"UY NORTH DAKOTA PRODUCTS"

GROUND WATER IN THE FAIRMOUNT AREA, RICHLAND COUNTY, NORTH DAKOTA, AND ADJACENT AREAS IN MINNESOTA

By

Quentin F. Paulson
Geologist, Geological Survey
United States Department of the Interior

NORTH DAKOTA GROUND WATER STUDIES NO. 22

Prepared by the United States Geological Survey in cooperation with the North Dakota State Water Conservation Commission, and the North Dakota Geological Survey

PUBLISHED BY
NORTH DAKOTA STATE WATER CONSERVATION COMMISSION
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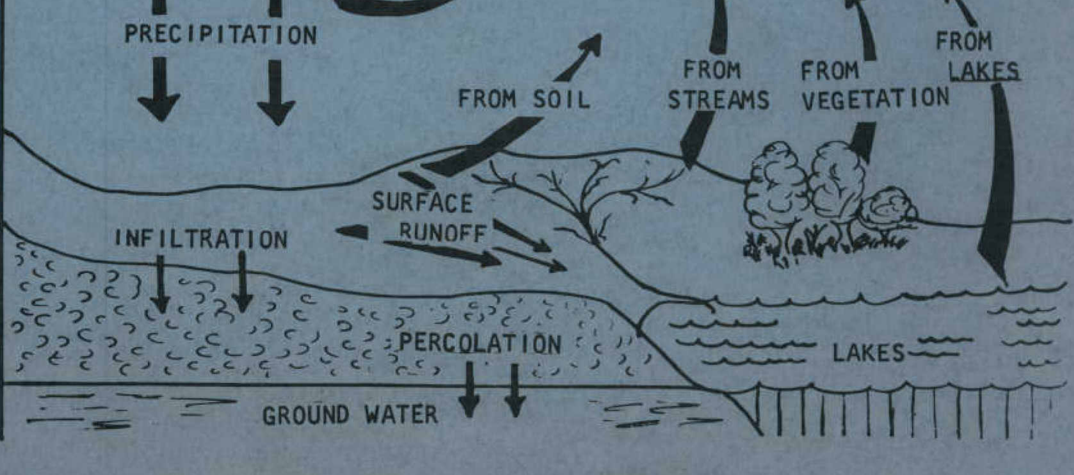

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ILLUSTRATIONS

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ABSTRACT

The Fairmount area is near the southern end of the gently north-sloping basin formerly occupied by glacial Lake Agassiz. Beach sediments deposited during the Campbell lake phase and consisting of low ridges of stratified sand and gravel, are present in the area. The area is rather poorly drained by the northward-flowing Bois de Sioux River and its tributary, the Rabbit River.

The sedimentary rocks in the area range in thickness from about 150 feet at the southern end to about 280 feet at the northern end. They overlie pre-Cambrian granite and are divided into the following units from the surface down: Mankato drift, which is subdivided into (a) Lake Agassiz deposits and (b) till and associated deposits of sand and gravel; older drift, subdivided into lake deposits, buried outwash (?) deposits, and till and associated deposits of sand and gravel; the Benton shale; and the Dakota (?) sandstone.

Important aquifers occur in the buried outwash (?) deposits associated with the older drift, and in the Dakota (?) sandstone. Relatively small aquifers of lesser importance occur in the Lake Agassiz deposits and in the more or less local deposits of sand and gravel occurring both in the lower part of Mankato and in the older drift.

Water in the buried outwash (?) deposits is of satisfactory chemical quality. Dissolved solids in four samples taken from that source ranged from 260 to 1,000 parts per million. Hardness ranged from 210 to 250 parts per million.

Water in the Dakota (?) sandstone locally is of better quality than ordinarily occurs in other parts of North Dakota. Sodium, chloride, and sulfate are the predominant mineral constituents. The water is considerably softer than

that in the buried outwash (?) deposits.

Water in a shallow aquifer associated with the Mankato drift about 3 miles west of Fairmount is highly mineralized and excessively hard.

INTRODUCTION

Scope and Purpose of the Investigation

A study of the geology and ground-water resources of Richland County, N. Dak., is being made by the United States Geological Survey in cooperation with the North Dakota State Water Conservation Commission and the North Dakota Geologi Survey as part of a series of investigations in the State. The purpose of these studies is to determine the occurrence, movement, discharge, and recharge of the ground waters, and the quantity and quality of such water available for all purposes, including municipal, domestic, irrigation, and industrial. At present, the most critical need is for adequate and perennial water supplies for many towns and small cities throughout the State. For this reason the countywide studies are started in the vicinity of those towns requesting the help of the State Water Conservation Commission and the State Geologist in locating suitable ground-water supplies. Progress reports, such as this one, are released before the completion of the general studies so that the data may be made available for use in connection with existing problems.

The Fairmount area, the subject of this report, comprises about 72 square miles. The village of Fairmount is approximately in the center of the area. The field work done in the area during the present investigation consisted of a study of the surface geology, an inventory of the wells, test drilling, and collection of water samples.

The investigation was made under the general supervision of A. N. Sayre, Chief, and P. D. Akin, District Engineer, Ground Water Branch, Water Resources Division, U. S. Geological Survey. The test drilling with a State-owned rig and other field work were done under the direct supervision of the author during the 1951 field season.

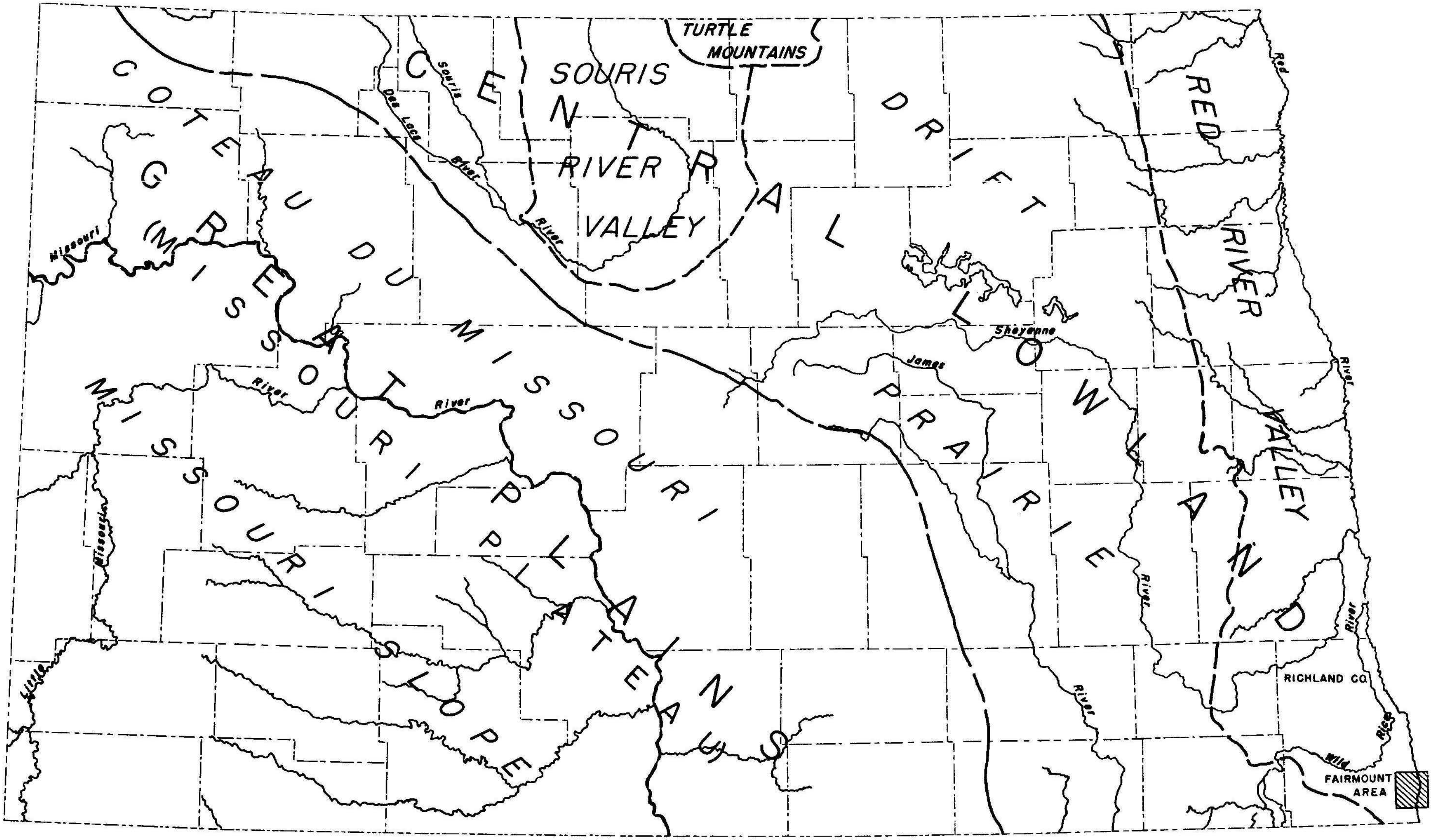


FIGURE 1.—MAP OF NORTH DAKOTA SHOWING PHYSIOGRAPHIC DIVISIONS, AS MODIFIED FROM SIMPSON, AND LOCATION OF THE FAIRMOUNT AREA.

Previous Investigations and Acknowledgements

A general survey of the geology and ground-water resources of Richland County was made by Simpson (129, p. 208-214, 296), and several well records and chemical analyses of ground waters in the Fairmount area are given in his report. Abbott and Voedisch (1938, p. 94-95) made a study of the municipal ground-water supplies of most of the larger villages and cities in North Dakota and included in their report a chemical analysis of water obtained from a public-supply well in Fairmount.

A study of the surficial geology of the area was first made by Upham (1895) as part of his study of glacial Lake Agassiz, and later by Leverett (1932). The ground-water resources of that part of the area which lies in Minnesota were investigated by Allison (1932) during a general study of the water resources of northwestern Minnesota.

The present investigation was greatly facilitated by the willing cooperation given by the residents of the Fairmount area and particularly by the assistance given by Elmer Naggetz, Earl Schouweiler, and C. E. Thompson and other members of the village council. Valuable information concerning logs, depths and performances of many wells in the Fairmount area was readily supplied by A. Vorwick and P. Vorwick, well drillers in the Fairmount area. The writer is grateful also to the Thein Well Drilling Co. of Clara City, Minn. for kindly furnishing the log of a test hole drilled for the village of Fairmount in the fall of 1951.

Location and General Features of the Area

The fairmount area of this report comprises about 72 square miles, of which about 50 square miles is in Richland County, in the extreme southeastern part of North Dakota, and about 22 square miles is in Wilkin and Traverse Counties, Minn. (see fig. 1). The area includes all of T. 130 N. and parts of Tps. 129 and 131 N., R. 47 W.; and parts of Tps. 129, 130, and 131 N., R. 48 W.

The village of Fairmount, the only community in the area, is in the central part. U. S. Highway 81 and State Highway 11 cross the area from north to south and east to west, respectively, and intersect at Fairmount. State Highway 11 becomes State Highway 55 east of the Bois de Sioux River, the State line. The Chicago, Milwaukee, St. Paul, and Pacific Railway and the Minneapolis, St. Paul, and Sault Ste. Marie Railway traverse the area similarly and also intersect at Fairmount. The Great Northern Railway crosses the area laterally about half a mile north of the Minneapolis, St. Paul, and Sault Ste. Marie line.

Fairmount (1950 pop. 705) serves as a shopping and trading center for the people living in the surrounding farm area. Farming is the chief occupation in the area; wheat, flax, and corn are the major crops.

The average annual precipitation, based on a 59-year record by the U. S. Weather Bureau at Wahpeton, 13 miles north of Fairmount, is 20.67 inches. The average annual temperature, also based on the 59-year record at Wahpeton, is 42.1°F.

The area is in the Western Young Drift section of the Central Lowlands physiographic province(Fenneman, 1938, p. 559) and it is a part of the Red River Valley area as described by Simpson (1929, p 4-7).

The Red River Valley is a broad, flat glacial-lake plain. With the exception of the beaches and deltas of glacial Lake Agassiz, the plain is practically featureless.

The Fairmount area is near the southern end of the lake plain. Beach ridges, probably formed during the Campbell beach phase of Lake Agassiz, extend northwestward across the western part of the area, and northeastward across the eastern part. They converge southward to the lake's outlet, the northern end of which is located south of the Fairmount area, approximately at the latitude of the North Dakota-South Dakota boundary.

The area is drained rather poorly by the Bois de Sioux River and its tributary, the Rabbit River. Although in recent years the channel of the Bois de Sioux River has been dredged and straightened, aerial photographs clearly show the former meandering course of the channel.

Present Water Supply and Future Needs

At the present time, ground water is used by practically all residents in the area for most purposes including municipal, industrial, and farm-domestic and stock. Some residents near the Bois de Sioux or Rabbit River obtain water from those streams for watering stock.

Data were obtained on most of the existing wells in the area and are tabulated on pages 36 to 39. The locations of the wells are shown in plate 1.

Fairmount has a municipal water-distribution system. The system is supplied by a single well located about three-quarters of a mile east of the village. The water is transported to the village by means of a pipeline extending from the well to an elevated reservoir tank, from which the water is distributed to the various mains in thevillage.

