone | St. Peter | | | | | | D | |
| Dolomite | Galena | 997 | 100 | 1950 | | | D, S | |
| Dolomite | do | 970 | 90 | 1949 | | | D, S | |
| Sandstone | St. Peter | 1,062 | 70 | 1949 | 76 | 63 | M | Geologic log available;* analysis of water given in table 4. |
| Sandstone | St. Peter | 1,050 | | | | | A | Analysis of water given in table 4. |
| Sandstone | Jordan | 1,028 | 312 | 1956 | 420 | 16 | M | Geologic log available.* |
| Sandstone | do | 1,031 | 278 | 1944 | 126 | None** | PS | Geologic log given in table of logs; analysis of water given in table 4. Depth to water while drilling thru Galena and St. Peter formations—155 feet. |
| Dolomite | Galena | 960 | 31.01 | Apr. 30, 1959 | | | D, S | Analysis of water given in table 4. |

## TABLE 6. RECORDS OF SELECTED

| Well number | Owner or tenant | Well construction | | | | | Method of lift | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Casing | | | |
| | | Type | Depth (feet) | Diameter (inches) | Type | Depth (feet) | Pump | Power |
| 93-5-2R1 | John Hagensick | Dr | 96 | 6 | I | 97 | L | E |
| 93-5-4R1 | Peter Miller | Dr | 269 | 6 | I | 54 | L | G |
| 93-5-14F1 | W. C. Reimer | Dr | 66 | 6 | I | 66 | L | E |
| 93-5-17D1 | Milo Murphy | Dr | 207 | 6 | I | 40 | L | W |
| 93-5-18K1 | Ewald Theise | Dr | 261 | 6 | I | 48 | L | W |
| 93-5-21D1 | Dr. McGrath | Dr | 196 | 6 | I | 25 | L | E |
| 93-5-23E1 | Elkader City Well 3 | Dr | (515) | 8 | I | 216 | T | E |
| 93-5-23E2 | Elkader City Well 2 | Dr | 432 | 6 | I | 78 | T | E |
| 93-5-26F1 | Carnation Milk Company | Dr | 225 | 8 | I | 96 | ...... | ...... |
| 93-5-30A1 | Jerry Liddy | Dr | 164 | 6 | I | 82 | L | W |
| 93-6-15J1 | Fred Orr | Dr | 303 | 6 | I | 81 | L | W |
| 93-6-20H1 | F. E. Sharp | Dr | 313 | 6 | I | 153 | L | W |
| 93-6-20H2 | Melvin Gregerson | Dr | 158 | 5 | I | ........ | L | G |
| 93-6-28F1 | A. R. Kraft | Dr | 220 | 6 | ........ | ........ | ...... | ...... |
| 93-6-33C1 | Drs. Hall and Hall | Dr | 125 | ........ | ........ | ........ | ...... | ...... |
| 93-6-34H1 | Albert Schuldt | Dr | 60 | 6 | ........ | ........ | ...... | ...... |
| 94-3-8M1 | Allen Barnhouse | Dr | 115 | 5 | I | ........ | L | W |
| 94-3-32R1 | Herbert Koopman | Dr | 84 | 6 | I | 45 | L | E |
| 94-4-5B1 | Meyer Brothers | Dr | 380 | 6 | I | 23 | L | W |
| 94-4-15R1 | Amvets Club, National | Dr | 209 | 6 | I | 101 | T | E |
| 94-4-18F1 | Farmersburg City Well | Dr | 705 | 8-6 | I | 85 | T | E |
| 94-4-26Q1 | L. Schroder | Dr | 270 | 6 | I | 94 | L | W |
| 94-4-27J1 | Albert Haeger | Dr | 230 | 5 | I | ........ | L | E |
| 94-5-25E1 | St. Olaf Creamery | Dr | 201 | 6 | I | 62 | T | E |
| 94-5-25M1 | St. Olaf Town Well 1 | Dr | 330 | 6 | I | ........ | T | E |
| 94-5-26H1 | St. Olaf Town Well 2 | Dr | 378 | 8 | I | 302 | T | E |
| 94-5-31K1 | Roy Ehlers | Dr | 212 | 6 | I | 12 | L | E |
| 94-5-34B1 | Ames College Farm | Dr | 382 | 6 | I | 36 | L | E |
| 94-6-5J1 | Alfred Buraas | Dr | 100 | 5½ | I | 28 | Pr | E |
| 94-6-10K1 | Mary Olson | Dr | 143 | 6 | I | ........ | L | E |
| 94-6-11G1 | Gunder Cheese Factory | Dr | 95 | 6 | I | ........ | T | E |
| 94-6-16P1 | O. Jacobson | Dr | 225 | 5 | I | ........ | L | E |
| 95-3-8C1 | Arch Adney | Dr | 125 | 6 | I | 12 | L | E |
| 95-3-15K1 | Marquette City Well 2 | Dr | 442 | 12-8 | I | 150 | T | E |
| 95-3-15K2 | Marquette City Well 1 | Dr | 585 | 6 | I | 180 | T | E |
| 95-3-16L1 | Marquette Stockyard Well | Dr | 450 | ........ | I | ........ | ...... | ...... |
| 95-3-16L2 | C. M. St. P. & P. R.R. Well 1 | Dr | 440 | 20-12 | I | 90 | T | E |
| 95-3-16L3 | C. M. St. P. & P. R.R. Well 2 | Dr | 450 | 8-6 | I | 150 | T | E |
| 95-3-16M1 | Guy Walke | Dr | 83 | 6 | I | 23 | L | W |
| 95-3-22Q1 | McGregor City Well 2 | Dr | 1,006 | 6-3 | C | 40 | ...... | ...... |

## WELLS IN CLAYTON COUNTY—Continued

| Principal water-bearing beds | | | Water-level | | Pumping data | | | |
|---|---|---|---|---|---|---|---|---|
| Character of material | Geologic subdivision | Altitude of land surface (feet) | Distance below land surface (feet) | Date of measurement | Production (gpm) | Draw-down (feet) | Use of water | Remarks |
| Dolomite | do | 786 | 60 | 1949 | ........ | ........ | D, S | Analysis of water given in table 4. |
| Dolomite | do | ........ | 200 | 1950 | ........ | ........ | D, S | |
| Dolomite | do | 752 | 31 | 1950 | ........ | ........ | D, S | |
| Dolomite | do | ........ | 200 | 1950 | ........ | ........ | D, S | |
| Dolomite | do | 1,020 | 115 | 1949 | ........ | ........ | D, S | |
| Dolomite | do | ........ | 90 | 1949 | ........ | ........ | D, S | |
| Sandstone | Jordan | 732 | Flows | 1934 | 200 | ........ | M | Geologic log available*; analysis of water given in table 4. Well originally drilled to 659 feet, then deepened to 1426 feet, and finally plugged back to 515 feet. |
| Sandstone | St. Peter | 732 | Flows | 1934 | ........ | ........ | M | Analysis of water given in table 4. |
| Sandstone | do | 757 | 36 | 1951 | 50 | None** | A | Geologic log available.* |
| Dolomite | Galena | 1,022 | 75 | 1950 | ........ | ........ | D, S | Geologic log available.* |
| Dolomite | do | 1,181 | 275 | 1949 | ........ | ........ | D, S | |
| Dolomite | Maquoketa | ........ | 200 | 1950 | ........ | ........ | D, S | |
| Dolomite | Silurian | ........ | 143 | .............. | ........ | ........ | D, S | Analysis of water given in table 4. |
| Dolomite | Maquoketa(?) | ........ | 150 | .............. | ........ | ........ | D, S | |
| Dolomite | Maquoketa | ........ | 25 | 1957 | ........ | ........ | D, S | |
| Dolomite | do | ........ | 30 | 1956 | ........ | ........ | D, S | |
| Dolomite | Prairie du Chien | ........ | 56 | .............. | ........ | ........ | D, S | |
| Dolomite | Galena | 995 | 40 | 1949 | ........ | ........ | D, S | |
| Sandstone | St. Peter | 1,060 | 97 | 1949 | ........ | ........ | D, S | |
| Dolomite | Galena | 1,111 | 60 | 1949 | ........ | ........ | PS | |
| Sandstone | Jordan | 985 | 231 | 1939 | 80 | 5.6 | M | Geologic log available*; analysis of water given in table 4. Depth to water while drilling thru Galena and St. Peter—111 feet. |
| Sandstone | St. Peter | 985 | 125 | 1958 | ........ | ........ | D, S | Well was deepened to St. Peter in 1957; original well was finished in Galena dolomite at 194 feet, and water level was 75 feet. |
| Dolomite | Galena | 1,107 | 90 | 1947 | ........ | ........ | D, S | Geologic log available.* |
| Sandstone | St. Peter | 841 | 71 | 1957 | 50 | 24 | Ind | |
| Sandstone | do | 861 | 191 | 1927 | ........ | ........ | A | Analysis of water given in table 4. |
| Sandstone | do | 937 | 187 | 1951 | 55 | 37 | M | Geologic log available*; analysis of water given in table 4. Depth to water while drilling thru Galena dolomite—80 feet. |
| Dolomite | Galena | 918 | 150 | 1950 | ........ | ........ | D, S | |
| Sandstone | St. Peter | 900 | 180 | 1949 | ........ | ........ | D, S | |
| Dolomite | Maquoketa | ........ | 35.90 | June 27, 1957 | 10 | 10 | D, S | Geologic log available.* |
| Dolomite | do | ........ | ........ | .............. | ........ | ........ | D, S | |
| Dolomite | Maquoketa | ........ | 45 | .............. | 32 | None** | Ind. | |
| Dolomite | Galena | ........ | ........ | .............. | ........ | ........ | D, S | |
| Sandstone | St. Peter | 1,080 | 60 | 1950 | ........ | ........ | D, S | |
| Sandstone | Dresbach | 633 | Flows | 1950 | 75 | None** | M | Geologic log available*; analysis of water given in table 4. |
| Sandstone | do | ........ | Flows | .............. | ........ | ........ | A | Analysis of water given in table 4. |
| Sandstone | do | 624 | Flows | 1917 | ........ | ........ | S | Analysis of water given in table 4. |
| Sandstone | do | 624 | Flows | 1917 | 250 | ........ | Ind. | Geologic log available.* |
| Sandstone | do | 628 | Flows | 1941 | ........ | ........ | Ind. | Geologic log available.* |
| Sandstone | Jordan | ........ | 75 | 1949 | ........ | ........ | D, S | |
| Sandstone | Dresbach | 632 | Flows | 1877 | 630 | ........ | A | Analysis of water given in table 4. Well plugged in May 1951 |

