STATE OF SOUTH DAKOTA
Ralph Herseth, Governor

STATE GEOLOGICAL SURVEY
Allen F. Agnew, State Geologist

SPECIAL REPORT 6

GEOLOGY AND GROUND WATER RESOURCES AT HOWARD, SOUTH DAKOTA

by

Donald G. Jorgensen

UNION BUILDING
UNIVERSITY OF SOUTH DAKOTA
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GEOLOGY AND GROUND WATER RESOURCES AT HOWARD, SOUTH DAKOTA

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INTRODUCTION

Present Investigation

This report contains the results of a special investigation by the South Dakota State Geological Survey during the summer and fall of 1959 in and around the city of Howard, Miner County (fig. 1), for the purpose of helping the city to locate a water supply. The city now receives its water from three wells. Two of the wells produce from a sand and gravel layer in the glacial drift, and the third well gets water from the "wash" above the Sioux quartzitic sandstone. Because of the inadequate quantity of water produced by these wells, the city wishes to construct a new well or wells which will alleviate the probl em.

A ground water survey was made of a 36 square mile area within a 3 mile radius of the city. The survey consisted of geologic mapping, water sampling, drilling 35 test holes, and making a resistivity survey during which 72 stations were occupied (fig. 2).

The field work and the preparation of this report were performed under the supervision of Merlin J. Tipton. The aid of James Hammell, Clark Mulliner, Charles Mickel, Lamonte Sorenson, and Donald Gapp is gratefully acknowledged. The cooperation of the residents of Howard, especially Mayor E. M. Tripp and City Auditor Walter Eggert, aided the survey greatly.

Location and Extent of Area

The city of Howard is located in Miner County, in east-central South Dakota, and has a population of approximately 1250. The area is on the western side of the Coteau des Prairies (Prairie Hills), in the Central Lowlands physiographic province (fig. 1).

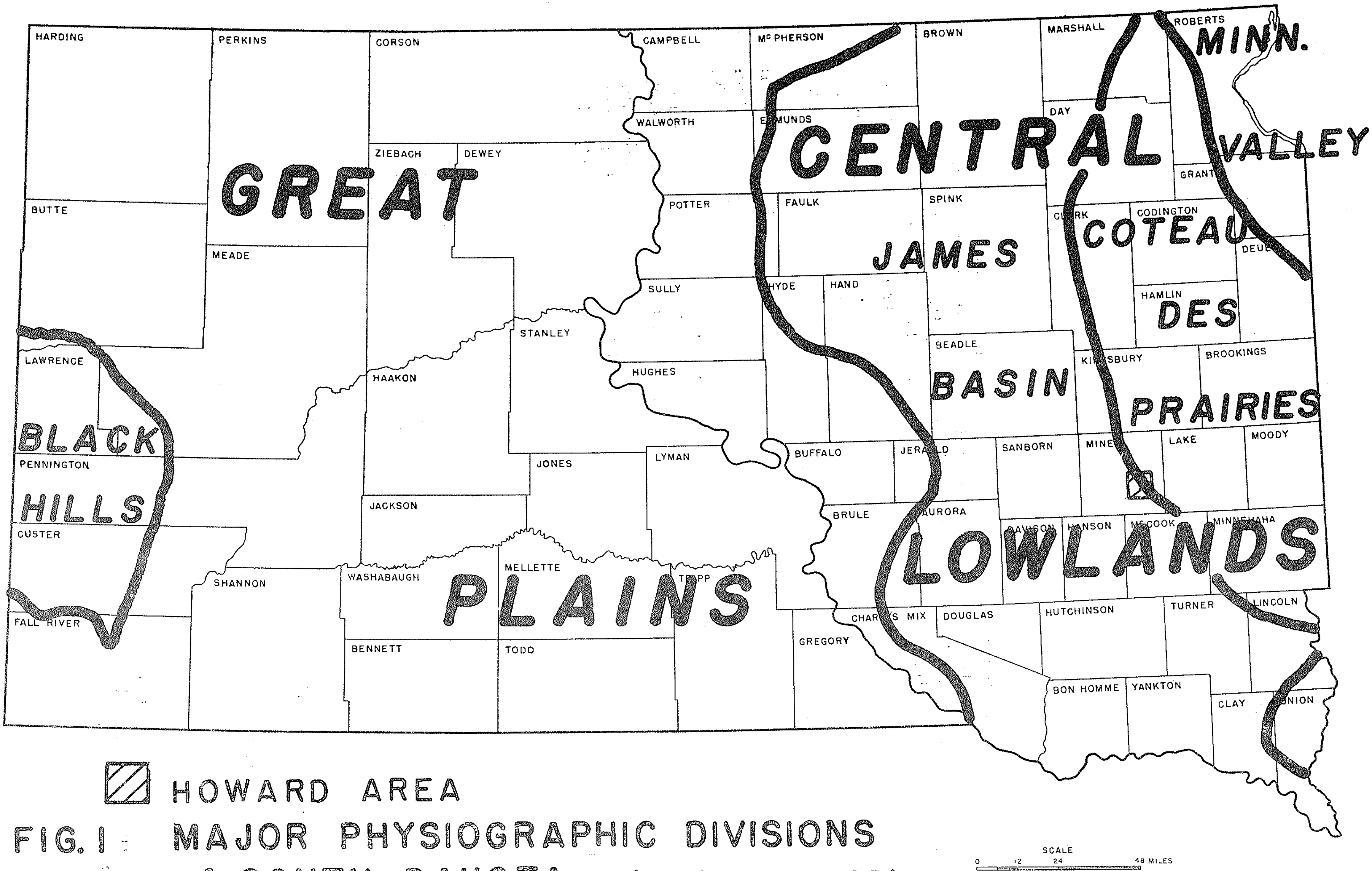
Climate

The climate is typically continental temperate, with large daily and seasonal fluctuations.