The village supply well (130-47-21dba2) is 113 feet deep and has a diameter of 8 inches. The well is finished with 10 feet of screen at the bottom and is gravel packed. The well is reported to have yielded originally more than 100 gallons a minute, but in 1951 it was yielding only about 30 gallons a minute. It seems likely that the decrease in yield is due to some fault of the well, possibly incrustation of the screen, rather than to depletion of the local ground-water supply. In the fall and winter of 1951 a new well, shown in plate 2 as the Thein test hole (130-47-21dba1), was drilled a short distance east of the village supply well. It is reported that the well has been completed and is now being pumped in service at a rate of about 100 gallons a minute.

Several unused publicly owned wells, ranging in depth from 120 to 135 feet, are located west of the village supply well. These wells were formerly used as village supply wells but were abandoned because of the danger of contamination from a nearby sewer.

The Cudahy Meat Packing Co. in Fairmount has a well 231 feet deep (130-47-20dbc1). Part of the company's water-supply requirement is supplied by this well but the larger part is obtained from the village water-supply system.

There are several other private wells in the village from which domestic water supplies were obtained prior to the installation of the municipal water-supply system. These wells are not being used at the present time.

Currently, about 50,000 gallons of water per day is used by the village for domestic and industrial purposes. It is estimated that requirements in the foreseeable future may be about twice this amount, or about 100,000 gallons per day.

Well-Numbering System

The well-numbering system in this report is based upon the location of the well with respect to the land-survey divisions used in North Dakota and western Minnesota. The first number is the township north of the base line which extends laterally across the middle of Arkansas. The second number is the range west of the 5th principal meridian. The third number is the section within the designated township. The letter a, b, c, and d designate, respectively, the northeast, northwest, southwest, and southeast quarter sections, the quarter-quarter sections and, the quarter-quarter-quarter sections (10-acre tracts). If more than one well occurs within a 10-acre tract, consecutive numbers are given to them as they are scheduled. This number follows the letters. Thus well 129-47-8aaa (see USGS test 482, pl. 1) is in T. 129 N., R. 47 W., sec. 8. It is in the northeast quarter of the northeast quarter of the northeast quarter of the section. Similarly, well 130-47-22cabl (see USGS test 471, pl.1) is in T. 130 N., R. 47 W., sec. 22. It is in the northwest quarter of the northeast quarter of the southwest quarter of the section and is the first of a number of wells scheduled in that 10-acre tract. Numbers for wells not accurately located within the section may contain only one or two letters after the section number, indicating that the location of such wells is accurate only to the quarter or quarter-quarter section, respectively.

Figure 2 illustrates how the number system is applied.

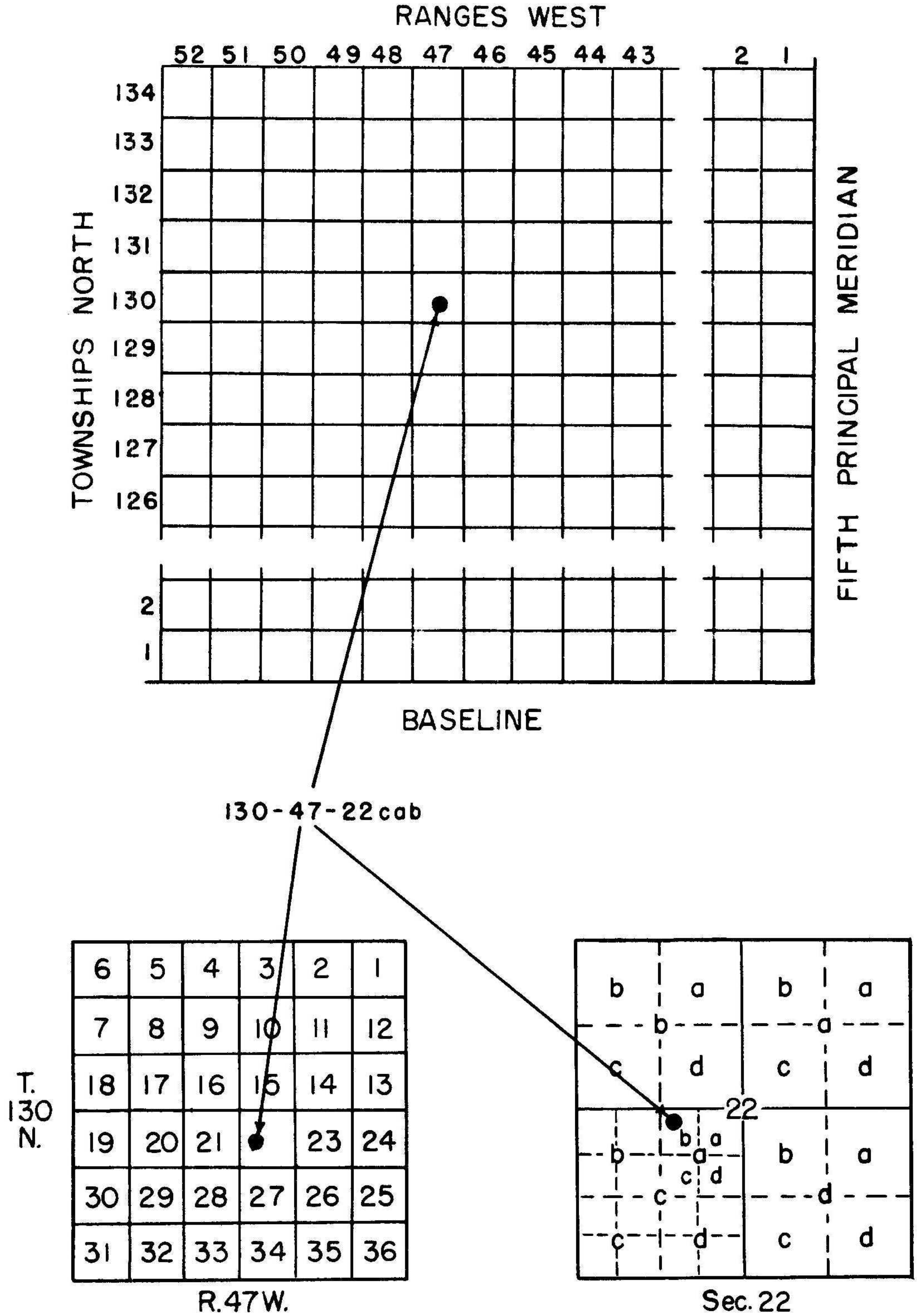


Figure 2 .--Sketch illustrating well-numbering system.

The test holes drilled by the U. S. Geological Survey were given serial numbers in the field. These serial numbers have been retained in the report for purposes of reference and for ease of recognition by the local people.

GEOLOGY AND OCCURENCE OF GROUND WATER

Principles of Occurrence of Ground Water

The solid materials in the earth's crust may be hard like granite or slate, soft like shale or clay, consolidated like sandstone, or unconsolidated like loose sand and gravel. In the Fairmount area the rocks that form the earth's crust are of two kinds: the sedimentary rocks, which overlie the granite, and the granite itself which is of igneous origin.

The sedimentary rocks of the area were formed by the deposition of small fragments of rock materials followed by a minor amount of chemical action which caused partial cementation or consolidation of some of the materials. Because of the shapes and sizes of the individual rock particles, a considerable amount of open space occurs in the sedimentary rocks. The rocks are, therefore, said to be porous and the quantitative measure of the open space with respect to the whole volume of the rock is called its porosity. The sedimentary rocks were deposited on the eroded surface of the granite, which had been formed by igneous action long before.

Below the water table, under natural conditions, the open or pore spaces in the sedimentary rocks are filled with water. The porosity of a rock material is, therefore, a measure of its capacity to store water when saturated. However, the capacity of a rock to yield water to wells by gravity drainage may be much less than would be indicated by its porosity because part or all of the water may be held in the pore spaces by molecular attraction between the water and the rock material. If the pore spaces are large, as in coarse gravel, practically all the water stored in the pore spaces may be removed by gravity drainage.

If the individual particles composing the rock are small, as in clay or shales, the porosity of the rock may be considerable but practically none of the stored water can be removed by gravity drainage. The volume of water, expressed as a percentage, that will drain by gravity from a unit volume of the saturated rock material is called its specific yield.

Another characteristic of a rock material that is important, insofar as water supply is concerned, is the difficulty or ease with which water may move through the material. If the porespaces are relatively large, as in coarse gravel or sand and gravel, the resistance to the movement of water through the material is not great and the rock is said to be permeable. However, if the pore spaces are small, as in clay or shale, the resistance to the movement of water may become very great and the rock is said to be impermeable or to have a low permeability.

Any rock formation that will yield water to wells in sufficient quantity to be of importance as a source of supply is called an aquifer (Meinzer, 1923, p. 52). The sedimentary rocks of the Fairmount area that are composed mainly of sand, or sand and gravel, would constitute the most productive aquifers, whereas those composed mainly of clay or shale might not yield sufficient quantities of water to be called aquifers.

If water in an aquifer is not confined by impervious strata above, the water is said to occur under water-table conditions. In this case, water may be obtained from storage in the aquifer by causing a lowering of the water table, as in the vicinity of a pumping well, which results in gravity drainage of the rock material.

If the water is confined in the aquifer by an overlying impermeable stratum, however, so that the water in a well penetrating the aquifer rises above the top of the aquifer under hydraulic pressure, the water is said to occur under artesian conditions. It is not necessary that the well flow for it to be classed as artesian under this definition. In this case, water is yielded as the water level in in the well is lowered, but the aquifer remains saturated and the water is yielded, at least temporarily, because of its own expansion and the compression of the aquifer due to lowered pressure, rather than by gravity drainage. The water-yielding capacity is called the coefficient of storage and generally is very much smaller than the specific yield of the same material when drained by gravity.

In the Fairmount area, both artesian and water-table aquifers occur in the sedimentary formations but the artesian aquifers are of much greater importance because of their larger areal extent.

It is evident from the foregoing discussion that the suitability of an aquifer to furnish a water supply for any given purpose will depend upon the permeability of the materials composing the aquifer and upon its volume or capacity to store water. In addition, there must be adequate recharge to the aquifer if the water-supply development is to last indefinitely, for it is apparent that even a small draft will eventually deplete the water in storage unless there is adequate recharge. There have been instances in North Dakota,as in other States, where aquifers composed of materials having rather high permeability but havingonly small areal extent and being completely surrounded by impermeable material have been pumped nearly dry in a comparatively short period of time, to the disappointment of those concerned. The rather high initial yield of the wells gave the erroneous impression that a great volume of water would be available from the aquifer indefinitely.

Recharge to the various aquifers in the Fairmount area is discussed in the sections dealing with the various formations.

The granite, which underlies the sedimentary rocks in the area, is not porous in the same sense that the term is used in connection with the sedimentary rocks. The upper part of the granite is weathered and there is secondary porosity in this weathered zone. However, the products of weathering in this area are mostly clay and of no great importance as an aquifer. There doubtless are fractures in the unweathered granite that would yield small supplies of water. However, the probability of obtaining water supplies from wells sufficient for even meager domestic and farm use appears to be too small to warrant drilling very far into the granite. Also, only the upper part of the granite is likely to contain openings that would yield water.

General Stratigraphic Relationships

Information concerning the stratigraphy in the Fairmount area was obtained in part from a study of the samples obtained from 16 test holes drilled in the area. The test holes were drilled with the use of a hydraulic-rotary drilling machine and ranged in depth from 159 to 280 feet. All the test holes were drilled to granite. The locations of the test holes are shown in plate 1 and their logs are given on pages 40 to 53. Geologic sections compiled from the test holes and from several privately owned wells are shown in plate 2.

The following is the strategraphic section for the Fairmount area:

Cenozoic era

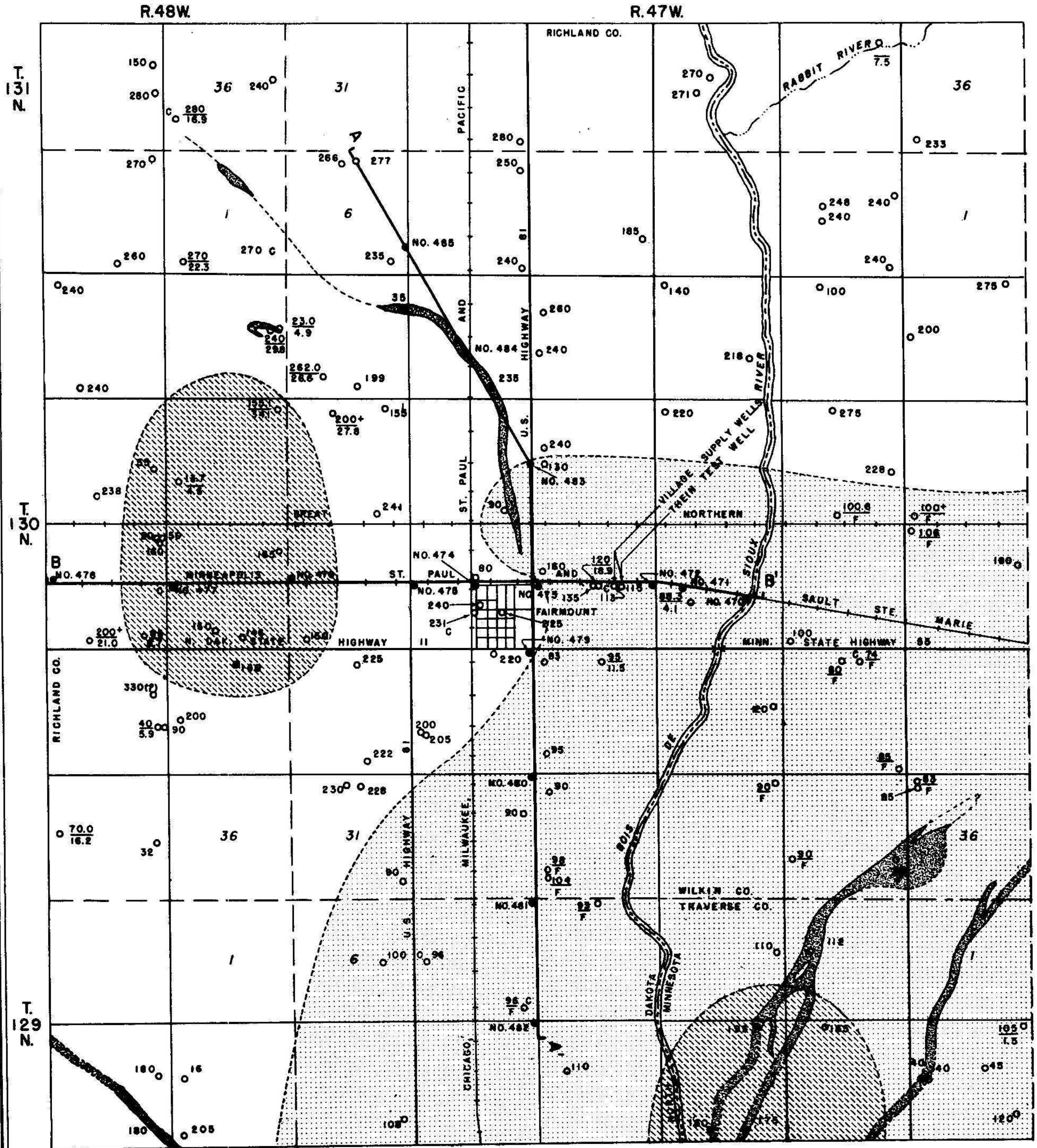
- Quaternary system
  - Pleistocene series
    - Wisconsin stage
      - Mankato drift
        - Lake Agassiz deposits
        - till and associated deposits of sand and gravel
    - Pre-Wisconsin (?) stage
      - older drift
        - lake deposits
        - buried outwash (?) deposits
        - till and associated deposits of sand and gravel

Mesozoic era

- Cretaceous system
  - Upper Cretaceous series
    - Benton shale
    - Dakota (?) sandstone

Pre-Cambrian

- Granite



AREA IN WHICH MOST WELLS ARE BETWEEN 80 AND 110 FEET DEEP, AND END IN BURIED OUTWASH (?) DEPOSITS

AREA IN WHICH MOST WELLS ARE BETWEEN 200 AND 300 FEET DEEP, AND END IN DAKOTA (?) SANDSTONE

AREA IN WHICH WELLS END IN GLACIAL DRIFT AT VARYING DEPTHS LESS THAN 200 FEET

DEPOSITS OF GLACIAL LAKE AGASSIZ: LOW RIDGES OF SAND AND GRAVEL DEPOSITED DURING CAMBELL BEACH PHASE GENERALLY TOO THIN TO YIELD SIGNIFICANT AMOUNTS OF WATER

C $\frac{280}{16.9}$

EXISTING WELL: UPPER NUMBER, OR SINGLE NUMBER, INDICATES DEPTH OF WELL; LOWER NUMBER INDICATES DEPTH TO WATER IN THE WELL; F INDICATES FLOW; C INDICATES CHEMICAL ANALYSIS

● NO. 482

USGS TEST HOLE

GRAVEL PIT

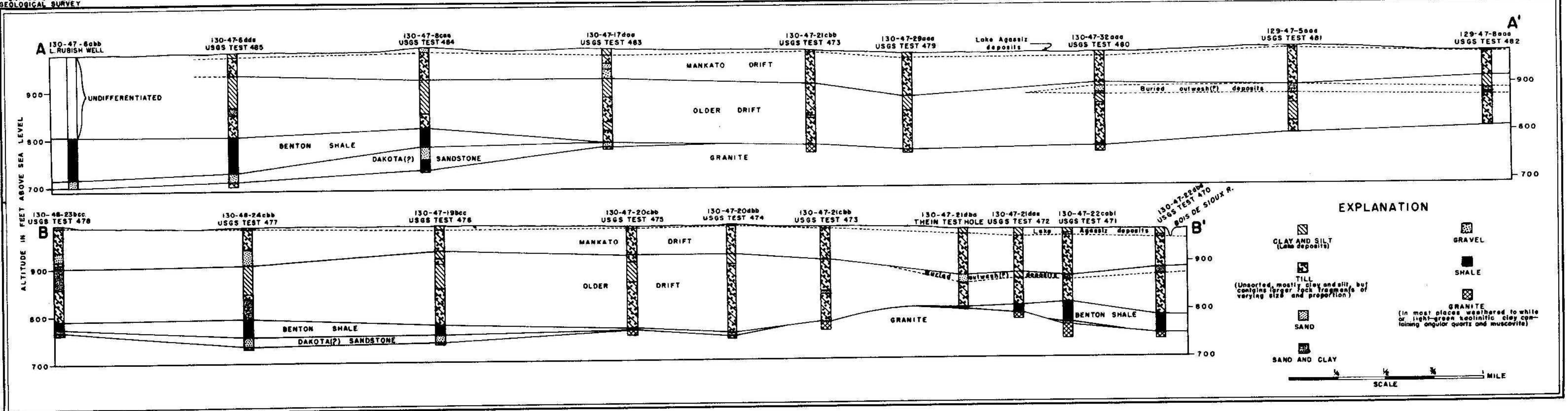
B———B'

LOCATION OF GEOLOGIC SECTION

1 .5 0 1 MILE

SCALE

MAP SHOWING AQUIFERS AND LOCATIONS OF WELLS AND TEST HOLES IN THE FAIRMOUNT AREA



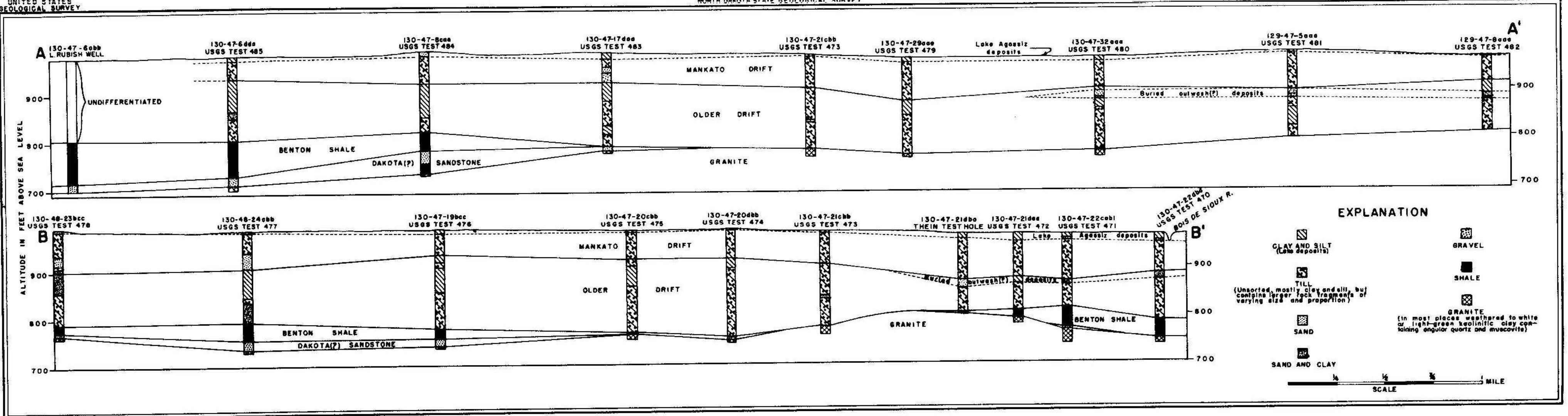
GEOLOGIC SECTIONS IN THE FAIRMOUNT AREA.

(LOCATION OF SECTIONS SHOWN ON PLATE 1)

UNITED STATES
GEOLOGICAL SURVEY

NORTH DAKOTA STATE WATER CONSERVATION COMMISSION
NORTH DAKOTA STATE GEOLOGICAL SURVEY

NORTH DAKOTA GROUND-WATER
STUDIES NO. 22, PLATE 2



GEOLOGIC SECTIONS IN THE FAIRMOUNT AREA.
(LOCATION OF SECTIONS SHOWN ON PLATE I)

Wisconsin Stage

Mankato drift

Glacial drift, deposited during the Mankato substage of the glacial epoch, forms the surficial deposits over the entire area. The upper part of the drift consists of lake deposits formed in glacial Lake Agassiz, which occupied the Red River Valley during the last part of the Mankato substage. Till and associated deposits of sand and gravel underlie the Lake Agassiz deposits in the area (formerly occupied by the lake) and crop out over broad areas adjacent to the lake basin on the east and west.

The average thickness of the Mankota drift penetrated by 16 test holes drilled in the Fairmount area is 72 feet. The maximum thickness penetrated is 97 feet and the minimum is 51 feet.

Lake Agassiz deposits:--Lake Agassiz deposits,consisting of sorted and stratified deposits of clay, silt,sand and gravel, cover the Fairmount area. In the test holes drilled under the supervision of the Geological Survey (USGS test holes) they ranged in thickness from 3 to 18 feet, but they may be thicker in some parts of the area where test drilling was not done. The coarser materials occur in shore or near-shore features such as beaches, spits, and bars and also, in some places, at the bottom of the Lake Agassiz deposits. Clay and silt, which constitute the major part of the deposits, form a thin cover over most of the areas between the shore features. The maximum thickness of 18 feet was penetrated by USGS test 472 (130-47-21daa).

With the exception of the materials penetrated in USGS test 472, the Lake Agassiz deposits could not be divided readily into clay and silt units as has been done in other parts of the lake basin where the deposits are much thicker (Dennis, Akin, and Worts, 1949, p. 17-21; Paulson, 1951, p. 12-16). In USGS test 472 the deposits consist of 12 feet of yellowish-brown silt underlain by 5 feet of bluish-gray clay which in turn is underlain by 1 foot of sand. In all the other test holes the Lake Agassiz deposits are principally silt or sand of varying shades of tan. A small amount of gravel was found in some of the test holes.

The Lake Agassiz deposits were laid down in a large proglacial lake which Upham (1896, p. 5) named Lake Agassiz. The formation of the lake is believed to have occurred during the last phases of the Wisconsin stage of Pleistocene glaciation. The origin and history of glacial Lake Agassiz have been discussed in detail in a considerable number of publications, of which the works of Upham (1896) and Leverett (1932) are the most comprehensive. The origin and history of the lake will be discussed here only insofar as they are pertinent to the origin of the deposits present in the Fairmount area.

According to Leverett (1932, p. 121) Lake Agassiz had its beginning as a small ice-marginal lake located near Milnor in southeastern North Dakota. The lake, at this stage, formed a beach known as the Milnor beach, along its western shoreline at an altitude about 25 feet higher than the Herman beach, which is the highest beach extending more or less completely around the lake basin. Because of recession of the ice front toward the north and downcutting of the lake's outlet through the Minnesota River valley toward the south, the lake level receded and a series of beaches were left at successively lower levels along the former shorelines.

There is considerable evidence that when the lake receded to the level marked by the lowest Campbell beaches, the southern outlet ceased to function and drainage was accomplished through some other outlet, probably extending northeast through Minnesota. Whether the lake was completely drained at that time is not definitely known, but the presence of soil zones, peat, tree trunks, and other remnants of vegetation in various parts of the lake basin between lake clays at a considerable depth below the present land surface seems to indicate that complete drainage did occur. It is believed that a southward readvance of the ice caused the formation of a second stage of the lake which rose only to the level of the lower Campbell shoreline and, as it receded, left a series of successively lower beaches.

The Fairmount area is near the southern end of the Lake Agassiz basin and the beach ridges in the area converge rather sharply toward the south(see plate 1) in the direction of the former outlet. During the present investigation the beaches in the Fairmount area were mapped with the aid of aerial photographs, which made the beach locationsas shown on plate 1 more accurate than those shown by the maps of Upham (1896, pl. XXIV) and Leverett (1932, fig. 18).

Leverett assigned all the beach ridges that he mapped in the Fairmount area to the Campbell beaches. Upham, on the other hand, has shown several beaches occurring within the Campbell beaches which he assigned to the McCauleyville stages. Evidence of the inner beaches was not found during the present investigation and the writer shares Leverett's opinion (1932, p. 139) that the McCauleyville beaches do not extend into the area and that, consequently, Lake Agassiz had no connection with the southern outlet during the McCauleyville stage.

The beaches shown in plate 1, therefore, are assumed to belong to the Campbell beaches.

Because the Lake Agassiz deposits are relatively thin over most of the area, they do not form an aquifer of importance. Only two wells that were scheduled in the area (129-48-12bcc and 130-48-13cbd) appear to be shallow enough to derive their principal supply from these deposits. Even those two wells may tap aquifers associated with the till rather than aquifers in the lake deposits. Some of the other wells in the area that are 50 feet or less in depth may obtain part of their water from an aquifer in the lake deposits but, on the whole, it appears more likely that the aquifers are associated with the underlying till.

Because the deposits are exposed at the surface over the area, any aquifers found in them would be well situated to receive seasonal recharge from local rain and melting snow. However, in a series of dry years, any shallow aquifer is likely to dry up entirely. In any event, any aquifer found in the lake deposits probably would not be suitable for meeting water requirements in excess of minor farm and domestic needs.