## TABLE 6. RECORDS OF SELECTED

| Well number | Owner or tenant | Well construction | | | | | Method of lift | |
|---|---|---|---|---|---|---|---|---|
| | | Type | Depth (feet) | Diameter (inches) | Casing | | Pump | Power |
| | | | | | Type | Depth (feet) | | |
| 95-3-22Q3 | McGregor City Well 3 | Dr | 520 | 6-3 | I | 215 | ...... | ...... |
| 95-3-22Q2 | McGregor City Well 4 | Dr | 502 | 12-9 | I | 200 | ...... | ...... |
| 95-3-22R1 | McGregor City Well 5 | Dr | (479) | 10 | I | 282 | T | E |
| 95-3-22R2 | McGregor City Well 6 | Dr | 116 | 10 | I | 90 | T | E |
| 95-3-35P1 | Pikes Peak State Park | Dr | 630 | 6 | I | 60 | Ps | E |
| 95-4-22E1 | Miller Tavern | Dr | 51 | 6 | I | 27 | Ps | E |
| 95-4-22L1 | Gerald Mielke | Dr | 49.3 | 6 | ...... | ...... | J | E |
| 95-4-29R1 | Art Seeland | Dr | 86 | 6 | I | 18 | L | E |
| 95-4-31D1 | W. H. Johanningmeier | Dr | 335 | 6 | I | 257 | L | E |
| 95-4-32R1 | Milton Miller | Dr | 380 | 6 | ...... | ...... | L | G |
| 95-5-5R1 | Luana City Well | Dr | 339 | 6 | I | 63 | T | E |
| 95-5-9E1 | Luana City Well | Dr | 347 | 8 | I | 131 | T | E |
| 95-5-9N1 | Luana Creamery 1 | Dr | 300 | 8 | I | 128 | T | E |
| 95-5-9N2 | Luana Creamery 2 | Dr | 358 | 8 | I | 69 | T | E |
| 95-5-11K1 | Monona City Well 1 | Dr | 815 | 8 | I | 631 | T | E |
| 95-5-11K2 | Monona City Well 2 | Dr | 814 | 10 | I | 408 | T | E |
| 95-5-14H1 | Clark Redasel | Dr | 70 | 6 | I | ...... | ...... | ...... |
| 95-5-14J1 | Donald Sabbann | Dr | 380 | 6 | I | ...... | ...... | ...... |
| 95-5-22G1 | Aaron Tieden | Dr | 98 | 6 | I | 20 | ...... | ...... |
| 95-5-23J1 | Lavern Garms | Dg | 20 | 36 | ...... | ...... | L | E |
| 95-5-25N1 | E. L. Montour | Dr | 396 | 6 | I | ...... | ...... | ...... |
| 95-5-28J1 | C. Johanningmeier | Dr | 288 | 6 | ...... | ...... | ...... | ...... |
| 95-5-29M1 | R. Johanningmeier | Dr | 104 | 6 | ...... | ...... | ...... | ...... |
| 95-6-3B1 | Ervin Dickman | Dr | 107 | 6¼ | I | 60 | ...... | ...... |
| 95-6-5Q1 | Harold Everman | Dr | 86 | 6 | I | ...... | L | W |
| 95-6-16J1 | W. Meyer | Dr | 65 | ...... | ...... | ...... | ...... | E |
| 95-6-17Q1 | Fred Williams | Dr | 99 | 5 | I | 50 | L | W |
| 95-6-22N1 | Arthur Baltz | Dr | 50 | 6 | ...... | ...... | Ps | E |
| 95-6-23D1 | Keith Carlson | Dr | 145 | 5 | I | ...... | L | W |
| 95-6-26M1 | G. H. Koopman | Dr | 65 | 6 | ...... | ...... | Ps | E |
| 95-6-30F1 | E. L. Nelson | Dr | 274 | 6 | I | 72 | ...... | ...... |
| 95-6-31D1 | Harry Helderson | Dr | 168 | 5 | I | ...... | L | W |
| 95-6-33N1 | Selmer Erickson | Dr | 291 | 6 | I | 52 | Ps | E |
| 95-6-34M1 | Owen Hines | Dr | 140 | 6 | I | 88 | T | E |
| 95-6-35F1 | Lee Farmer | Dr | 205 | 5 | I | ...... | L | W |
| 96-6-32L1 | Postville Packing Company | Dr | 930 | 10 | I | 100 | T | E |
| 96-6-33L1 | Postville City Well 2 | Dr | 1,071 | 12 | I | 600 | T | E |

## WELLS IN CLAYTON COUNTY—Continued

| Principal water-bearing beds | | | Water-level | | Pumping data | | | |
|---|---|---|---|---|---|---|---|---|
| Character of material | Geologic subdivision | Altitude of land surface (feet) | Distance below land surface (feet) | Date of measurement | Production (gpm) | Drawdown (feet) | Use of water | Remarks |
| Sandstone | do | ........ | Flows | 1890 | ........ | ........ | A | |
| Sandstone | do | 625 | Flows | 1898 | 400 | ........ | A | Analysis of water given in table 4. |
| Sandstone | do | 625 | Flows | 1948 | 325 | 12 | M | Geologic log is given in table of logs; analysis of water given in table 4. Original depth of well was 645 feet; plugged back to 481 feet on Oct. 3, 1949, and to 479 feet on May 26, 1951. |
| Dolomite | St. Lawrence | 638 | 15 | 1952 | 394 | 18 | M | Geologic log available*; analysis of water given in table 4. |
| Sandstone | Jordan | 1,134 | 495 | 1936 | 15 | 15 | PS | Geologic log is given in table of logs; analysis of water given in table 4. |
| Sandstone | St. Peter | 1,020 | 30 | 1949 | ........ | ........ | PS | |
| Sandstone | do | 933 | 24.45 | Oct. 4, 1957 | 10 | ........ | D | |
| Dolomite | Galena | 1,054 | 40 | 1949 | ........ | ........ | D, S | |
| Sandstone | St. Peter | 1,054 | ........ | ........ | ........ | ........ | D, S | Geologic log available*; analysis of water given in table 4. |
| Sandstone | do | 1,090 | 125.62 | Oct. 9, 1957 | ........ | ........ | S | |
| Dolomite | Galena | 1,137 | 165 | 1941 | 50 | None** | M | Geologic log available*; analysis of water given in table 4. |
| Dolomite | do | 1,134 | 106 | 1958 | 210 | 7 | M | Geologic log available.* |
| Dolomite | do | 1,147 | 104 | 1949 | ........ | ........ | Ind. | Geologic log available.* |
| Dolomite | do | ........ | 111 | 1957 | 175 | 8 | Ind. | Geologic log available.* |
| Sandstone | Jordan | 1,216 | 437 | 1937 | 75 | ........ | M | Geologic log available*; analysis of water given in table 4. Depth to water while drilling thru Galena and St. Peter—161 feet. |
| Sandstone | do | 1,216 | 427 | 1932 | 327 | 83 | M | Geologic log available*; analysis of water given in table 4. |
| Dolomite | Galena | 1,200 | 13 | ........ | ........ | ........ | A | |
| Sandstone | St. Peter | 1,180 | 199.40 | June 26, 1957 | ........ | ........ | D, S | |
| Dolomite | Galena(?) | ........ | 55 | 1957 | 15 | ........ | D, S | |
| Dolomite | Maquoketa | 1,080 | 4.62 | June 27, 1957 | ........ | ........ | S | |
| Sandstone | St. Peter | 1,120 | 240 | 1957 | 30 | 100 | D, S | Geologic log available.* |
| Sandstone | do | 1,040 | 230 | 1959 | ........ | ........ | D, S | |
| Dolomite | Galena | ........ | 54 | 1957 | ........ | ........ | D, S | |
| Dolomite | Maquoketa | ........ | ........ | ........ | 10 | ........ | D, S | Geologic log available.* |
| Dolomite | do | ........ | 35.02 | May 16, 1957 | ........ | ........ | D, S | |
| Dolomite | do | ........ | 8.94 | May 16, 1957 | ........ | ........ | D, S | |
| Dolomite | Maquoketa | ........ | ........ | ........ | ........ | ........ | D, S | |
| Dolomite | do | ........ | 40 | 1953 | ........ | ........ | D, S | |
| Dolomite | do | ........ | ........ | ........ | ........ | ........ | D, S | |
| Dolomite | do | ........ | 11.75 | June 27, 1957 | ........ | ........ | D | |
| Dolomite | Galena | 1,165 | 100 | 1957 | 5 | ........ | D, S | Geologic log available.* |
| Dolomite | do | ........ | ........ | ........ | ........ | ........ | D, S | |
| Dolomite | do | 1,049 | 230 | 1956 | ........ | ........ | D, S | |
| Dolomite | Galena(?) | 1,126 | 81.67 | May 16, 1957 | ........ | ........ | D, S | |
| Dolomite | Galena | ........ | ........ | ........ | ........ | ........ | D, S | |
| Sandstone | Jordan | 1,207 | 80 | 1949 | 340 | 80 | Ind. | Analysis of water given in table 4. Depth to water while drilling thru St. Peter—81 feet. |
| Sandstone | do | ........ | 370 | 1957 | 220 | 80 | M | Geologic log available.* |

## TABLE 7. MEASURED GEOLOGIC SECTIONS IN QUARRIES IN CLAYTON COUNTY.

Locations Shown in Figure 6.

| Quarry number | Formation | Member | Exposed thickness (feet) | Elevation of quarry floor (feet) |
|---|---|---|---|---|
| 91-1-26L1Q..... | Galena dolomite | Prosser limestone | 50 | 657 |
| 91-1-28K1Q..... | do | do | 30 | 683 |
| 91-2-9P1Q...... | do | Dubuque dolomite<br>Stewartville dolomite | 5<br>20 | 820 |
| 91-2-18L1Q..... | Kankakee limestone | | 15 | |
| 91-2-21H1Q..... | Galena dolomite | Prosser limestone | 45 | 692 |
| 91-3-21M1Q..... | Kankakee limestone | | 30 | 1,068 |
| 91-4-4K1Q...... | Kankakee limestone<br>Edgewood limestone | | 14<br>21 | 1,029 |
| 91-4-11M1Q..... | Galena dolomite | Dubuque dolomite | 13 | |
| 91-4-12M1Q..... | do | do | 15 | |
| 91-4-27K1Q..... | Kankakee limestone<br>Edgewood limestone | | 27<br>8 | 965 |
| 91-5-18P1Q..... | Kankakee limestone | | 29 | 1,096 |
| 91-5-22P1Q..... | Kankakee limestone<br>Edgewood limestone | | 15<br>13 | |
| 91-5-22Q1Q..... | Edgewood limestone | | 15 | |
| 91-6-4H1Q...... | Kankakee limestone<br>Edgewood limestone | | 27<br>16 | |
| 91-6-18Q1Q..... | Hopkinton dolomite | | 20 | 1,145 |
| 91-6-29C1Q..... | do | | 22 | 1,096 |
| 92-2-19R1Q..... | Galena dolomite<br>Decorah shale | Prosser limestone<br>Ion | 42<br>17 | 701 |
| 92-2-20G1Q..... | Decorah shale<br>Platteville limestone | Guttenberg limestone<br>Spechts Ferry<br>McGregor<br>Pecatonica dolomite | 23<br>7<br>24<br>12 | 623 |
| 92-3-20N1Q..... | Galena dolomite | Dubuque dolomite<br>Stewartville dolomite | 4<br>22 | |
| 92-3-26B1Q..... | do | Dubuque dolomite<br>Stewartville dolomite | 9<br>14 | |
| 92-3-35G1Q..... | do | Prosser limestone | 65 | 689 |
| 92-4-12F1Q..... | do | Dubuque dolomite<br>Stewartville dolomite | 8<br>35 | |
| 92-4-17G1Q..... | do | Dubuque dolomite | 18 | 789 |
| 92-4-17L1Q..... | do | Dubuque dolomite<br>Stewartville dolomite | 10<br>11 | 775 |
| 92-4-28J1Q...... | do | Dubuque dolomite<br>Stewartville dolomite | 13<br>8 | 770 |
| 92-5-5N1Q...... | Kankakee limestone | | 25 | 1,090 |
| 92-5-9L1Q...... | Maquoketa shale<br>Galena dolomite | Elgin limestone<br>Dubuque dolomite<br>Stewartville dolomite | 8<br>32<br>6 | |
| 92-5-10R1Q..... | Kankakee limestone<br>Edgewood limestone | | 5<br>20 | |
| 92-5-21E1Q..... | Galena dolomite | Dubuque dolomite<br>Stewartville dolomite | 25<br>10 | 746 |
| 92-5-36C1Q..... | do | Dubuque dolomite | 20 | |

## TABLE 7. MEASURED GEOLOGIC SECTIONS IN QUARRIES IN CLAYTON COUNTY—Continued.
Locations Shown in Figure 6.

| Quarry number | Formation | Member | Exposed thickness (feet) | Elevation of quarry floor (feet) |
|---|---|---|---|---|
| 92-5-36D1Q..... | Maquoketa shale | Elgin limestone | 3 | 756 |
| | Galena dolomite | Dubuque dolomite | 18 | |
| 92-5-36D2Q..... | Galena dolomite | do | 24 | |
| 92-5-36D3Q..... | do | do | 18 | |
| 92-6-5C1Q...... | Maquoketa shale | Ft. Atkinson dolomite | 22 | 848 |
| | | Clermont shale | 6 | |
| 92-6-8N1Q...... | Kankakee limestone | | 20 | 1,071 |
| 92-6-11Q1Q..... | Maquoketa shale | Elgin limestone | 8 | 791 |
| | Galena dolomite | Dubuque dolomite | 12 | |
| 93-2-7G1Q...... | Platteville limestone | Pecatonica dolomite | 12 | |
| | | Glenwood shale | 3 | |
| | St. Peter sandstone | | 85 | |
| 93-2-29N1Q..... | Galena dolomite | Prosser limestone | 40 | 872 |
| 93-3-7J1Q....... | do | Dubuque dolomite | 18 | |
| 93-3-16B1Q..... | Galena dolomite | Prosser limestone | 45 | 816 |
| 93-3-16C1Q..... | do | do | 48 | 850 |
| 93-4-9N1Q...... | do | Dubuque dolomite | 20 | 913 |
| 93-4-14R1Q..... | do | Stewartville dolomite | 18 | |
| 93-4-19Q1Q..... | do | do | 32 | |
| 93-5-12K1Q..... | do | Dubuque dolomite | 18 | 912 |
| 93-5-12K2Q..... | Galena dolomite | Dubuque dolomite | 10 | |
| | | Stewartville dolomite | 15 | |
| 93-5-12K3Q..... | do | Stewartville dolomite | 12 | 806 |
| 93-5-14D1Q..... | do | Dubuque dolomite | 30 | 885 |
| 93-5-16R1Q..... | do | do | 25 | |
| 93-5-22P1Q..... | do | Stewartville dolomite | 10 | |
| 93-5-27D1Q..... | do | do | 40 | 799 |
| 93-6-20B1Q..... | Kankakee limestone | | 25 | 1,193 |
| 93-6-36P1Q..... | do | | 31 | 1,099 |
| 94-3-5L1Q...... | Platteville limestone.... | McGregor | 19 | 800 |
| | | Pecatonica dolomite | 15 | |
| 94-3-10P1Q..... | Galena dolomite | Prosser dolomite | 18 | |
| 94-3-17G1Q..... | Platteville limestone | Spechts Ferry | 5 | 817 |
| | | McGregor | 25 | |
| | | Pecatonica dolomite | 16 | |
| | | Glenwood shale | 4 | |
| | St. Peter sandstone | | 2 | |
| 94-3-17L1Q..... | Decorah shale | Ion | 10 | 919 |
| 94-4-30M1Q..... | Galena dolomite | Dubuque dolomite | 30 | 948 |
| 94-4-30M2Q..... | do | do | 20 | 968 |
| 94-5-1H1Q...... | do | do | 28 | |
| 94-5-1J1Q....... | do | Dubuque dolomite | 25 | 958 |
| | | Stewartville dolomite | 22 | |
| 94-5-5P1Q.... | Maquoketa shale. | Elgin limestone.... | 32 | |

## TABLE 7. MEASURED GEOLOGIC SECTIONS IN QUARRIES IN CLAYTON COUNTY—Continued.

Locations Shown in Figure 6.