Till and associated deposits of sand and gravel:--The Mankato drift is composed (for the most part) of till and associated deposits of sand and gravel. The till is light gray in the unweathered part and yellowish brown in the weathered upper 5 to 10 feet. It consists of varying proportions of rock fragments ranging in size from clay to boulders and is rather highly calcareous. Clay and silt usually are the predominant constituents and form the matrix throughout which sand, gravel, and boulders are scattered. The whole mass has a conspicuous lack of sorting. Fragments of calcitic and dolomitic limestone and of metamorphic and igneous rocks are common. The till is relatively impermeable and does not yield water to wells in any practical amount.

Associated with the till are deposits of more or less sorted and stratified sand and gravel. Except for the lack of shale detritus, these deposits are composed of the same rock materials that occur in the till.

Where the deposits of sand and gravel occur within the zone of ground-water saturation they generally form good aquifers. The value of one of these aquifers to the ground-water economy of the area depends largely on its areal extent, the thickness of its saturated part, its porosity and permeability, and its accessibility to recharge.

Twenty-eight feet of water-bearing sand was penetrated in USGS test 477 (130-48-24cbb) from 48 to 76 feet below the land surface. The sand is loose, medium to coarse textured, and comparatively well sorted. At the present time, the aquifer is being utilized by several farms in the area north of USGS test 477 (see pl. 1). In order to evaluate the productivity and areal extent of the aquifer, a test well should be constructed and pumped, and additional exploratory test holes should be drilled.

A water sample was obtained from USGS test 477 and was analyzed for chemical content, the results of which are given on page 53 . The sample contained 2,660 parts per million of dissolved solids and the hardness was 1,440 parts per million.

In USGS test 483 (130-47-17daa), drilled a mile north of Fairmount alongside U. S. Highway 81, 31 feet of very coarse sand and fine to medium gravel were penetrated from 28 to 59 feet below the land surface. Little is known concerning the areal extent of these deposits but they probably are confined to a rather local area. It is doubtful that they would be connected with the deposits penetrated in USGS test 477.

Only about a dozen wells in the area tap aquifers in the Mankato drift, and most, if not all, of these are in sand and gravel deposits within the till. That most of the wells in the area tap aquifers below the Mankato drift is fair evidence that the Mankato drift does not contain aquifers of any great importance. The aquifers tapped probably are discontinuous and of relatively small areal extent.

Where the sand and gravel deposits occur in sufficient numbers and complexity, they may be interconnected to such a degree as to make the entire formation a weak aquifer; this may be especially true where a rather thick and long deposit of sand and gravel occurs in such a way that smaller deposits are intercepted along its edges.

Recharge to the aquifers is principally through downward percolation of precipitation on the land surface in the immediate vicinity of the aquifers and, perhaps, from the water that may move laterally through the till from adjacent areas. The amount of water that may be received by the individual aquifers is dependent largely upon surface conditions (poor surface drainage, so that water would have ample opportunity to percolate downward), and upon the permeability of the overlying and surrounding till. It is impossible to determine just how much recharge can reach a given aquifer without records of water level fluctuations over a considerable length of time. However, the opportunity for receiving recharge is greater for the larger aquifers and for those nearer the land surface. Some of the aquifers in the area doubtless are nearly or completely surrounded by relatively impermeable materials so that they can receive recharge only at a very low rate.

Pre-Wisconsin (?) Stage

Older drift

Older drift, consisting of lake clay, possible buried outwash deposits, and till and associated deposits of sand and gravel, underlie the Mankato drift in most of the Fairmount area. At least one of these units was penetrated by each of the USGS test holes drilled in the area. The total thickness of the older drift penetrated in the USGS test holes ranges from 57 to 176 feet. The average thickness is 116 feet, which is more than $1\frac{1}{2}$ times the average thickness of the Mankato drift.

The age of the older drift is not definitely known. The clay and silt in the outwash deposits, and in some places the upper 5 to 10 feet of the till, is tan or yellowish brown, indicating a period of weathering prior to late Wisconsin glaciation.

The older drift is probably correlative to the "old gray" drift which Allison states underlies the "young gray" or Mankato drift over most of northwestern Minnesota (1932, p. 8). The "old gray" drift is believed to be of Kansan age (Allison, 1932, p. 8), but the possibility that it may include Wisconsin drift, younger than Mankato, is recognized.

Lake deposits:-- Relatively uniform deposits of clay and silt, thought to be lake sediments formed in a glacial lake ancestral to Lake Agassiz, occur at or near the top of the older drift over much of the area. These older lake deposits consist of dark-gray calcareous clay and silt which is moderately well indurated and contains only minor amounts of sand or gravel. As shown in plate 2, the thickest lake deposits occur in the northern part of the area. In USGS test 484(130-47-8caa) and 485(130-47-6dda), 72 and 63 feet of the older lake deposits were penetrated, respectively.

There is conclusive evidence of multiple glaciation in the Red River Valley, and it seems likely that this older glacial lake had much the same history as did Lake Agassiz. That is to say, glacial melt water and northward-flowing drainage probably were ponded in the RedRiver Valley along the southern margins of an ice sheet that existed prior to the Mankato ice sheet. That the lake may have had a considerable areal extent is indicated by the presence of possible correlative lake clays in the Fargo area (Dennis, Akin, and Worts, 1949, p. 26-29) about 60 miles north of Fairmount, and the probable existence of such deposits in the Wyndmere area (Dennis, Akin, and Jones, 1949, p. 25), more than 20 miles west-northwest of Fairmount.

The older lake deposits, for practical consideration, are very nearly impermeable and no wells in the area are known to obtain water from them.

Buried outwash(?) deposits:-- Deposits of sand and gravel, thought to be buried glacial outwash, occur in the upper part of the older drift over most of the area south and east of Fairmount. The probable extent of these deposits in the Fairmount area is shown in plate 1 as the "area in which most wells are between 80 and 110 feet deep and end in buried outwash(?) deposits." The deposits were penetrated in most of the test holes drilled south and east of Fairmount at depths usually ranging from 80 to 100 feet. The known thickness of the deposits ranges from 9 to 18 feet and averages 14 feet.

The buried outwash (?) deposits consist mostly of fine clayey sand in the upper part and fine to medium gravel in the lower part. The coarser and probably more permeable deposits were penetrated in the test holes drilled south of Fairmount.

That these deposits are glacial outwash is suggested by their association with glacial till, their widespread areal extent, and their fairly uniform thickness. However, the presence of oxidized clay and silt, numerous shell fragments, and carbonaceous material in the upper part of the deposits in some places suggest interglacial modification of that part of the deposits, at least. There is, of course, a distinct possibility that all the buried outwash(?) deposits were actually formed during an interglacial period. This view is somewhat supported by the presence of oxidized till beneath the deposits in several places, indicating a period of weathering prior to their deposition. At present little subsurface information is available for adjacent areas that would throw much light on the matter.

The buried outwash(?) deposits are water bearing and constitute an important aquifer in the area. Many farm supplies and the Fairmount municipal supply are obtained from these deposits. The aquifer was not penetrated by any of the test holes drilled west of Fairmount, and it is believed that the western edge of the area in which most wells are between 80 and 110 feet deep, as shown in plate 1, roughly approximates the western edge of the aquifer. The aquifer may extend farther north than the area outlined on the basis of well depths, however, inasmuch as it may have been penetrated by the wells in that part of the area but was not utilized because of the desire for softer water available from the Dakota(?) sandstone at greater depths. At any rate, the aquifer doubtless extends east and south of the Fairmount area, possibly the greater part of it lying in Minnesota. Upham (1896, p. 550-555) and Allison (1932, p. 226-227, 238-239) listed a considerable number of flowing wells having comparable depths in nearby areas in Wilkin and Traverse counties, Minn. The chemical quality of the waters from the wells listed by Allison is similar to that of the water in the buried outwash(?) deposits in the Fairmount area.

The water in the buried outwash(?) deposits occurs under artesian conditions, so that, although the deposits lie 80 to 110 feet below the land surface, the water rises in wells to within only a few feet of the land surface, or in low spots flows at the land surface. Artesian conditions are made possible by (1) confinement of the water-bearing beds in the buried outwash(?) deposits between overlying deposits of relatively impervious till of the Mankato drift and underlying deposits of older till and lake clay, also relatively impervious, and (2) recharge of the deposits in an area of higher elevation to the east or northeast.

The aquifer appears to rise in elevation toward the east or northeast. The section of the aquifer drilled east of Fairmount rises toward the east at the rate of about 10 feet per mile. The aquifer apparently "pinches out" toward the west in the Fairmount area indicating an "artesian slope" type of structure as defined by Simpson (1929, p. 50).

Because the buried outwash(?) deposits are overlain by the relatively impermeable Mankato drift in the Fairmount area and because a large proportion of the wells flow, it is reasonably certain that the deposits receive no recharge from sources within the Fairmount area. Probably the principal recharge area occurs in the higher morainic area adjacent to the Lake Agassiz basin in Minnesota east of the Fairmount area. In the morainic area, water from rain and melted snow collects in the numerous kettles and "potholes" that have no surface drainage. The part of this water that escapes evaporation and transpiration by plants seeps into the ground and then moves laterally very slowly to lower elevations. The buried outwash(?) deposits themselves may not extend into the morainic areas but they may connect with some of the sand and gravel deposits associated with the overlying and possibly the underlying till adjacent to them on the east, so that pressures from the higher morainic area could be readily transmitted to the lake-basin area without the actual movement of a great deal of water.

Some recharge may be derived from higher areas within the lake basin itself where the till is exposed at the surface and may be somewhat more sandy, and, therefore, more permeable, than it is in general. Allison (1932, p. 235-236) reports that "an extensive area of lake-washed sandy till occurs west and southwest of Lawndale and Rothsay" in Wilkin County, Minn. The central part of this area of lake-washed till is about 25 miles northeast of Fairmount and the southern tip of the area is about 15 miles from Fairmount.

Present data are inadequate either to determine the amount of recharge that reaches the buried outwash (?) deposits or to determine quantitatively the permeability of the deposits at any locality or in general. Because the deposits cover a relatively large area and contain a considerable amount of water in storage, they constitute the most important aquifer in the area in which they occur.

The village ofFairmount is the largest single user of water from the buried outwash(?) deposits. Since 1947 a municipal supply well (130-47-21dba2) has yielded about 30 gallons a minute. However, during the fall and winter of 1951 a newwell (130-47-21dbal) was drilled, and it is reported that this well is yielding about 100 gallons a minute at present. The well is said to have a maximum capacity of 200 gallons a minute, but it is not known how much drawdown occurs in the well at that rate.

Results of the test drilling indicate that the buried outwash(?) deposits underlying the area south of Fairmount probably are more permeable than that part of the deposits east of the village from which water is now obtained. USGS test 480 (130-47-32aaa), 481 (129-47-5aaa), and 482 (129- 47-8aaa), drilled 1, 2, and 3 miles south of Fairmount, respectively, penetrated thin but apparently extensive and interconnected deposits of gravel at depths ranging from 85 to 93 feet. These deposits occur at the bottom of the buried outwash(?) deposits and appear to have good permeability. It seems probable that, if additional ground-water supplies for the village of Fairmount will be necessary, this area warrants careful consideration.

The quality of the water occurring in the buried outwash (?) deposits generally is better than that of any other known source in the Fairmount area. Chemical analyses of the water from four wells ending in the buried outwash (?) deposits are shown on page 33 . The water generallycontains less dissolved solids (260 to 1,000 ppm in the four samples) than water from the Dakota (?) sandstone (1,200 to 3,380 in three samples) but is considerably harder. All the samples contained excessive amounts of iron.

Till and associated deposits of sand and gravel:--The till of the older drift bears considerable resemblance to that of the Mankato drift and in some of the test holes where the buried outwash(?) deposits were absent difficulty was experienced in placing the contact between the two drifts. The older drift usually can be distinguished from the Mankato by its greater induration and usually darker shades of gray. Like the till of the Mankato drift it is calcareous and contains a large proportion of limestone detritus.

It seems likely that the darker color of the older till and lake clay is due to the presence of considerable amounts of detritus derived from the underlying Benton shale, which is usually dark gray to nearly black. However, in some parts of the area (see logs USGS test 473 and 477) the till of the older drift is light gray and contains large amounts of rounded quartzose sand grains derived from the Dakota (?) sandstone in places where the Benton shale had been stripped off.

Ordinarily the till is not water bearing but in places where it is composed largely of reworked Dakota (?) sandstone it may be a weak aquifer or may form a hydrologic connection between aquifers in the Dakota (?) sandstone and deposits of sand or gravel associated with the till.

As in the Mankato drift, deposits of sand and gravel occur within the older drift. In USGS test 477 (130-48-24cbb), 52 feet of fine clayey sand was penetrated from 140 to 192 feet below the land surface. These deposits apparently form an aquifer of local areal extent near the base of the drift. As indicated by the well inventory, this aquifer furnishes water for a few farm wells in the area. The probable extent of the aquifer is shown on plate 1 by the symbol for the "area in which most wells end in glacial drift at varying depths less than 200 feet." Another local aquifer in sand and gravel deposits in the older drift occurs in the southeastern part of the area and furnishes water to four farm wells in that area. The probable extent of the aquifer is shown by the same symbol as that used for the first mentioned aquifer. A few other thin beds of sand occurring in the older till were found in the test holes. However, because of their local areal extent, none of these is likely to be of importance as a source of water supply for other than the small demands for domestic and farm uses. The aquifers probably cannot receive any large amount of recharge because of the relatively impermeable materials surrounding them. However, some of the aquifers may be hydrologically connected with the extensive Dakota (?) sandstone and thus may receive recharge from that source. Such aquifers probably would produce dependable supplies for larger farm requirements or for small industrial or municipal supplies.

The water in deeper aquifers associated with the older drift probably is similar to that of the Dakota (?) sandstone, although less mineralized. Sodium, chloride, and sulfate presumably are the principal constituents.

Benton Shale

Cretaceous shale underlies the older drift throughout most of the Fairmount area with the exception of the southeastern part. Because of its lithology and position directly overlying the Dakota (?) sandstone, the shale is believed to be part of the Benton shale of Late Cretaceous Age.

Where penetrated by test drilling the Benton shale ranges in thickness from a few feet to a maximum of 74 feet in USGS test 485 (130-47-6dda), the northermost test hole drilled in the area. It consists largely of plastic clay ranging in color from light gray in the upper part to dark gray or nearly black in the lower part. Pyrite is common in the form of crystals and as replacement of fossils.

A core of the shale containing fish bones, scales, and a small fauna of Foraminifera was obtained from USGS test 485. Shark teeth and tooth fragments were fairly common in the drill cuttings. Some of the fossils were identified by paleontologists of the U. S. National Museum and the U. S. Geological Survey.

Fish scales were identified as "probably pertaining to either Halopteryx(?) insculptus Cope, from the upper Cretaceous of New Jersey, or Pelocorapis berycinus Cope, from the Benton of Kansas" (Ruth Todd, personal communication, Feb. 1952).

The shark teeth were identified as belonging to Isurus appendiculatus (Agassiz), a shark ranging from the Upper Cretaceous to the Miocene. This species had been previously recognized in the Cretaceous of Minnesota (David Dunkle, personal communication, Feb. 1952).

The following genera of Foraminifera were identified: Pelosina (?), Haplophragmoides, Ammobaculities, Gaudrynia (?), Lenticulina (?), Gümbelitria(?) and Gümbelina.

Concerning the environment of deposition of the Foraminifera, M. Ruth Todd, (personal communication, Feb. 1952) U. S. Geological Survey, made the following statements:

"The extremely small size of the forms and the lack of many of the normal constituents of Cretaceous faunas suggest that this fauna was deposited under abnormal conditions, probably brackish, shallow, and without access to oceanic water, and probably cooler than conditions under which Cretaceous faunas lived in the southern part of the continent."

Because of its extremely low permeability, the Benton shale probably would not yield enough water to be considered an aquifer in the Fairmount area.

Dakota(?) Sandstone

Except in the southeastern part of the Fairmount area the lowest sedimentary materials are thin but persistent deposits of sand or gravel at depths ranging from 200 to 280 feet below the land surface, lying below the Benton shale where it is present, or below the older glacial drift. These deposits lie directly on the weathered surface of the preCambrian granite and are believed to be an eastward extension of the Dakota sandstone, the famous artesian aquifer described in areas farther west in North Dakota (Wenzel and Sand,1942).

It is possible that the deposits assigned to the Dakota (?) sandstone in this report are not true Dakota of Late Cretaceous age but rather, may be correlative with the Fall River sandstone which occurs in the Black Hills region and is of Early Cretaceous age (Rubey, 1931, p. 4-5). At present there is little conclusive evidence regarding the age of the deposits with the exception that they probably are Cretaceous. Consequently, the term Dakota (?) sandstone is retained, although questionably, for use in this report.

The thickness of the Dakota (?) sandstone, where penetrated by test drilling, ranges from only a few feet in some parts of the area to a maximum of 49 feet in USGS test 484 (130-47-8caa). A thickness of about 15 feet is most common. As shown in the geologic sections (pl.2) the deposits, like the Benton shale, become thicker toward the north.

The Dakota(?) sandstone consists largely of very fine to fine sand but in places contains beds of gray clay or shale. In some of the test holes a thin basal layer of very coarse sand and gravel was penetrated. In USGS tests 484 and 485 several feet of lignite or other carbonaceous material was penetrated at the base of the Dakota (?) sandstone.

Most of the sand grains are quartz and are well rounded, except for the larger grains which are angular. Muscovite and pyrite are common in the sand. The samples obtained from the uncased rotary test holes drilled under the supervision of the U. S. Geological Survey contained large amounts of clay. However, well drillers in the area, using cable-tool drilling methods and cased holes, generally describe it as consisting of unconsolidated deposits of clean white sand.

The depsoits are not present everywhere in the area because of local protuberances in the underlying granite which form "islands" in the deposits of Cretaceous age. Generally, the granite is higher in the southeastern part than elsewhere. A "high" in the granite was reached by test holes and wells drilled one-half to three-quarters of a mile east of Fairmount (see pl. 2). The high areas in the granite probably never were covered by Cretaceous sediments but, rather, were source areas for those sediments.

The Dakota (?) sandstone is the most extensive aquifer in the area. As shown in plate 1, considerably more than half the wells in the area end in this formation. The wells range in depth from 200 to 280 feet, the deepest wells being in the northern part of the area. All are drilled or jetted and are 1½ to 5 inches in diameter. Because of the fineness of the water-bearing sands, most of the wells are equipped with screens.

Although artesian conditions prevail in the Dakota (?) sandstone, flowing wells are not obtained. According to reports, flows never were obtained in the Dakota(?) sandstone in the Fairmount area, even during the early years of development. Water levels were measured in a few of the wells in the area during the course of the investigation and these, along with most reported water levels, ranged between 15 and 30 feet below the land surface. Probably flows are not obtained from the Dakota (?) sandstone in the Fairmount area because of natural discharge of water from the aquifer at lower elevations in the Red River Valley to the north and in the Minnesota River valley to the south with consequent pressure-lowering effects in adjacent areas.

Little quantitative information is available at present concerning the permeability of the water-bearing sands in the Dakota(?) sandstone, or the yields that may be expected from them. Probably the largest single user of water from this source in the Fairmount area is the Cudahy Packing Co. About 20 gallons a minute is withdrawn from a well 231 feet deep. It is not known how much sand was penetrated in the well. However, in USGS test 474 (130-47-20dbb), which was drilled about a quarter of a mile north of the Cudahy well, 5 feet of very coarse sand was penetrated from 229 to 234 feet below the land surface.

In 1950, at a time when the Cudahy well was temporarily out of commission owing to mechanical breakdown of the pump, it is reported that the water level in the well rose from 112 feet to 90 feet below the land surface during a period of 3 weeks. Water levels in most wells ending in the Dakota (?) sandstone generally are less than 30 feet below land surface. The fact that the water in the Cudahy well recovered only to a depth of 90 feet after a period of 3 weeks suggests that the transmisibility of the aquifer in that area is quite low and that the head has been drawn down over a sizable area by the pumping from that well.

The Dakota sandstone or its equivalent underlies most of the Great Plains and the Dakota sandstone itself is exposed in relatively narrow bands along the flanks of the Rocky Mountains and the Black Hills. It is in these areas of exposure, which are at an altitude several thousand feet higher than the Great Plains, that most of the recharge occurs. Widely scattered outcrops of sand, sandstone, and gravel assigned to the Dakota sandstone have been noted in southern Minnesota (Thiel, 1944, p. 76-77) but, because of their restricted areas and low altitudes, they are more likely to be areas where natural discharge occurs rather than areas in which significant recharge occurs.

Water, derived from precipitation and by seepage from streams flowing over outcrops, enters the more permeable zones of the formation. Percolating slowly downward, and laterally, through the interstices between the sand grains, and through crevices the water may eventually travel hundreds of miles through the formation before it is intercepted by wells or discharges naturally.

Because of the difference in altitude between the relatively high areas of recharge and the altitude of the Dakota sandstone as it occurs in North Dakota, the water in the sandstone is under hydrostatic pressure which in the early years of development was very great. Pressures great enough to raise the water more than 100 feet above the land surface were not uncommon in the Ellendale-Jamestown area (Wenzel and Sand, 1942, p. 31).

In the Fairmount area no reports were obtained of original high pressures in wells in the Dakota (?) sand stone. However, because of extensive preglacial erosion of the Cretaceous formations in the Fairmount area, much of the protective shale cover may have been removed from the Dakota(?)sandstone in places, thus permitting large-scale leakage and loss of pressure to overlying beds.This is strongly suggested by the similarity in chemical quality of the water in the Dakota(?) sandstone and that in the deeper drift aquifers.

As would be expected, because of the great distance the water in the Dakota sandstone has moved from the recharge areas, and because of the long period of time necessary for the movement, comparatively large amounts of dissolved mineral matter are present in the water. Chemical analyses of the water taken from three wells ending in the Dakota (?) sandstone in the Fairmount area are given on page 33 . Although all three analyses show relatively high mineralization, waters from two of the wells (129-47-20dbc1 and 130-48-1ddc) are less mineralized than is generally common in waters obtained from the Dakota sandstone. Again, this condition may be due to lack of sufficient confinement of the aquifer, so as to permit intermixing with waters from the glacial drift. Such intermixing would most likely result in the dilution of the water from the Dakota(?) sandstone.

The remaining water, obtained from well 131-48-36ccb, is very highly mineralized (3,380 ppm) and seems to be typical of the average water from the Dakota sandstone (Simpson, 129, p. 41), although somewhat softer.

All three analyses show large amounts of sodium, chloride, and sulfate. The water from well 131-48-36cbb was perceptibly salty to the taste. The waters contained relatively small amounts of calcium and magnesium and are the softest of any of the ground waters in the area. For this reason they should be satisfactory for laundry use. However, the low content of calcium and magnesium, which means a high percentage of sodium, indicates that the water would not be well suited for irrigation.

As is typical with most water from the Dakota sandstone, the samples contained significant amounts of fluoride. Excessive fluoride may cause mottling of the enamel of the teeth of children: the limit recommended by the Public Health Service is 1.5 parts per million.

Pre-Cambrian Granite

The pre-Cambrian granite was reached in all the test holes drilled in the area, at depths ranging from 15° to 270 feet. As shown in plate 2, the highest occurrence of granite in the area (probably the highest known occurrence in North Dakota) was reached by USGS test hole 482 (129-47-8aaa) at a depth of 159 feet below the land surface, near the southern edge of the area. From this location the surface of the granite slopes gently northward or nothwestward, the slope becoming more pronounced in the northern part of the area.

The surface of the granite as shown in section B-B' of plate 2, from west to east, exhibits more local relief than that shown in the north-south section (A-A'). Whether this may indicate the presence of northward-trending ridges in the granite cannot be proved because of lack of subsurface data. A ridge, or some other form of topographic "high", was reached by test holes and wells drilled a short distance east of Fairmount.

In most places where the granite is overlain by deposits of Cretaceous age, its uppermost part consists largely of decomposition products of granite-forming minerals. This decomposition of the granite occurred during the great period of time preceding Cretaceous sedimentation when the granite was exposed to weathering. The thickness of the decomposition zone in the granite probably varies considerably because of the original variation in depth of weathering and because of glacial erosion which in some places caused the removal of all the decomposed zone. IN USGS tests 472 (130-47-21daa) and 473 (130-47-21cbb)

12 feet and 19 feet, respectively, of decomposed granite was penetrated. It is believed that the decomposed zone was completely penetrated in each of these test holes, inasmuch as the drill reached very hard rock. However, no samples of the hard, unaltered rock were obtained. In places in the southern part of the area, where the Cretaceous rocks are not present, there is no decomposed zone at the top of the granite.

A sample from a core obtained in USGS test 475 (130-47-20cbb) between 220 and 230 feet was examined by means of an electron microscope by members of the U. S. Geological Survey. It was determined that the sample consisted mainly of kaolin-group clay minerals and traces of quartz and feldspar. Concerning the identification of the clay mineral or minerals, it was reported: "Sharpness of lines suggests nacrite, dickite, or kaolinite. Electron-microscope pictures taken by E. J. Dwornik show that the clay is composed principally of both large and small flakes of irregular shape, but a few seem to have crude hexagonal outlines suggestive of kaolinite. A few poorly defined tubular crystals of halloysite are present. Hence it is concluded that the clay is principally kaolinite and a small amount of halloysite." (F. A. Hildebrand, personal communication, Sept., 1952).

In some places the top of the decomposed zone is marked by a layer of red or brown clay but more often the clay is white, grading downward into light green. The decomposed granite grades transitionally into the fresh, unaltered granite, which extends downward to unknown depths.

Neither the decomposed nor the unaltered granite is known to be water bearing in the Fairmount area. It is possible that in places the hard, unaltered granite contains joints or other openings in which ground water may collect. However, it is doubtful that water supplies of any importances could be developed from the granite.

QUALITY OF WATER AND CHEMICAL ANALYSES

In order that the reader may more easily understand the significance of the chemical analyses, the following partial list of chemical standards promulgated by the U. S. Public Health Service for drinking water used on interstate carriers is given:

Chemical constituent	Maximum concentration permitted (parts per million)
Dissolved solids	500 (1,000 permitted if necessary)
Chloride (Cl)	250
Sulfate (SO_4)	250
Magnesium (Mg)	125
Fluoride (F)	1.5
Iron (Fe) and manganese (Mn) together	0.3

The presence of excessive amounts of nitrate in ground water may indicate organic contamination. Also, water containing more than about 45 parts per million nitrate as NO_3 (Comly, 145, Silverman, 1949) may be injurious to infants.

The analyses of samples taken from eight wells in the Fairmount are are given on page 33 . Four of the samples were obtained from wells ending in the buried outwash (?) deposits, three from wells ending in the Dakota (?) sandstone, and one from an uncased test hole ending in a shallow acquifer in the Mankato drift.