| Quarry number | Formation | Member | Exposed thickness (feet) | Elevation of quarry floor (feet) |
|---|---|---|---|---|
| 94-5-14G1Q..... | Galena dolomite | Dubuque dolomite<br>Stewartville dolomite | 15<br>10 | |
| 94-5-25D1Q..... | do | Prosser limestone | 21 | |
| 94-5-20L1Q..... | do | Dubuque dolomite | 16 | |
| 94-5-30R1Q..... | do | do | 18 | 851 |
| 94-6-4C1Q...... | Maquoketa shale | Ft. Atkinson dolomite | 20 | 993 |
| 94-6-9C1Q...... | do | Ft. Atkinson dolomite<br>Clermont shale | 22<br>3 | 971 |
| 94-6-21C1Q..... | Maquoketa shale<br>Galena dolomite | Elgin limestone<br>Dubuque dolomite | 7<br>28 | |
| 94-6-27H1Q..... | Galena dolomite | Dubuque dolomite | 18 | |
| 94-6-28D1Q..... | do | do | 24 | |
| 94-6-35F1Q..... | do | do | 30 | 812 |
| 95-3-16M1Q..... | Prairie du Chien | Oneota dolomite | 160 | 735 |
| 95-3-22M1Q..... | St. Peter sandstone | | 12 | |
| 95-3-34A1Q..... | do | | 25 | 909 |
| 95-3-34J1Q..... | Galena dolomite | Prosser limestone | 25 | 892 |
| 95-4-21A1Q..... | do | do | 45 | 972 |
| 95-5-19Q1Q..... | Maquoketa shale | Elgin limestone | 18 | |
| 95-5-30A1Q..... | Galena dolomite | Dubuque dolomite | 13 | |

## TABLE 8. MEASURED SECTIONS OF SELECTED ROCK EXPOSURES IN CLAYTON COUNTY

| Exposure number | Formation | Member | Exposed thickness (feet) | Elevation (feet) |
|---|---|---|---|---|
| 91-2-21H1E..... | Galena dolomite | Dubuque dolomite | 14 | 757 (top of Prosser limestone) |
| | | Stewartville dolomite | 52 | |
| | | Prosser limestone | 5 | |
| 91-3-2J1E....... | do | Stewartville dolomite | | 772 (top of Prosser limestone) |
| | | Prosser limestone | | |
| 91-4-14E1E..... | Kankakee limestone | | | 733 (top of Galena dolomite) |
| | Edgewood limestone | | | |
| | Maquoketa shale | Brainard shale | 100 | |
| | | Ft. Atkinson dolomite | 19 | |
| | | Clermont shale | 14 | |
| | | Elgin limestone | 38 | |
| | Galena dolomite | Dubuque dolomite | 34 | |
| 92-2-8L1E...... | Galena dolomite | Prosser limestone | | 728 (top of Decorah shale) |
| | Decorah shale | Ion | | |
| | | Guttenberg limestone | | |
| 92-2-33D1E..... | Galena dolomite | Dubuque dolomite | 26 | 692 (top of Decorah shale) |
| | | Stewartville dolomite | 77 | |
| | | Prosser limestone | 132 | |
| | Decorah shale | Ion | 10 | |
| | | Guttenberg limestone | 8 | |
| 92-3-36L1E..... | Galena dolomite | Stewartville dolomite | | 808 (top of Prosser limestone) |
| | | Prosser limestone | | |
| 92-6-3L1E...... | Maquoketa shale | Elgin limestone | 16 | 783 (top of Galena dolomite) |
| | Galena dolomite | Dubuque dolomite | 1 | |
| 93-3-22E1E..... | Decorah shale | Ion | 23 | 762 (top of Ion) |
| | | Guttenberg limestone | 27 | |
| 94-3-5P1E...... | St. Peter sandstone | | 6 | 876 (top of St. Peter sandstone) |
| 94-3-8P1E...... | Prairie du Chien | Willow River dolomite | 7 | 710 (top of exposure) |
| 94-6-4C1E...... | Maquoketa shale | Ft. Atkinson dolomite | 10 | 922(top of Clermont) |
| | | Clermont shale | 9 | |
| 94-6-35D1E..... | Maquoketa shale | Elgin limestone | 10 | 852 (top of Dubuque dolomite) |
| | Galena dolomite | Dubuque dolomite | 11 | |
| 95-3-9A1E...... | Platteville limestone | McGregor | | 972 (top of St. Peter sandstone) |
| | | Pecatonica dolomite | | |
| | | Glenwood shale | | |
| | St. Peter sandstone | | | |
| | Prairie du Chien | Willow River dolomite | | |
| 95-3-28P1E..... | Platteville limestone | Pecatonica dolomite | | 895 (top of St. Peter sandstone) |
| | | Glenwood shale | | |
| | St. Peter sandstone | | | |
| 95-3-29J1E...... | Galena dolomite | Prosser limestone | 40 | 898 (top of St. Peter sandstone) |
| | Decorah shale | Ion | 18 | |
| | | Guttenberg limestone | 6 | |
| | Platteville limestone | Spechts Ferry | 9 | |
| | | McGregor | 22 | |
| | | Pecatonica dolomite | 16 | |
| | | Glenwood shale | 5 | |
| | St. Peter sandstone | | 44 | |
| | Prairie du Chien | Willow River dolomite | 6 | |
| 95-3-34G1E..... | Decorah shale | Ion | 20 | 909 (top of St. Peter sandstone) |
| | | Guttenberg limestone | 14 | |
| | Platteville limestone | Spechts Ferry | 5 | |
| | | McGregor | 24 | |
| | | Pecatonica dolomite | 16 | |
| | | Glenwood shale | 4 | |
| | St. Peter sandstone | | 15 | |
| 95-4-21A1E..... | Galena dolomite | Prosser limestone | 3 | 952 (top of Ion) |
| | Decorah shale | Ion | 12 | |

## LOGS OF SELECTED WELLS

Logs of eight representative wells in Clayton County are included here to indicate the character of principal rock formations underlying the county. The locations of these wells are shown on plate 2, and other data on these wells are given in table 6. More detailed records of these and other wells in the county are available in the cooperative files of the Iowa and U. S. Geological Surveys at Iowa City.

Modifications of the stratigraphic nomenclature and formational boundaries on the older sample logs have been made on the basis of current interpretations of the subsurface geology of this part of the state, comparison of surface and subsurface samples, and field mapping.

91-2-16A1. Sample log of Millville Creamery well, Millville, Iowa, in the NW¼NE¼NE¼ sec. 16, T. 91 N., R. 2 W. Drilled in 1950 by Varner Well Co., Dubuque, Iowa. Altitude of land surface, 638 feet. Sample study by R. W. Screvens.

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Quaternary system | | |
| Pleistocene series | | |
| Deposits of Wisconsin stage (?) | | |
| Deposits of Iowan substage (?) | | |
| Till, brown, oxidized, unleached | 10 | 10 |
| Deposits of Kansan stage (?) | | |
| Loess, light-brown | 10 | 20 |
| Deposits of Kansan or Nebraskan stage | | |
| Till, brown, oxidized, unleached | 20 | 40 |
| Ordovician system | | |
| Mohawkian series | | |
| Platteville limestone | | |
| McGregor member | | |
| Dolomite, dark-gray and buff; some limestone, buff, sublithographic; about 10 percent chert, yellow to white | 5 | 45 |
| Dolomite, dark-gray and buff; no chert; limestone makes up a large part of the rock | 10 | 55 |

| | | |
|---|---|---|
| Ordovician system—Continued | | |
| Limestone, sublithographic, gray; contains black fossils | 10 | 65 |
| Pecatonica dolomite member | | |
| Dolomite, orange to brown, fine- to medium-textured; limestone as above | 5 | 70 |
| Dolomite, brown to gray, medium-textured, contains black fossils | 10 | 80 |
| Dolomite, brown; and green shale; contains numerous phosphatic nodules | 5 | 85 |
| Glenwood shale member | | |
| Shale, green | 5 | 90 |
| Chazyan series | | |
| St. Peter sandstone | | |
| Sand, white to buff, frosted, curvilinear to subangular, medium-grained; about 30 percent green shale | 5 | 95 |
| Sand, white to buff, becoming finer-grained toward base | 30 | 125 |
| Beekmantownian series | | |
| Prairie du Chien formation | | |
| Willow River dolomite member | | |
| Dolomite, light-gray, very fine-textured, intermixed with grayish-brown, fine-to medium-grained dolomite; contains some white to buff tripolitic and oolitic chert | 5 | 130 T.D. |

91-4-21L1. Sample log of the Dr. D. W. Newman farm well near Edgewood in the SW¼NE¼SW¼ sec. 21, T. 91 N., R. 4 W. Well drilled in 1951 by Searsland and Winslow Well Co., Walcott, Iowa. Altitude of land surface, 1,167 feet. Sample study by R. W. Screven.