The water in the buried outwash (?) deposits probably has the best quality of the various ground waters in the area. The four samples (129-47-5cbb, 129-47-5ddd, 130-47-21dba2, and 130-47-26-aba) contained 670, 1,000, 550, and 260 parts per million of dissolved solids respectively. Total hardness of the four samples was 250, 210, 250 and 250 parts per million. Only minute quantities of sulfate were found in the samples, with the exception of 129-47-5cbb which contained 66 parts per million of sulfate. On the other hand, the samples contained rather large amounts of bicardonate,a relationship which has been noted in the literature on ground waters associated with hydrocarbons (Stabler, 1931, p. 51-53; Renick, 1924, p. 681-683).

It has been postulated that hydrocarbons or substances containing hydrocarbons such as methane, lignite and carbonaceous clay or sand, may react with the sulfate ions present in the ground water to form carbonate, bicarbonate, and hydrogen sulfide. Carbonaceous clay and sand were found in some of the samples of the buried outwash (?) deposits and their presence in the deposits would at least lend support to the theory.

Also, certain types of bacteria are believed to be responsible for the reduction of sulfate and precipitation of sulfide (most commonly in the form of pyrite). However, no evidence of sulfide minerals was found in the samples obtained from the buried outwash (?) deposits.

It has been suggested that, assuming that the buried outwash (?) deposits are of interglacial origin, or at least were weathered during an integlacial period, the sulfate-bearing materials may have been leached out when the deposits were exposed. However, this supposition in order to account for the low sulfate content of the water occurring in the buried outwash (?) deposits, necessarily implies that recharge water now reaching the aquifer must also contain very small amounts of sulfate. The recharge water presumably is derived from the morainic areas east of the glacial Lake Agassiz basin and probably must pass through deposits that are likely to contain significant amounts of sulfate before entering the buried outwash (?) deposits. If so, the sulfate-reducing process, whatever it is, must be continuing.

The water from the Dakota (?) sandstone, in all three of the samples analyzed, was more highly mineralized than is desirable for most domestic uses.

Samples 129-47-20dbc1, 130-48-1ddc, and 131-48-36-ccb contained 1,570, 1,200 and 3,380 parts per million of dissolved solids, respectively. The samples contained excessive amounts of sodium, chloride, and sulfate. Fluoride was present in all the samples, although not in excessive amounts. The water is considerably softer than the water in the buried outwash(?) deposits, or in other drift aquifers, and for that reason is more satisfactory for laundry and boiler use. However, because of the low calcium and magnesium content and the high percentage of sodium, the water probably is not suitable for irrigation purposes (Wilcox, 1943).

Sample 130-48-24cbb was obtained from USGS test 477 which ended in a sand deposit associated with the Mankato drift. The water was highly mineralized, containing 2,660 parts per million of dissolved solids, and the hardness was 1,440 parts per million.

CHEMICAL ANALYSES OF GROUND WATERS FROM
(parts per

Analyses made by North Dakota State Department of Health,
Bismarck, N. Dak.

(T), trace amount present
Dissolved solids is sum of determined constituents only

Location number	Cwner	Date of Analysis	Depth of well (feet)	Aquifer	Iron (Fe)	Calcium (Ca)
129-47-5cbb	C. A. Kutzer	8-20-52	96	BO	1.9	53
129-47-5ddd	W. R. Taylor	8-20-52	96	BO	1.7	21
130-47-20dbc1	Cudahy Packing Co.	8-23-51	231	D	.3	15
130-47-21dba2	Village of Fairmount	8-23-51	113	BO	.5	54
130-47-26aba	J. E. Waite	8-20-52	74	BO	1.1	43
130-48-1ddc	Tom Bertelson	5-22-52	270	D	.8	26
130-48-24cbb	USGS test 477	5-23-52	76	G	8.2	300
131-48-36ccb	Harry Ehlers	5-22-52	280	D	1.6	37

THE FAIRMOUNT AREA, N. DAK., AND MINN.
million)

BO, buried outwash(?) deposits
D, Dakota(?) sandstone
G, till and associated deposits of sand and gravel

Magnesium (Mg)	Sodium and Potassium (Na & K)	Carbonate (CO3)	Bicarbonate (HCO3)	Sulfate (SO4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (sum)	Total hardness (as CaCO 3)	Percent Sodium
28	170	0	570	66	56	.3	11	670	250	59
38	330	0	1,010	(T)	90	.2	17	1,000	210	76
10	550	0	400	360	390	1.3	43	1,570	80	94
28	130	0	600	(T)	27	.1	9	550	250	52
35	(T)	14	280	(T)	16	.1	9	260	250	-
11	410	0	450	300	230	.5	4	1,200	110	88
170	270	0	200	1,790	30	(T)	4	2,660	1,440	28
16	1,170	22	250	920	1,080	1.0	9	3,380	160	94

SUMMARY AND CONCLUSIONS

Information obtained by test drilling and from data on existing wells indicates the presence in the Fairmount area of two aquifers of comparatively large areal extent. Also, several smaller aquifers of considerable thickness but probably of rather local extent are present in the area. The approximate locations and areal extent of these aquifers are shown in plate 1.

The most extensive aquifer in the area is the Dakota (?) sandstone. This formation underlies most of the area at depths ranging from 200 to 280 feet except in the southeastern part where it is not present. In the northern part of the area the formation consists of 15 feet, or more, of sand and yields adequate amounts of potable water to suit practically all domestic and farm needs.

However, in the immediate vicinity of Fairmount the Dakota (?) sandstone is quite thin; probably, it is not much more than 5 feet thick. For this reason it seems doubtful that the formation in this locality could yield water in large enough amounts from a single well to meet the domestic and industrial needs of the village. The Cudahy Meat Packing Co. well, which is 231 feet deep, is believed to end in the Dakota (?) sandstone. The well is 6 inches in diameter, and it is reported that it will not yield more than about 20 gallons per minute. However, a large-diameter well or a battery of several wells might yield enough water for the needs of the village. A properly planned and executed pumping test on one or more of the wells in the Dakota (?) sandstone in Fairmount would throw much light on the feasibility of such a project.

The next largest aquifer in the area is the buried outwash (?) deposits. This aquifer underlies most of the area south and east of Fairmount and is reached by wells generally ranging in depth from 80 to 110 feet. East of

Fairmount, where the village supply wells are located, the aquifer is composed of sand which in some places contains considerable clay and silt. The clay and silt tend to reduce the permeability of the aquifer and, consequently, the amount of water yielded by the aquifer in those places. However, beginning about a mile south of Fairmount and continuing as far south as was investigated by test drilling, a thin but apparently continuous bed of gravel occurs at the bottom of the aquifer. The gravel as obtained in the drill cuttings is coarse and relatively free of clay and silt, and it seems likely that those deposits would yield water in adequate amounts for the municipal needs of Fairmount or for comparable industrial or agricultural needs.

The presence of several other aquifers in the area was disclosed by test drilling and existing well data. Although these aquifers may be somewhat local in areal extent, where penetrated by test drilling they were sufficiently thick and permeable to merit consideration as possible sources for municipal or other moderately large scale use.

The aquifer, penetrated between 48 and 76 feet in USGS test 477 (130-48-24cbb), about $2\frac{1}{2}$ miles west of Fairmount, appears to be capable of yielding comparatively large amounts of water. The same may be said of the aquifer penetrated between 28 and 59 feet in USGS test 483 (130-47-17daa), about a mile north of Fairmount. The value of these and other local aquifers should be further investigated by means of additional test drilling and by test pumping.

For most purposes for which water is required in the Fairmount area, the water in the buried outwash (?) deposits has the best chemical quality of all the ground waters obtainable in the area.

Type of well: B, bored; Dr, drilled; Du. dug; J. jetted

Depth of well, and depth to water: Measurements given to tenths are measured well depths or water levels, as the case may be. Those given in whole numbers are reported.

Location number	Owner or name	Depth of well (feet)	Diameter (inches)	Type	Date completed	Depth to water (feet)
129-47						
2bcd	C. A. Tuttle	112	2	Dr	1950	.....
3add	John Dorgeloos	110	3	Dr	1900	12
4abb	A. V. Gajer	93	2	Dr	1898	Flow
5aaa	USGS test 481	183	5	Dr	1951	.....
5cbb	C. A. Kutzer	96	3	Dr	1950	15
5ddd	W. R. Taylor	96	3	Dr	1900	Flow
6dba	Frank Grundysen	100	2	Dr	....	20
7dda	G. W. Williams	108	2	Dr	....	10-12
8aaa	USGS test 482	160	5	Dr	1951	.....
9bdc	E. F. Rydell	110	3	Dr	1939	35
10aab	Walter Beyer	195	5	Dr	1945	.....
10cdc	Wm. Marquardt	160	3	Dr	1926	10
10dcb	Herman Beyer	175	2	Dr	1905	13
11bab	Frank Propp	165	3	Dr	....	15
12aaa	G. A. Propp	105	1½	Dr	1933	1.5
12acc	H. Larson	45	5	Dr	....	.....
12cbb1	Fred Aupperle	40	3	Dr	....	1
12cbb2	....do.......	40	2	Dr	....	½
12ddb	Earl McAloney	120	...	..	....	......
129-48						
2abb	Vacant farm	...	...	Dr	....	10.3
11add	L. W. Lien	180	2	J	1949	15-17
11ddd	Roy Snyder	180	4	J	1946	.....
12bcc	M. Leinen	16	48	D	....	.....
12ccc	John Snyder	205	2	Dr	1942	10
130-47						
2ada	F. Schillinger	240	3-2	J	1926	10
2bdd	Gus Voss	248	3	J	....	.....
2cab	Edward Bucholz	245	3-2	J	....	8
2ddd	R. Schillinger	240	3-2	J	....	.....
4cad	Ed.Omeara	185	3	Dr	....	.....
5aaa	A. J. Matheson	250	3	Dr	....	15
5ddd	Peter Wawers	240	3	Dr	....	.....

Use of water: D, domestic; S, stock; PS, public supply U, unused; I, industrial.

Geologic horizon: BO, buried outwash (?) deposits: D, Dakota(?) sandstone: G, till and associated deposits of sand and gravel.

Date of measurement	Use	Description of water-bearing material	Geologic horizon	Remarks
....	D,S	Fine sand	BO	Water reported hard. Farm located on beach ridge; formerly had several shallow dug wells.
....	D,S	....	BO	Water reported hard.
6-22-51	S	....	G	Water soft.
....	U	....	..	Hole refilled. See log.
....	D	Gravel	BO	Water reported medium hard. See chemical analysis.
6-28-51	D,S	Fine sand	BO	Water reported hard; weak flow. See chemical analysis.
....	D,S	Fine blue sand	BO	Water reported hard.
....	D,S	....	BO	Do.
....	U	....	..	Hole refilled. See log.
....	D,S	White sand	BO	Water reported medium hard.
....	D,S	Gravel	D	Water reported soft.
....	D,S	Sand	G	Water reported soft.
....	D,S	Coarse gravel	G	Water reported soft. Several unused shallow wells on farm.
....	D,S	Sand	G	Water reported soft.
6-10-51	D,S	Sand from 98 to 108 feet	BO	Water reported hard; excessive iron.
....	D,S	Gravel	G	
....	D	Coarse sand	G	Water reported medium hard.
....	S	....do........	G	Do.
....	D,S	....	..	Reported inadequate.
6-29-51	U	....	..	
....	D,S	Coarse gray sand	D	Water reported soft.
....	D,S	....	D	Do.
....	D,S	....	..	Water reported hard.
....	D,S	Gravel	D	Farm buildings located on Lake Agassiz beach ridge.Formerly had 30' dug well,but water reported not potable.
....	D,S	Fine blue sand	D	Water reported medium hard.
....	D,S	....	D	Water reported soft.
....	D,S	....	D	Do.
....	D,S	Fine sand	D	Do.
....	D,S	Sand	..	Do.
....	D,S	Fine white sand	D	Water reported soft, sand reported at 130 feet, but water reported too hard.
....	D,S	Fine white sand	D	Water reported soft.

Location number	Owner or name	Depth of well (feet)	Diameter (inches)	Type	Date completed	Depth to water (feet)
130-47 -Continued						
6abb	Lloyd Rubish	277	3	J	1949	.....
6baa	E. W. Nelson	266	3 to 2½	J	1949	.....
6dda	USGS test 485	280	5	Dr	1951	.....
6ddc	Stephen Campbell	335(?)	2	Dr	....	20
7ada	Amos Penn	35	2	Dr	....	.....
7cdb	Martin Sikorsky	262.3	5	Dr	....	26.6
7dcc	W. H. Newby	199	2½	Dr	1900	......
8caa	USGS test 484	260	5	Dr	1951	.....
8dca	Joe Rassier	235	3	Dr	....	.....
9bcb	Clarence Kutzer	260	3	Dr	....	.....
9cbb	George Gast	240	3	Dr	....	.....
9ddc	Herman Muehler	...	3	Dr	....	.....
10bbb	John Herding	140	3	Dr	....	.....
10ddb	Harry Scheidegger	218	2	Dr	1922	10
11bab	August Voss	100	2	Dr	1900	.....
12aab	Olaf Trovatten	275	3	J	....	75
12ccb	Leonard Sethke	200	2	J	1940	6
13ccc	William Krause	100+	..	Dr	1900	Flow
14add	Herb. Kutzer	228	3	J	1919	....
14baa	August Miller	275	2	Dr	....	15
14cdd	Vacant farm	100.6	3-2-1	Dr	....	Flow
15bbb	H. M. Griffith	220	2	J	....	.....
16bcb	August Colburg	240	3	J	1930	20
16cbb	Ed. Smith	130	2	Dr	....	.....
17ccb	W. Schroeder	...	2	J	....	.....
17daa	USGS test 483	210	5	Dr	1951	.....
17ddc	Chet Meade	90	3	J	....	.....
18aab	Bessie Parkle	155	2	Dr	....	.....
18bab	Grant Peterson	200+	4	..	....	26.77
18dcd	Earl Schouweiler	241	4	Dr	1950	12
19bcc	USGS test 476	250	5	Dr	1951	.....
19ccc	Clarence Swanson	150	4	Dr	1931	40
20acc	E. H. Whetstein	80	3	J	....	.....
20cbb	USGS test 475	230	5	Dr	1951	.....
20dbb	USGS test 474	240	5	Dr	1951	.....
20dbc1	Cudahy Packing Co.	231	6	Dr	1930	90
20dbc2	Dakota Locker Co.	240	4	Dr	....	.....
20dca	Bill Simpson	225	5	Dr	1917	.....
21bbc	F. A. & E. J. Matheson	160	..	J	....	.....
21cbb	USGS test 473	217½	5	Dr	1951	.....
21daa	USGS test 472	189	5	Dr	1951	.....

Date of measurement	Use	Description of water-bearing material	Geologic horizon	Remarks
....	D,S	Fine white sand	D	Water reported soft. See log.
....	D,S	Tanish-gray sand	D	Water reported soft.
....	U	....	..	Hole refilled. See log.
....	D,S	....	..	
....	D,S	Gravel	G	Farm on Lake Agassiz beach. Water reported hard.
6-20-51	D,S	....	D	Water reported soft.
....	D,S	Fine white sand	D	Do.
....	U	....	..	Hole refilled. See log.
....	D,S	Fine sand	D	Water reported soft.
....	D,S	White sand	D	Do.
....	D,S	Whitish gray sand	D	Do.
....	D,S	....	..	Water reported hard.
....	D,S	Sand	..	
....	D,S	Fine sand	D	Water reported soft.
....	D,S	....	BO	Water reported hard.
....	D,S	Sand	D	Water reported soft; adequate for 60 head of cattle and 140 hogs.
....	D,S	Fine sand	..	....
6-12-51	D,S	....	..	Water reported soft.
....	D,S	....	D	Do.
....	D,S	....	D	Do.
6-12-51	U	....	BO	Water flows weakly from 1 inch orifice 2.0 feet above land surface.
....	D,S	Fine sand	D	Water reported soft.
....	D,S	Fine blue sand	D	Water reported soft. Formerly had well 130 feet deep, but water was too hard
....	D,S	Coarse sand from 126 to 130 feet.	BO	Water reported hard.
....	D,S	....	..	Water reported soft.
....	U	....	..	Hole refilled. See log.
....	S	....	..	Water reported unfit for human consumption, very hard and poor tasting.
....	D,S	....	..	Water reported soft.
6-20-51	D,S	....	D	Do.
....	D,S	White "sugar"sand from 236-241 ft.	D	Water reported soft. See log.
....	U	....	..	Hole refilled. See log.
....	D,S	....	..	Water reported hard.
....	S	....	..	Water reported hard; not used for domestic purposes.
....	U	....	..	Hole refilled. See log.
....	U	....	..	Do.
....	I	Coarse gravel	D	See chemical analysis. Reported to pump 20 GPM.
....	U	Sand	D	
....	D	Coarse sand	D	Water reported soft.
....	D,S	....	..	
....	U	....	...	Hole refilled. See log.
....	U	....	..	Do.

Location number	Owner or name	Depth of well (feet)	Diameter (inches)	Type	Date completed	Depth to water (feet)
130-47 -Continued						
21dba1	Village of Fairmount	115	26-16	Dr	11-51	.....
21dba2	Village of Farimount	113	8	Dr	1947	30
21dbb1	....do.....	135	8	Dr	....	20
21dbb2	....do.....	120	6	Dr	....	18.9
22cab1	USGS test 471	230	5	Dr	1951	.....
22cab2	Vacant farm	88.3	4	Dr	....	4.13
22dbd	USGS test 470	230	5	Dr	1951	.....
23ccc	K. West	100	3	Dr	....	.....
24ada	Weibe Bros.	180(?)	..	Dr	....	Flow
24bbb	James Clarey	106	3	Dr	1900	Flow
26aba	J. E. Waite	74	2½	Dr	1890's	Flow
26baa	Donald Weatherby	80	..	Dr	....	Flow
26ddd	V. Zatecka	85	..	Dr	....	Intermittent Flow
27add1	Mrs.F.A. Ostrich	120	..	Dr	1900	6
27add2	...do...........	120	..	Dr	....	6
28abb	Paul Pinkney	95	3	Dr	1936	11.5
28bbb	Mrs. C. Pinkney	83	3	Dr	1914	.....
28ccb1	Hurdelbrink Bros.	95	3	Dr	....	.....
28ccb2	...do............	95	3	Dr	....	5
29aaa	USGS test 479	210	5	Dr	1951	.....
29aba	Carl Swanson	220	5-3½	Dr	....	80
29cbc1	R. S. Branson	200	2	J	1937	25
29cbc2	....do.......	205	4	Dr	1950	20
30abb	Glenn Swanson	225	4	J	....	.....
30dcd	H. Bertelson	222	2½	Dr	....	.....
31abb	Branson	228	3	Dr	....	10
31baa	Henry Schmitt	230	3	Dr	....	25
31ddd	Thad Branson	90	3	Dr	....	.....
32aaa	USGS test 480	210	5	Dr	1951	.....
32add	J. A. Barner	90	5	Dr	1890	20
33bbb	Burt Kurtz	90	5	Dr	1915	7
33ccb1	A. J. Gajer	98	3	Dr	1924	Flow
33ccb2	....do.....	104	2	Dr	1904	Flow
34aaa	V. Stueve	90	6	Dr	....	Flow
35cbc	Darrell Weinkauf	90	3	Dr	....	Flow

Date of measurement	Use	Description of water-bearing material	Geologic Horizon	Remarks
....	PS	Fine to medium sand from 99 to 115 feet	BO	Presently pumped at 100 GPM. Same location as Thein test hole drilled to 170 feet. See log.
....	PS	Sand from 92 to 103 feet.	BO	See chemical analysis. Presently pumped at 30 GPM, but originally pumped at 135 GPM.
....	U	Sand	BO	Several unused public supply wells at this location.
6- 7-51	U	..do...	BO	
....	U	....	..	Hole refilled. See log.
6- 7-51	U	Sand	BO	Water reported to have originally flowed.
....	U	....	..	Hole refilled. See log.
....	D,S	Sand	BO	
6-13-51	D,S	....	..	Reported medium hard.
6-12-51	D,S	....	BO	Water reported medium hard; flows about 10 GPM.
6-12-51	D,S	Sand	BO	Water flows about 10 GPM. See chemical analysis.
6-12-51	D,S	Sand	BO	Water flows from 1 inch orifice 3.3 feet above land surface. Reported hard; turns enamel brown.
....	D,S	..do...	BO	Water reported hard.
....	D	..do...	BO	Do.
....	S	..do...	BO	Do.
6- 6-51	D,S	..do...	BO	Do.
....	D	..do...	BO	Water reported excessively hard; use rain water as much as possible.
....	D	..do...	BO	Water reported hard.
....	S	..do...	BO	Water reported hard; used to flow.
....	U	....	..	Hole refilled. See log.
....	D,S	Coarse gravel	D	Water reported soft. Noticable interferance from Cudahy's well.
....	S	....	D	Water reported soft.
....	D	White sand	D	Do.
....	D,S	Coarse gravel	D	Do.
....	D,S	Fine white sand	D	Water reported soft.
....	D,S	....do.........	D	Do.
....	D,S	Gray sand	D	Do.
....	D,S	....	BO	Water reported medium soft.
....	U	....	..	Hole refilled. See log.
....	D,S	Sand	BO	Water reported medium hard; adequate for 25 head of cattle and 100 sheep.
....	D,S	..do...........	BO	Water reported hard; flowed before Fairmount municipal wells were put in.
6-22-51	D	Fine Sand	BO	Water reported hard. Weak flow.
6-22-51	S	...do..........	BO	Do.
6-14-51	D,S	Sand	BO	Water reported soft.
6-14-51	S	Sand	BO	Water flows intermittently; not used for drinking because of contamination

Location number	Owner or name	Depth of well (feet)	Diameter (inches)	Type	Date completed	Depth of water (feet)
130-47 -Continued						
35dad	Marvin Evenson	90	..	Dr	....	0-1
36bbb1	Ray Ready	83	2	Dr	1900	Flow
36bbb2	....do.......	85	3	Dr	....	0
130-48						
1ccd	M. Christianson	270	3	Dr	....	22.3
1ddc	T. Bertelson	270	..	Dr	....	18
2aaa	Albert Steffens	270	3	J	1928	12
2dcd	Albert Gast	260	3	J	....	20
11bbb	Wm. J. Mahler	240	3	J	1943	12
11cdc	Carl Mahler	240	3-2	Dr	1914	18
12adc1	Vacant farm	240	2	Dr	....	29.8
12adc	......do.....	23.0	40	B	....	4.95
13aaa	A. Arnold	155.1	4	Dr	....	34.1
13cbd	Vacant farm	13.7	48	B	....	4.49
14add	Fred Kingdom	55	2	Dr	....	≁3.25
14cda	John A Founder	238	3	Dr	1926	18
23aad1	M. Schmit	50	2	Dr	....	20
23aad2	...do.........	50	4	Dr	....	20
23aad3	...do.........	160	2	Dr	....	40
23bcc	USGS test 478	230	5	Dr	....	.....
23cdc	G. Schmit	200≁	3	Dr	....	20.97
23ddc	E. Schmit	85	3	J	1951	8.7
24aad	J. E. Ohearn	165	..	Dr	....	.....
24cbb	USGS test 477	257	5	Dr	....	.....
24cdc	Arden Eide	...	..	J	1944	.....
24ddc	H. Nelson	146	5	Dr	1919	11
25abb	M. Schmit	140	2	Dr	1910	25
25cbb	Mrs. Lou Abbott	200	3	J	....	.....
26adb	W. J. Campbell	330(?)	6	Dr	....	20
26dab1	Art Speer	40	4	Dr	....	5.9
26dab2	.....do.......	90	..	Dr	....	.....
35bbc	Sidney Johnson	70.0	6	Dr	....	16.2
35daa	Henry Bassier	32	..	Dr	....	.....
131-47						
32ddd	Henry Witzke	280	2½	Dr	1919	15(1939)
34bdd	August Schroeder	270	3	J	....	.....
34cab	Phillip Boll	271	3	Dr	....	.....
35aac1	Vacant farm	...	3	Dr	....	7.47
36ccc	Peter Moenbach	233	3-2	Dr	....	10
131-48						
35add	John Dozak	150	3	Dr	....	.....
35daa	Ed Dozak	280	3	Dr	....	.....
36add	Art Gast	240	3	J	1921	8
36ccb	Harry Ehlers	280	3	J	1931	16.9

Date of measurement	Use	Description of water-bearing material	Geologic horizon	Remarks
6-14-51	D,S	..do...	BO.	Water reported hard; flows intermittently.
6-14-51	D	Fine sand	BO	Water reported hard.
....	S	..do...	BO	Do.
6-25-51	D,S	....	D	Water reported soft.
....	D,S	....	D	See chemical analysis.
....	D,S	....	D	Water reported medium hard, salty.
....	D,S	....	D	Water reported soft, salty.
....	D,S	Fine gray sand	D	Water reported soft.
....	D,S	Fine gray sand	D	Water reported soft.
6-29-51	S	....	D	Do.
6-29-51	U	Gravel	G	Water reported hard.
6-28-51	D,S	....	..	Water reported soft.
6-29-51	U	....	..	
6-29-51	S	....	G	Water flows at land surface.
....	D,S	Gray sand	D	Water reported soft.
....	...	....	G	Water reported hard.
....	S	....	G	Do.
....	D	Fine gray sand	..	Water reported soft.
....	U	....	..	Hole refilled. See log.
6-26-51	D,S	....	..	
6-51	D,S	....	G	Water reported hard.
....	D,S	Sand	G	Water reported soft.
....	U	....	..	Hole refilled. See log, chemical analysis.
....	D,S	....	G	Water reported soft.
....	D,S	Gray sand	G	Do.
....	...	....	G	Do.
....	...	....	G	Do.
....	D,S	Gray sand at 196 feet	G	Water reported soft. Casing perforated at 196 feet and water believed to be entering from that level.
6-27-51	S	....	G	Water reported hard.
....	U	....	G	
6-27-51	D,S	....	G	Water reported hard.
....	S	Gravel		Do.
....	D,S	Sand	D	
....	D,S	Fine gray sand	D	Water reported hard.
....	D,S	...do.........	D	Do.
6-21-51	U	....	..	
....	D,S	Fine sand from 225 to 233 feet	D	Water reported medium soft.
....	D,S	Sand	...	Water reported hard.
....	D,S	....	D	Water reported soft, salty.
....	D,S	....	D	Do.
6-26-51	D,S	....	D	See chemical analysis.