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Quaternary system | | |
| Pleistocene series | | |
| Deposits of Wisconsin stage (?) | | |
| Deposits of Iowan (?) substage | | |
| Loess, yellow to buff | 15 | 15 |
| Deposits of Kansan or Nebraska stage | | |
| Till, yellow to buff, oxidized and leached | 15 | 30 |
| Till, yellow to buff, oxidized and unleached | 5 | 35 |
| Till, yellow to buff, oxidized and unleached, pebbly | 10 | 45 |
| Silurian system | | |
| Niagaran series | | |
| Hopkinton dolomite | | |
| Dolomite, yellow to buff, fine- to medium-textured | 30 | 75 |
| Dolomite, yellow to buff, fine- to medium-textured; contains white, granular chert | 10 | 85 |
| Dolomite, yellow to buff, fine- to medium-textured | 10 | 95 |
| Alexandrian series | | |
| Kankakee limestone | | |
| Dolomite, yellow to buff, fine- to medium-textured; chert, partly tripolitic | 10 | 105 |
| Dolomite, yellow to buff, fine- to medium-textured; large amounts of chert, partly tripolitic | 30 | 135 |
| Dolomite, yellow to buff, fine- to medium-textured: some chert, white to buff | 10 | 145 |

| | | |
|---|---|---|
| Silurian system—Continued | | |
| Dolomite, yellow to buff, fine- to medium-textured; minor amounts of chert | 10 | 155 |
| Dolomite, yellow to buff, fine- to medium-textured; about 30 percent chert | 10 | 165 |
| Dolomite, mostly gray to buff; about 15 percent chert | 10 | 175 |
| Dolomite, yellow to buff, fine- to medium-textured; some chert | 10 | 185 |
| Dolomite, yellow to buff, medium- to coarse-textured; some chert | 20 | 205 |
| Dolomite, yellow to buff, some gray and argillaceous | 10 | 215 |
| Dolomite, yellow to buff; chert, white to gray with black specks, partly tripolitic | 10 | 225 |
| Edgewood limestone | | |
| Dolomite, brown to gray, very argillaceous | 30 | 255 |
| Ordovician system | | |
| Cincinnatian series | | |
| Maquoketa shale | | |
| Brainard shale member | | |
| Shale, light-green, powdery; trace of gray, granular dolomite | 10 | 265 |
| Shale, light-green, slightly dolomitic | 40 | 305 |
| Shale, green and gray, slightly dolomitic | 10 | 315 |
| Shale, gray, very slightly dolomitic | 20 | 335 |
| Shale, gray, very slightly dolomitic; chert, white, granular | 10 | 345 |
| Shale, gray, very slightly dolomitic; no chert | 20 | 365 |
| Ft. Atkinson dolomite member | | |
| Dolomite, gray to brown, with black fossils | 10 | 375 |
| Dolomite, gray to brown; chert, buff, granular | 10 | 385 |
| Clermont shale member | | |
| Shale, grayish-green | 20 | 405 |

| | | |
|---|---|---|
| Elgin limestone member | | |
| Dolomite, grayish-brown; large amount of grayish-green shale | 10 | 415 |
| Dolomite, grayish-brown; contains a minor amount of shale | 20 | 435 |
| Dolomite, grayish-brown; shale, brown with black carbonaceous specks | 20 | 455 |
| Mohawkian series | | |
| Galena dolomite | | |
| Dubuque and Stewartville dolomite members | | |
| Dolomite, light-brown to buff, fine- to medium-textured, with cinnamon specks | 45 | 500 |
| Dolomite, light-brown to buff, fine- to medium-textured; limestone, light-buff, fine-textured | 50 | 550 |
| Prosser limestone member | | |
| Dolomite, light-brown to buff, fine- to medium-textured; chert, buff to white, granular and some tripolitic | 10 | 560 |
| Dolomite, light-brown to buff, fine- to medium-textured; no chert | 10 | 570 |
| Dolomite, light-brown to buff, fine- to medium-textured; with trace of chert; limestone, buff, very fine-textured, with dolomite rhombs | 10 | 580 |
| Dolomite, light-brown to buff, fine- to medium-textured; limestone, buff, very fine-textured, with dolomite rhombs | 10 | 590 |
| Limestone, buff, very fine-textured, with dolomite rhombs | 10 | 600 |
| Limestone, buff, very fine-textured; some chert, white, granular and tripolitic | 10 | 610 |
| Dolomite, light-buff, fine- to medium-textured; chert, white, tripolitic | 20 | 630 |
| Limestone, light-buff, very fine-textured, with dolomite rhombs | 10 | 640 |

| | | |
|---|---|---|
| Limestone, light-buff, very fine-textured; minor amount of chert | 20 | 660 |
| Limestone, light-buff, very fine-textured; much chert | 10 | 670 |
| Limestone, light-buff, very fine-textured; no chert | 10 | 680 |
| Decorah shale | | |
| Ion member | | |
| Limestone, buff-gray to brown, very fine-textured, fragmental | 20 | 700 |
| Guttenberg limestone member | | |
| Limestone, buff to brown, very fine-textured, partly fragmental | 12 | 712 |
| Platteville limestone | | |
| Spechts Ferry member | | |
| Shale, greenish-gray, soft, chunky; some limestone, buff to brown, very fine-textured | 11 | 723 |
| McGregor member | | |
| Limestone, gray to buff-brown, fragmental, very fine- to fine-grained | 22 | 745 |
| Pecatonica dolomite member | | |
| Dolomite, buff to gray, fine-grained, mottled | 10 | 755 |
| Limestone, gray to buff, very fine-grained, with black carbonaceous fossils; dolomite, buff to gray to mottled | 5 | 760 |
| Glenwood shale member | | |
| Sandstone, curvilinear to subangular, frosted grains; large amount of dolomite, buff to gray | 5 | 765 |
| Shale, green, laminated; trace of sandstone; much dolomite, buff to gray, mottled | 5 | 770 |
| Shale, green, chunky | 5 | 775 |
| Chazyan series | | |
| St. Peter sandstone | | |
| Sandstone, curvilinear to subangular, frosted grains, medium- to fine-grained | 55 | 830 |

| | | |
|---|---|---|
| Beekmantownian series | | |
| Prairie du Chien formation | | |
| Willow River dolomite member | | |
| Chert, white to gray and buff, mottled, granular, oolitic and tripolitic, some sand, medium- to fine-grained | 5 | 835 |
| Dolomite, gray to white, fine silty texture; chert, white to gray and buff; shale, hard, waxy, green, laminated | 10 | 845 |
| Dolomite, gray to white, silty texture | 10 | 855 |
| Dolomite, gray to white; chert, white to gray and buff, partly tripolitic; trace of fine sand | 10 | 865 |
| Root Valley sandstone (?) member | | |
| Sandstone, angular to subrounded, frosted, fine- to medium-grained; large amount of dolomite; trace of chert | 10 | 875 T.D. |

91-6-27L1. Sample log of the Goodrich farm well near Strawberry Point in the SE¼NE¼SW¼ sec. 27, T. 91 N., R. 6 W. Drilled in 1946 by Varner Well Co., Dubuque, Iowa. Altitude of land surface, 1,119 feet. Sample study by M. C. Parker.

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Quaternary (?) system | | |
| Undifferentiated residuum | | |
| Chert, white, weathered to unweathered; residual clays, red and green | 25 | 25 |
| Silurian system | | |
| Alexandrian series | | |
| Kankakee limestone | | |
| Chert, yellow to tan, opaque; dolomite, hard, yellow to buff, granular; red residual clay | 5 | 30 |
| Chert, partly tripolitic; dolomite, yellow to buff, granular; red residual clay | 5 | 35 |
| Chert, yellow to tan, much of this is tripolitic; dolomite; red residual clay | 5 | 40 |
| Chert, yellow to tan; dolomite, yellowish-gray, crystalline | 5 | 45 |
| Dolomite, yellowish-gray, crystalline; chert, tripolitic | 5 | 50 |
| Dolomite, yellowish-gray; chert, white to yellow, opaque, partly tripolitic; red residual clay | 5 | 55 |
| Dolomite, yellowish-gray, crystalline; trace of chert, white to yellow, opaque | 5 | 60 |
| Dolomite, yellow to tan, medium- to coarse-textured; much chert, white, tripolitic, and yellow to gray, opaque | 15 | 75 |
| Dolomite, yellow to tan, medium- to coarse-textured; chert, chalky, white and opaque, conchoidal | 20 | 95 |

| | | |
|---|---|---|
| Dolomite, cream to tan, granular; minor amount of chert | 20 | 115 |
| Dolomite, cream to tan, granular; large amount of chert, chalky, white, opaque | 10 | 125 |
| Dolomite, gray to tan, dense, pyritic; trace of chert, white, opaque | 5 | 130 |
| Dolomite, gray to tan | 10 | 140 |
| Dolomite, yellow to tan, crystalline; some chert, white to brown, opaque, conchoidal | 10 | 150 |
| Dolomite, yellow to tan, crystalline, porous; chert, white to brown | 5 | 155 |
| Dolomite, yellow to tan; trace of chert, white to brown | 10 | 165 |
| Edgewood limestone | | |
| Dolomite, light-gray to tan, dense, pyritic; trace of chert, white to brown, conchoidal | 10 | 175 |
| Dolomite, light-gray to tan, dense; minor amount of chert, white, opaque and tripolitic | 20 | 195 |
| Dolomite, light-gray to tan and gray to greenish-gray, coarse, granular, argillaceous; trace of chert, white, opaque and tripolitic | 5 | 200 |
| Ordovician system | | |
| Cincinnatian series | | |
| Maquoketa shale | | |
| Brainard shale member | | |
| Shale, gray and green, dolomitic, no structure | 15 | 215 T.D. |

92-2-17L1. Sample log for Guttenberg city well 2 at the center of the east line of the NE¼SW¼ sec. 17, T. 92N., R. 2 W. Drilled in 1937 by C. W. Varner, Dubuque, Iowa. Altitude of land surface, 625 feet. Sample study by E. H. Scobey.