LOGS OF WELLS AND TEST HOLES IN THE FAIRMOUNT AREA

129-47-5aaa
USGS test 481

Formation	Material	Thickness (feet)	Depth (feet)
Mankato drift:			
	Clay and silt, tan	5	5
	Till, tan	10	15
	Till, light-gray, sandy	66	81
older drift:			
	Sand, fine to medium. Clay, yellowish-brown	12	93
	Sand and gravel, possibly cemented. Numerous shell fragments	6	99
	Till, yellowish-brown	5	104
	Till, dark-gray	16	120
	Clay, dark-gray, silty	33	153
	Sand, fine, clayey	5	158
	Till, light-gray	24	182
granite unaltered:			
	Hard rock, no sample	1	183

129-47-8aaa
USGS test 482

Formation	Material	Thickness (feet)	Depth (feet)
Mankato drift:			
	Silt and clay, tan	5	5
	Till, tan	11	16
	Till, light-gray	40	56
	Gravel	1	57
older drift:			
	Clay, dark-gray, indurated	25	82
	Sand, fine to medium, clayey	11	93
	Sand and gravel, possibly cemented	4	97
	Till, dark-gray, hard	62	159
granite unaltered:			
	Hard rock, no sample	1	160

LOGS OF WELLS AND TEST HOLES IN THE FAIRMOUNT AREA--Continued

130-47-6abb
Lloyd Rubish
(Log furnished by Phil Vorwick, well driller, Tyler, N. Dak.)

Formation	Material	Thickness	Depth
glacial drift, undifferentiated:			
	Clay, yellow, gravelly..................	50	50
	Rocks and gravel........................	5	55
	Clay, gray, sandy.......................	95	150
	Clay, gray, sandy, very hard............	20	170
Benton shale:			
	Shale, blue, clayey.....................	50	220
	Shale, black, hard layers, Numerous shells near bottom................	40	260
Dakota(?) sandstone:			
	Sand, fine, white (water)............	17	277

130-47-6dda 932
USGS test 485

Formation	Material	Thickness (feet)	Depth (feet)
Mankato drift:	Clay, silt, and sand	5	5
	Clay and silt, grayish-orange	5	10
	Till, grayish-orange	8	18
	Till, light-gray	13	31
	Sand, fine	3	34
	Till, light-gray	24	58
older drift:			
	Clay, dark-gray, indurated	22	80
	Clay, dark-gray, indurated. Small amounts of sand and gravel	41	121
	Till, light-gray, sandy	5	126
	Sand, medium, clayey	14	140
	Till, light-gray, sandy	37	177
Benton shale:			
	Shale, light-gray	13	190 742
	Shale, grayish-black, clayey. Core from 200-210 feet, consists of dark-gray to black, clayey-shale with thin seams of silt and very fine sand, contains fish scales and foraminfera	61	251
Dakota(?) sandstone:			
	Sand, fine to medium, rounded, quartzose, may be interbedded with clay or shale. Numerous shell fragments	15	266
	Sand, very coarse, angular (or conglomerate)	3	269
	Lignite or other carbonaceous material	1	270
granite, decomposed:			
	Clay, brown	10	280

LOGS OF WELLS AND TEST HOLES IN THE FAIRMOUNT AREA--Continued

130-47-8caa
USGS test 484

Formation	Material	Thickness (feet)	Depth (feet)
Mankato drift:			
	Sand, fine to medium	5	5
	Clay, tan, silty	5	10
	Till, grayish-tan	7	17
	Till, gray	49	66
older drift:			
	Clay, yellowish-brown and gray, silty. Small amounts of sand and gravel	72	138
	Till, light-gray, sandy	30	168
Benton shale:			
	Shale, medium light-gray to dark-gray, clayey	39	207
Dakota(?)sandstone:			
	Sand, very fine to fine, possibly interbedded with clay or shale	29	236
	Shale, dark-gray, clayey. Numerous shell fragments	14	250
	Shale and thin beds of lignite or other carbonaceous material at bottom	6	256
granite, decomposed:			
	Clay, orange and white	4	260

130-47-17daa
USGS test 483

Formation	Material	Thickness (feet)	Depth (feet)
Mankato drift:			
	Silt and clay, tan	12	12
	Till, light-brown	6	18
	Till, light-gray	10	28
	Sand, coarse to very coarse	12	40
	Gravel, fine	10	50
	Gravel fragments (probably cemented gravel)	9	59
older drift:			
	Clay, dark-gray, indurated	39	98
	Till, dark-gray, indurated	52	150
	Clay, gray	17	167
	Till, gray, bouldery	29	196
Benton shale:			
	Shale, grayish-black	6	202
	Shale and fine sand. Shells	4	206
granite, decomposed:			
	Clay, white	4	210

130-47-18dcd
Earl Schouweiler
(Log furnished by Mr. Schouweiler)

Formation	Material	Thickness (feet)	Depth (feet)
glacial drift, undifferentiated:			
	Soil	2	2
	Clay, sandy	6	8
	Clay, sandy and gravelly (till)	91	99
	Sand,fine, and gravel	60	159
	Clay, blue	7	166
	Sand	11	177
	Mixed boulders and gravel (till)	58	235
Dakota (?) sandstone:			
	Sand, fine, sugary texture (water)	6	241

130-47-19bcc
USGS test 476

Formation	Material	Thickness (feet)	Depth (feet)
Mankato drift:			
	Silt, light-tan. Small amounts of sand and gravel	10	10
	Till, light-tan	5	15
	Till, light-gray	39	54
older drift:			
	Clay, gray, moderately well indurated.. Some sand and gravel	16	70
	Till, yellowish-brown and gray	7	77
	Sand, very coarse	3	80
	Clay and silt, dark-gray, well indurated	52	132
	Till, dark-gray, clayey, grading downward into light-gray, very sandy till	77	209
Benton shale:			
	Shale, grayish-black, clayey. Found one shark tooth	21	230
Dakota(?)sandstone:			
	Sand, quartz, very coarse, or conglomerate, probably interbedded with dark-gray shale	16	246
granite, decomposed:			
	Clay, white	4	250

130-47-20cbb
USGS test 475

Formation	Material	Thickness (feet)	Depth (feet)
Mankato drift:			
	Clay and silt, tan	5	5
	Till, tan	13	18
	Till, light-gray	9	27
	Sand	7	34
	Till, light-gray	26	60
older drift:			
	Till, grayish-tan	5	65
	Till, dark-gray	10	75
	Clay, dark-gray	42	117
	Till, dark-gray, hard, grading downward into light-gray, sandy till	98	215
Benton shale:			
	Clay or shale, dark-gray. Shark teeth	5	220
granite, decomposed:			
	Clay, white and pink, kaolinitic. Core obtained, 1½ feet of recovery	10	230

130-47-20dbb
USGS test 474

Formation	Material	Thickness (feet)	Depth (feet)
Mankato drift:			
	Clay and silt, grayish-tan	3	3
	Till, tan	16	19
	Till, light-gray	32	51
older drift:			
	Clay and silt, gray	19	70
	Till, dark-gray, hard	66	136
	Sand	3	139
	Till, light-gray, very sandy	88	227
Benton shale:			
	Shale, grayish-black	2	229
Dakota (?) sandstone:			
	Clay, white. Large amount of very coarse, quartz sand	5	234
granite, decomposed:			
	Clay, white, green at bottom	6	240

130-47-21cbb
USGS test 473

Formation	Material	Thickness (feet)	Depth (feet)
Mankato drift:			
	Silt and sand, grayish-tan	5	5
	Till, light-gray	65	70
older drift:			
	Till, dark-gray, hard	54	124
	Boulders	2	126
	Till, dark-gray	10	136
	Sand	6	142
	Till, gray	7	149
	Till, light-gray, consists largely of fine to medium quartz sand, probably derived from Dakota(?) sandstone	49	198
granite, decomposed:			
	Clay, green. Quartz grains	19	217
granite, unaltered:			
	Hard rock, no sample	½	217½

130-47-21daa
USGS test 472

Formation	Material	Thickness (feet)	Depth (feet)
Mankato drift:			
	Silt, yellowish-brown, a small amount of gravel	12	12
	Clay, bluish-gray, smooth	5	17
	Sand	1	18
	Till, light-gray	63	81
	Sand, fine	3	84
	Till, light-gray	8	92
older drift:			
	Clay and silt, gray	12	104
	Till, dark-gray, hard	56	160
Benton shale:			
	Shale, grayish-black, numerous shell fragments	16	176
granite, decomposed:			
	Clay, green. Quartz	12	188
granite, unaltered:			
	Hard rock, no cuttings	1	189

130-47-21dba1
Thein test hole
(Log furnished by Thein Well Drilling Co., Clara City, Minn.)

Formation	Material	Thickness (feet)	Depth (feet)
Mankato drift:			
	Soil, black	4	4
	Clay, yellow	14	18
	Clay, blue, soft	7	25
	Till, blue, sandy, hard layers	74	99
older drift:			
	Sand, fine to medium	16	115
	Till, blue, grading downward into gray, very sandy till	35	150
	Hardpan (till)	15	165
Benton shale:			
	Clay, dark bluish-gray to black	5	170
granite:			
	Hard rock, no sample		170

130-47-22cab1
USGS test 471

Formation	Material	Thickness (feet)	Depth (feet)
Mankato drift:			
	Clay and silt, light-tan, small amounts of sand	10	10
	Sand, very coarse	4	14
	Till, light-gray	83	97
older drift:			
	Sand, very fine to fine. Clay and silt	3	100
	Sand, medium to coarse. Gravel, fine, rounded	6	106
	Till, tan and gray. One piece of partly carbonized wood and some carbonaceous clay	12	118
	Sand, coarse	4	122
	Till, dark-gray, hard, bouldery	31	153
	Sand	1	154
Benton shale:			
	Shale, clayey, grayish-black	41	195
Dakota (?)sandstone:			
	Sand, very coarse (or conglomerate), composed predominantly of angular quartz. A few shark teeth and teeth fragments	5	200
	Sand, angular, quartz. Much black clay or shale which may be cave	10	210
granite, decomposed:			
	Clay, white, kaolinitic	5	215
	Clay, white and green, with imbedded quartz (some euhedral crystals)	15	230

130-47-22dbd
USGS test 470

Formation	Material	Thickness (feet)	Depth (feet)
Mankato drift:			
	Topsoil, black	2	2
	Clay and silt, light-tan	9	11
	Sand	5	16
	Till, light-gray	65	81
older drift:			
	Sand, very fine to fine, with tan clay and silt. Shell fragments	13	94
	Till, dark-gray, hard, bouldery	86	180
Benton shale:			
	Shale, clayey, grayish-black	39	219
granite, decomposed:			
	Clay, white, kaolinitic. Euhedral quartz	11	230

130-47-29aaa
USGS test 479

Formation	Material	Thickness (feet)	Depth (feet)
Mankato drift:			
	Silt, grayish-yellow. Small amounts of sand and gravel	10	10
	Till, grayish-yellow	8	18
	Till, gray, sandy	72	90
older drift:			
	Clay, brown and gray. Some brown, carbonaceous sand	30	120
	Till, dark-gray, clayey, grading downward into light-gray, sandy till	83	203
granite, decomposed:			
	Clay, white	2	205
	Clay, green	5	210

130-47-32aaa
USGS test 480

Formation	Material	Thickness (feet)	Depth (feet)
Mankato drift:			
	Silt and clay, some gravel.............	10	10
	Till, light-brown......................	10	20
	Till, light-gray.......................	45	65
older drift:			
	Clay, gray, hard.......................	8	73
	Sand, fine, clayey. Some brownish-black, carbonaceous clay............	12	85
	Gravel, fine to medium.................	5	90
	Clay, dark-gray, indurated.............	18	108
	Till, light-gray, sandy. Samples largely composed of fine to medium, well-rounded quartz, probably derived from Dakota(?) sandstone........................	86	194
Dakota(?) sandstone:			
	Shale, dark-gray. Sand, very coarse...	4	198
granite, decomposed:			
	Clay, white............................	2	200
	Clay, green............................	10	210

130-48-23bcc
USGS test 478

Formation	Material	Thickness (feet)	Depth (feet)
Mankato drift:			
	Sand, medium.........................	5	5
	Till, grayish-tan.....................	28	33
	Till, light-gray, sandy...............	22	55
	Sand, very fine, clayey...............	21	76
	Till, light-gray......................	7	83
	Gravel................................	7	90
older drift:			
	Sand, very fine. Much yellowish-brown clay......................	15	105
	Sand, mostly very coarse, not so clayey as 90-105..................	28	133
	Till, dark-gray, hard. Core from 130-140 feet, about 75% recovery.	67	200
Benton shale:			
	Shale, dark-gray, clayey..............	24	224
Dakota(?) sandstone:			
	Sand, very coarse, possibly cemented	5	229
granite, decomposed:			
	Clay, light-green.....................	1	230

130-48-25cbb
USGS test 477

Formation	Material	Thickness (feet)	Depth (feet)
Mankato drift:			
	Silt, light-tan	5	5
	Till, light-tan	11	16
	Till, light-gray, sandy	32	48
	Sand, medium to coarse, comparatively well-sorted and clean. Probably very permeable	28	76
	Till, light-gray	4	80
older drift:			
	Clay, dark-gray, indurated	48	128
	Till, gray, sandy	12	140
	Sand, fine to medium, clayey	52	192
Benton shale:			
	Shale, dark grayish-black, clayey. Much pyrite	38	230
Dakota(?) sandstone:			
	Sand, fine to medium, composed of quartz and muscovite, probably interbedded with gray shale	21	251
granite, decomposed:			
	Clay, white	6	257

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