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Quaternary system | | |
| Recent deposits | | |
| Soil, brown, silty | 8 | 8 |
| Ordovician system | | |
| Chazyan series | | |
| St. Peter sandstone | | |
| Sandstone, gray and yellow, medium- to fine-grained, frosted grains | 37 | 45 |
| Sandstone, quartz, medium-grained, subangular to curvilinear | 10 | 55 |
| Sandstone, as above; much dolomite, light-gray to buff, granular; some chert, oolitic, and white to opaque | 5 | 60 |
| Beekmantownian series | | |
| Prairie du Chien formation | | |
| Willow River dolomite member | | |
| Dolomite, light-gray, medium-textured; chert, white, opaque; sandstone, medium-grained | 10 | 70 |
| Dolomite, light-cream to gray, arenaceous; trace of sandstone, medium-grained | 10 | 80 |
| Dolomite, light-cream to gray; some chert, white to light-gray, opaque | 5 | 85 |
| Dolomite, light-cream to gray, arenaceous | 10 | 95 |
| Dolomite, light-cream to gray; traces of iron | 20 | 115 |
| Dolomite, light-cream to gray; minor amount of chert; trace of sand, medium-grained, frosted | 5 | 120 |
| Root Valley sandstone member | | |
| Dolomite, light-cream to gray; chert, oolitic and sandy; sand, frosted, medium-grained | 10 | 130 |

| | | |
|---|---|---|
| Dolomite, light-cream to gray; trace of chert, white; sandstone, medium-grained; shale, light-green | 10 | 140 |
| Oneota dolomite member | | |
| Dolomite, light-cream to gray, dense, coarsely-crystalline; some shale, light-green; trace of sand | 10 | 150 |
| Dolomite, cream to drab, porous | 20 | 170 |
| Dolomite, cream to drab, porous; some chert, white | 10 | 180 |
| Dolomite, light-cream to whitish-gray, granular, porous | 30 | 210 |
| Dolomite, light to drab, dense, porous; chert, white, dense | 10 | 220 |
| Dolomite, as above; trace of chert | 55 | 275 |
| Dolomite, light-gray, granular, porous | 25 | 300 |
| Dolomite, light-gray, medium-hard, granular, porous; some chert, white | 5 | 305 |
| Dolomite, light-gray, granular; trace of chert, white | 5 | 310 |
| Dolomite, light-gray; sandy, dense; sandstone, quartz, medium-grained | 5 | 315 |
| Dolomite, light-gray, sandy, trace of sandstone, medium-grained | 5 | 320 |
| Dolomite and sandstone, as above; shale, green, no structure | 5 | 325 |
| Dolomite, light-drab gray, sandy, dense; sandstone, quartz, frosted, medium-grained | 30 | 355 |
| Cambrian system | | |
| St. Croixan series | | |
| Jordan sandstone | | |
| Sandstone, dolomitic, medium-grained, frosted; some dolomite, light-gray, sandy | 5 | 360 |
| Sandstone, dolomitic, frosted grains, mostly curvilinear, medium-grained; minor amount of dolomite, light-gray, sandy | 10 | 370 |
| Sandstone, dolomitic, medium-grained | 5 | 375 |

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|---|---|---|
| Cambrian system—Continued | | |
| Sandstone, nondolomitic, medium-grained, frosted, mostly curvilinear | 55 | 430 |
| St. Lawrence formation | | |
| Dolomite, light-gray, fine- to medium-grained, granular | 5 | 435 T.D. |

92-6-3N1. Sample log of Volga town well in the SW¼SW¼ SW¼ sec. 3, T. 92 N., R. 6 W. Drilled in 1957 by Thorpe Well Co., Des Moines, Iowa. Altitude of land surface, 828 feet. Sample study by R. C. Northup.

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Quaternary system | | |
| Pleistocene series | | |
| Undifferentiated | | |
| Loess, yellow, noncalcareous | 5 | 5 |
| Ordovician system | | |
| Cincinnatian series | | |
| Maquoketa shale | | |
| Elgin limestone member | | |
| Dolomite, buff, finely saccharoidal, argillaceous | 30 | 35 |
| Shale, gray to greenish-brown, very dolomitic | 15 | 50 |
| Mohawkian series | | |
| Galena dolomite | | |
| Dubuque and Stewartville dolomite members | | |
| Limestone, light-gray to cream, fine-textured, cinnamon specks; with minor amount of tan dolomite | 20 | 70 |
| Dolomite, light-cream to tan, medium- to fine-textured; trace of white limestone containing dolomite rhombs | 30 | 100 |
| Prosser limestone member | | |
| Limestone, cream, fine-textured, with embedded dolomite rhombs; some tan dolomite and trace of grayish-white chert | 35 | 135 |
| Limestone, cream, fine-textured, some chert | 40 | 175 |
| Limestone, cream, fine-textured; with trace of chert | 30 | 205 |
| Limestone, cream, fine-textured; dolomite, tan, fine-grained | 20 | 225 T.D. |

93-4-7A1. Sample log of Clayton County Home well in NE¼ NE¼ sec. 7, T. 93 N., R. 4 W. Drilled by Hoeg and Ames, Lincoln, Iowa. Altitude of land surface, 1,031 feet. Sample study by S. E. Harris, Jr.

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Quaternary system | | |
| Undifferentiated deposits | | |
| Loess, tan, noncalcareous | 5 | 5 |
| Pleistocene series | | |
| Deposits of Kansan or Nebraskan stage | | |
| Till, yellowish-brown, oxidized, leached | 10 | 15 |
| Till, brown, oxidized, leached | 15 | 30 |
| Ordovician system | | |
| Cincinnatian series | | |
| Maquoketa shale | | |
| Elgin limestone member | | |
| Shale, yellowish-gray, uniform with sand grains throughout | 5 | 35 |
| Mohawkian series | | |
| Galena dolomite | | |
| Dubuque and Stewartville dolomite members | | |
| Dolomite, yellow, fine-textured, fossiliferous, phosphatic; limestone, light-brown, fine- to medium-textured | 5 | 40 |
| Limestone, drab to yellow, very fine-textured, dense | 5 | 45 |
| Dolomite, yellow, fine-grained; limestone, drab to yellow, very fine-textured | 10 | 55 |
| Limestone, yellowish-gray, fine- to medium-textured; dolomite crystals present | 5 | 60 |
| Dolomite, cream to gray, fine- to medium-textured; some limestone, yellowish-gray | 30 | 90 |

| | | |
|---|---|---|
| Ordovician system—Continued | | |
| Dolomite, cream to gray, fine- to medium-textured; limestone, light-cream with dolomite grains | 40 | 130 |
| Prosser limestone member | | |
| Dolomite, cream to buff, fine- to medium-textured, gray spots; limestone, cream, fine-textured; chert, white to gray, tripolitic | 25 | 155 |
| Limestone, cream, fine-textured, partly dusty, with dolomite grains; some dolomite, cream to buff; trace of chert, light-gray, conchoidal, dull | 5 | 160 |
| Limestone, light-gray to buff, fossiliferous, with dolomite grains; some chert, cream to gray | 10 | 170 |
| Limestone, light-gray to cream, dusty, fine-textured, with darker fossiliferous fragments | 20 | 190 |
| Limestone, light-gray to cream, fine-textured; chert, light-gray to yellow, opaque to subtranslucent | 5 | 195 |
| Limestone, light-gray to cream, fine-textured; trace of chert | 5 | 200 |
| Dolomite, yellow, with gray spots; limestone light-gray, fine-textured; chert | 10 | 210 |
| Dolomite and limestone, fine-textured | 10 | 220 |
| Limestone, light yellowish-gray, fine-textured | 10 | 230 |
| Limestone, yellowish-gray; some chert, light-yellow, conchoidal, opaque | 10 | 240 |
| Limestone, light yellowish-gray, gray spots, fine-textured | 15 | 255 |
| Decorah shale | | |
| Ion member | | |
| Limestone, light-gray, medium-textured, fossiliferous; some green shale fragments | 20 | 275 |

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|---|---|---|
| Ordovician system—Continued |  |  |
| Guttenberg limestone member |  |  |
| Limestone, very light-gray to yellow, very fine-textured; some brown shale | 10 | 285 |
| Platteville limestone |  |  |
| Spechts Ferry member |  |  |
| Shale, green, fossiliferous, blocky to fissile | 10 | 295 |
| Shale, very light-gray, soft | 5 | 300 |
| McGregor member |  |  |
| Limestone, gray, medium- to fine-textured, some granular | 5 | 305 |
| Limestone, light-gray, very fine-textured to lithographic, gray spots, fossiliferous | 20 | 325 |
| Pecatonica dolomite member |  |  |
| Dolomite, yellow to buff, fine- to medium-textured, with gray spots | 15 | 340 |
| Glenwood shale member |  |  |
| Shale, green, fissile, some pyrite | 8 | 348 |
| Chazyan series |  |  |
| St. Peter sandstone |  |  |
| Sandstone, quartz, frosted, curvilinear to subangular, calcareous cemented, pyrite near top | 107 | 455 |
| Shale, light-green, very fine-grained, soapy; trace of dolomite, light-yellow, very fine-textured | 5 | 460 |
| Beekmantownian series |  |  |
| Prairie du Chien formation |  |  |
| Willow River or Oneota dolomite member |  |  |
| Sandstone, quartz, frosted grains, with pyrite; shale, light-green; some chert, white, subvitreous | 5 | 465 |
| Dolomite, light-yellow, very fine-textured; trace of shale, green, waxy; chert, white | 30 | 495 |
| Dolomite, gray, fine- to medium-textured; trace of chert, white | 5 | 500 |

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|---|---|---|
| Ordovician system—Continued | | |
| Dolomite, light- to medium-gray, fine-textured; some sandstone, frosted, subangular to curvilinear, white; trace of chert | 20 | 520 |
| Dolomite, buff-gray, fine-textured, silty; trace of sandstone | 15 | 535 |
| Dolomite and sandstone, as above; some chert, white to light-gray, conchoidal | 10 | 545 |
| Dolomite, buff-gray, fine-textured; chert, white | 10 | 555 |
| Dolomite, buff, fine-textured; some chert, white to gray, specked with pyrite; trace of sandstone | 40 | 595 |
| Dolomite, light-buff, fine- to medium-textured; sandstone and chert | 5 | 600 |
| Dolomite, light-buff, fine- to medium-textured; trace of chert | 40 | 640 |
| Dolomite, light-buff; chert, white to brown, opaque, some tripolitic | 10 | 650 |
| Cambrian system | | |
| St. Croixan series | | |
| Jordan sandstone | | |
| Dolomite, light-buff; sandstone, fine-grained, frosted grains | 20 | 670 |
| Sandstone, white, frosted grains, subangular to curvilinear; cemented by silica and dolomite | 60 | 730 |
| Sandstone, as above; dolomite, cream-buff, very sandy, fine- to medium-textured | 10 | 740 |
| Sandstone, white, frosted grains, subangular, becoming more angular below | 30 | 770 |
| St. Lawrence formation | | |
| Sandstone, grayish-brown, with much dense dolomitic cement | 10 | 780 T.D. |

95-3-22R1. Sample log of McGregor city well 5 located in SE¼SE¼ sec. 22, T. 95 N., R. 3 W. Well drilled in 1948 by Layne-Western Co., Ames, Iowa. Altitude land surface, 625 feet. Sample study by M. C. Parker.

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Quaternary system | | |
| Pleistocene series | | |
| Deposits of late Wisconsin (?) stage | | |
| Silt, sandy, yellow to brown | 20 | 20 |
| Cambrian system | | |
| St. Croixan series | | |
| St. Lawrence formation | | |
| Dolomite, yellow to tan; some weathered quartz and limestone | 5 | 25 |
| Dolomite, yellow to tan, sandy; sand, medium-grained, frosted, with dolomitic cement | 5 | 30 |
| Dolomite, yellow to tan, sandy; trace of chert, white, opaque | 5 | 35 |
| No sample | 5 | 40 |
| Dolomite, pale-yellow to pink, very sandy, dense; small amount of tripolitic chert | 10 | 50 |
| Dolomite, pale-yellow to pink, very sandy, dense; white chert | 5 | 55 |
| Dolomite, pale-yellow to pink, very sandy, dense; no chert | 10 | 65 |
| Dolomite, pale-yellow to pink; some white chert | 10 | 75 |
| Sandstone, quartz, coarse, curvilinear, frosted; silt or fine sand, micaceous, with dolomitic cement | 5 | 80 |
| Dolomite, tan, medium- to fine-textured, sandy; sandstone, quartz, frosted grains | 5 | 85 |
| Dolomite, tan, medium- to fine-textured; much pyrite | 5 | 90 |
| Dolomite, light-gray, sandy, fine-textured; some glauconite; trace of pyrite | 5 | 95 |

| | | |
|---|---|---|
| Ordovician system—Continued | | |
| Dolomite, tan to buff, fine-textured, granular, sandy; with a little pyrite | 15 | 110 |
| Dolomite, tan to light-gray, medium-fine-textured, granular; some glauconite | 15 | 125 |
| Dolomite, light-gray, sandy, granular | 15 | 140 |
| Franconia sandstone | | |
| Sandstone, light-gray, medium-grained, frosted, dolomitic, glauconitic | 10 | 150 |
| Sandstone, light-gray to cream, frosted, fine-grained, argillaceous, dolomite cement, glauconitic | 50 | 200 |
| Dolomite, light-gray to yellow, sandy, silty, fine-textured, glauconitic | 45 | 245 |
| Dolomite, tan, coarsely crystalline, dense, sandy, silty | 10 | 255 |
| Dolomite, tan, coarsely crystalline, dense, sandy; sandstone, white with few pink grains, frosted, curvilinear to subangular | 15 | 270 |
| Dresbach group | | |
| Galesville sandstone | | |
| Sandstone, coarse, frosted, pitted, white with some gray, curvilinear to subrounded | 30 | 300 |
| Sandstone, white to buff, medium- to fine-grained, subangular to subrounded | 60 | 360 |
| No sample | 10 | 370 |
| Sandstone, white, medium-grained with some fine grains, frosted, with few dark grains | 40 | 410 |
| Eau Claire sandstone | | |
| Sandstone, white, medium-grained; some dolomitic cement | 10 | 420 |
| Sandstone, very fine-grained, frosted, curvilinear, with dolomitic cement; shale, gray, fissile, hard, silty | 50 | 470 |
| Shale, red to green, sandy, glauconitic; sandstone, very fine-grained | 10 | 480 |

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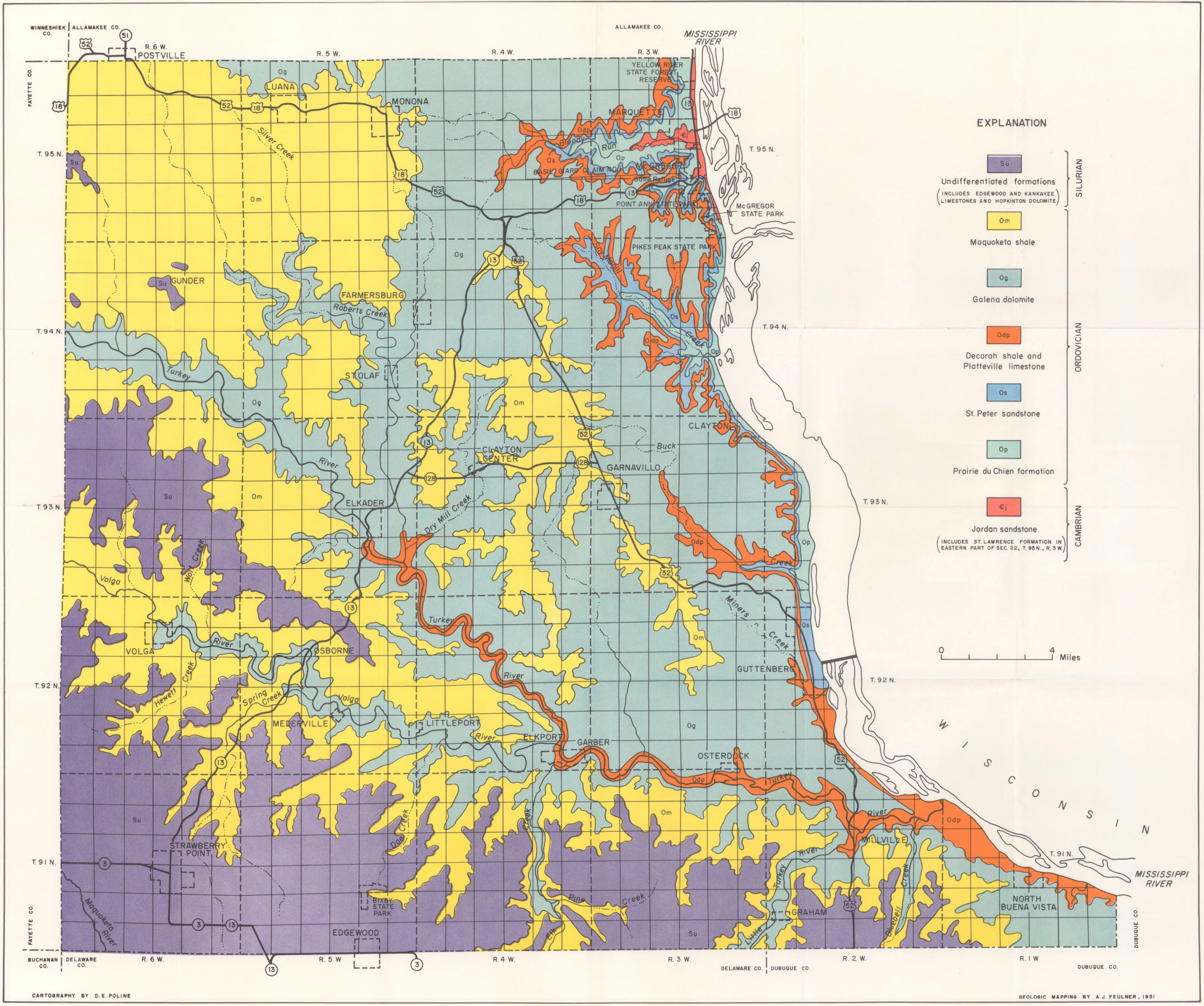
|---|---|---|
| Ordovician system—Continued | | |
| Sandstone, fine-grained, subangular, clear, loosely cemented, dolomitic; shale, green to gray, fissile | 15 | 495 |
| Sandstone, as above | 5 | 500 |
| Sandstone, fine-grained, argillaceous in part | 5 | 505 |
| Sandstone, fine- to medium-grained, subangular, partly frosted, very argillaceous | 25 | 530 |
| Mt. Simon sandstone | | |
| Sandstone, white to orange to red grains, angular to curvilinear, iron cemented in part, medium- to fine-grained | 10 | 540 |
| Sandstone, as above, but with fewer red grains | 20 | 560 |
| Sandstone, light- to medium-gray, curvilinear to subrounded, pitted, frosted, poorly cemented, coarse- to medium-grained | 50 | 610 |
| Sandstone, white, curvilinear to round, frosted, medium- to coarse-grained, cemented in part by dolomite | 35 | 645 T.D. |

95-3-35P1. Sample log for well at Pikes Peak State Park south of McGregor, located in SE¼SW¼ sec. 35, T. 95 N., R. 3 W. Drilled in 1936 by C. W. Varner, Dubuque, Iowa. Altitude of land surface, 1,134 feet. Sample study by K. E. Anderson.

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| No samples | 15 | 15 |
| Ordovician system | | |
| Mohawkian series | | |
| Galena dolomite | | |
| Prosser limestone member | | |
| Limestone, buff, fine-textured, dolomitic | 15 | 30 |
| Limestone, buff, fine- textured, dolomitic; with some white opaque chert | 10 | 40 |
| Dolomite, calcareous, cream to buff; white chert | 5 | 45 |
| Limestone, buff, dolomitic, vuggy; some white opaque chert | 10 | 55 |
| Dolomite, buff, calcareous; trace of white chert | 5 | 60 |
| Dolomite, buff, calcareous | 10 | 70 |
| Dolomite, buff, calcareous; some white tripolitic chert | 15 | 85 |
| Dolomite, buff, calcareous | 10 | 95 |
| Limestone, cream to light-buff | 5 | 100 |
| Decorah shale | | |
| Ion member | | |
| Limestone, gray, fossiliferous; minor amount of grayish-green shale | 10 | 110 |
| Guttenberg limestone member | | |
| Limestone, light-gray, fossiliferous | 12 | 122 |
| Platteville limestone | | |
| Spechts Ferry member | | |
| Limestone, buff, fossiliferous, with traces of pyrite; much grayish-green shale | 13 | 135 |
| McGregor member | | |
| Limestone, medium-gray, pyritic, fossiliferous; some dolomite | 15 | 150 |

| | | |
|---|---|---|
| Ordovician system—Continued | | |
| Limestone, medium-gray, fossiliferous | 15 | 165 |
| Pecatonica dolomite member | | |
| Dolomite, gray to cream, slightly porous | 13 | 178 |
| Glenwood shale member | | |
| Shale, green, pyritic | 5 | 183 |
| Chazyan series | | |
| St. Peter sandstone | | |
| Sandstone, frosted, well-rounded, well-sorted, slightly iron stained in upper part | 90 | 273 |
| Beekmantownian series | | |
| Prairie du Chien formation | | |
| Willow River dolomite member | | |
| Dolomite, buff to brown, sandy | 10 | 283 |
| Dolomite, buff to pink, sandy; some chert, white, opaque | 12 | 295 |
| Root Valley sandstone member | | |
| Dolomite, buff to pink; trace of oolitic chert; some sand | 15 | 310 |
| Oneota dolomite member | | |
| Dolomite, cream to buff, very fine-textured | 45 | 355 |
| Dolomite, cream to buff, very fine-textured; trace of white opaque chert | 10 | 365 |
| Dolomite, cream to buff, very fine-tetxtured; minor amount of white oolitic chert | 5 | 370 |
| Dolomite, cream to buff; much wihte opaque chert | 25 | 395 |
| Dolomite, buff, sandy; traces of chert, as above | 10 | 405 |
| Dolomite, buff, sandy, slightly coarse-textured | 15 | 420 |
| Dolomite, buff, sandy, coarse-textured; some chert | 10 | 430 |
| Dolomite, cream to buff, medium- to fine-textured | 40 | 470 |
| Dolomite, gray to buff, sandy; large amount of white granular chert | 10 | 480 |

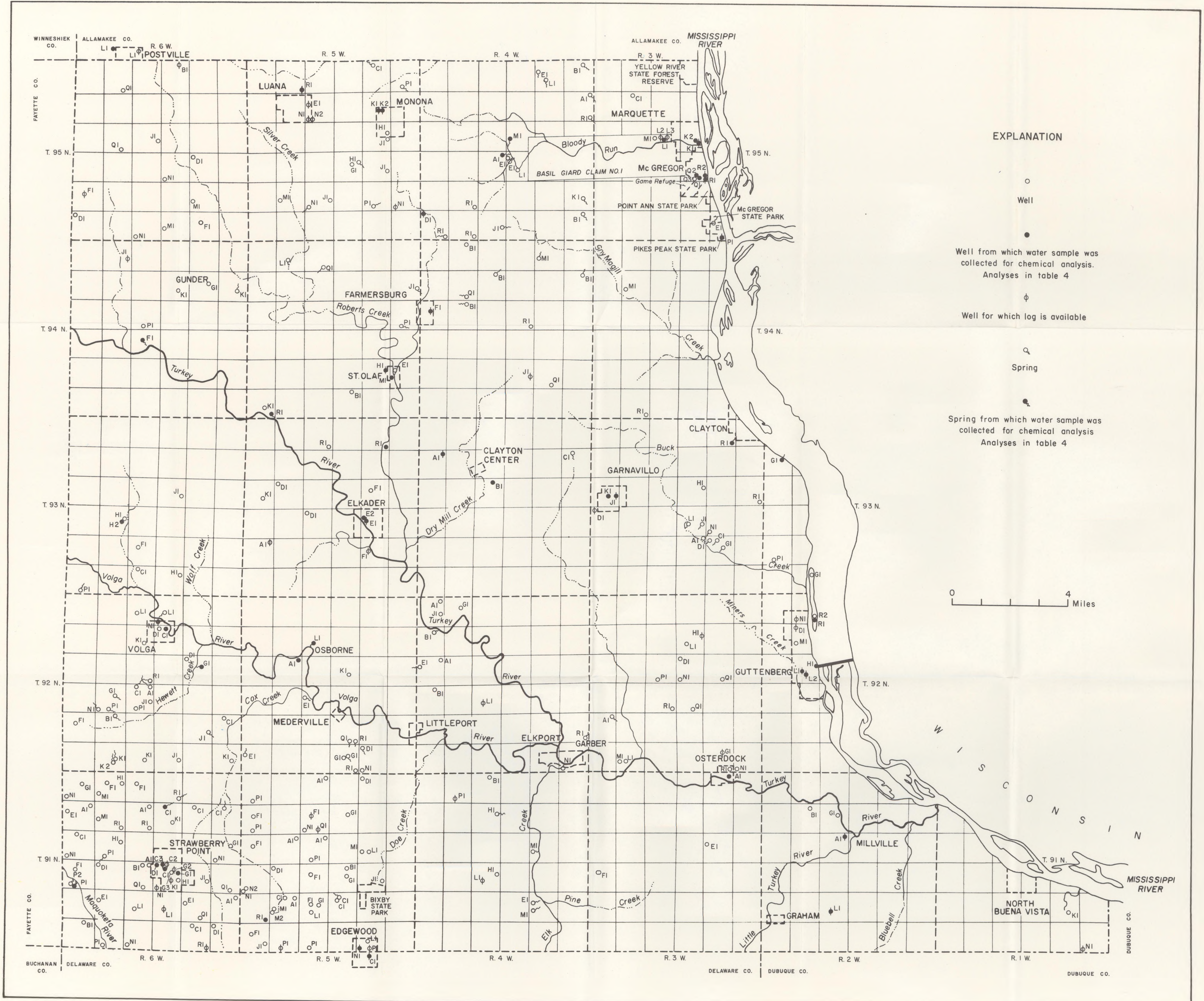
| | | |
|---|---|---|
| Ordovician system—Continued | | |
| Dolomite, buff, fine-textured; trace of white chert; sand, calcareous, frosted | 20 | 500 |
| Cambrian system | | |
| St. Croixan series | | |
| Jordan sandstone | | |
| Sandstone, white, medium-grained, frosted; dolomite, buff, fine-textured | 20 | 520 |
| Sandstone, white, medium-grained, frosted | 70 | 590 |
| Sandstone to siltstone, slightly dolomitic | 20 | 610 |
| St. Lawrence formation | | |
| Dolomite, slightly sandy with traces of glauconite | 20 | 630 T.D. |



CARTOGRAPHY BY D. E. POLINE

GEOLOGIC MAPPING BY A. J. FEULNER, 1951

MAP OF CLAYTON COUNTY, IOWA, SHOWING BEDROCK GEOLOGY



MAP OF CLAYTON COUNTY, IOWA SHOWING LOCATION OF WELLS AND SPRINGS

IOWA GEOLOGICAL SURVEY

PLATE 3

GEOLOGIC SECTION FROM STRAWBERRY POINT TO McGREGOR, CLAYTON COUNTY, IOWA