The average yearly temperature of the area from 1940-1958 is 45.86°F and the average annual precipitation for the same period of time is 21.82 inches, at Howard Station, U. S. Weather Bureau (fig. 3).

Topography and Drainage

The topography of the area is typically ground moraine--gently rolling hills. The area is drained to the south by the west fork of the Vermillion River and its tributaries, and Wolf Creek.



HOWARD AREA

FIG. I: MAJOR PHYSIOGRAPHIC DIVISIONS of SOUTH DAKOTA (Rothrock, 1943)

DATA MAP of HOWARD AREA

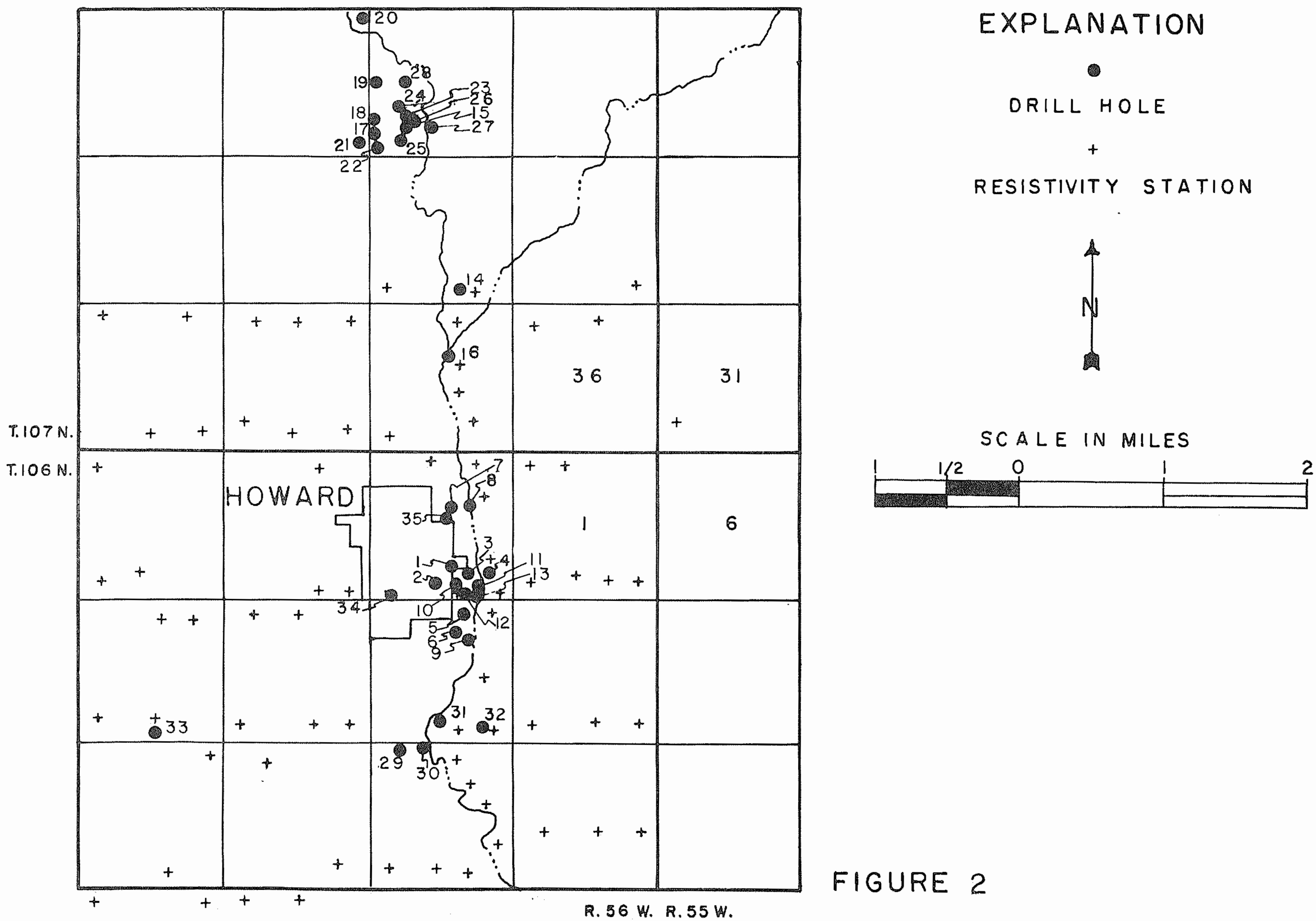


FIGURE 2

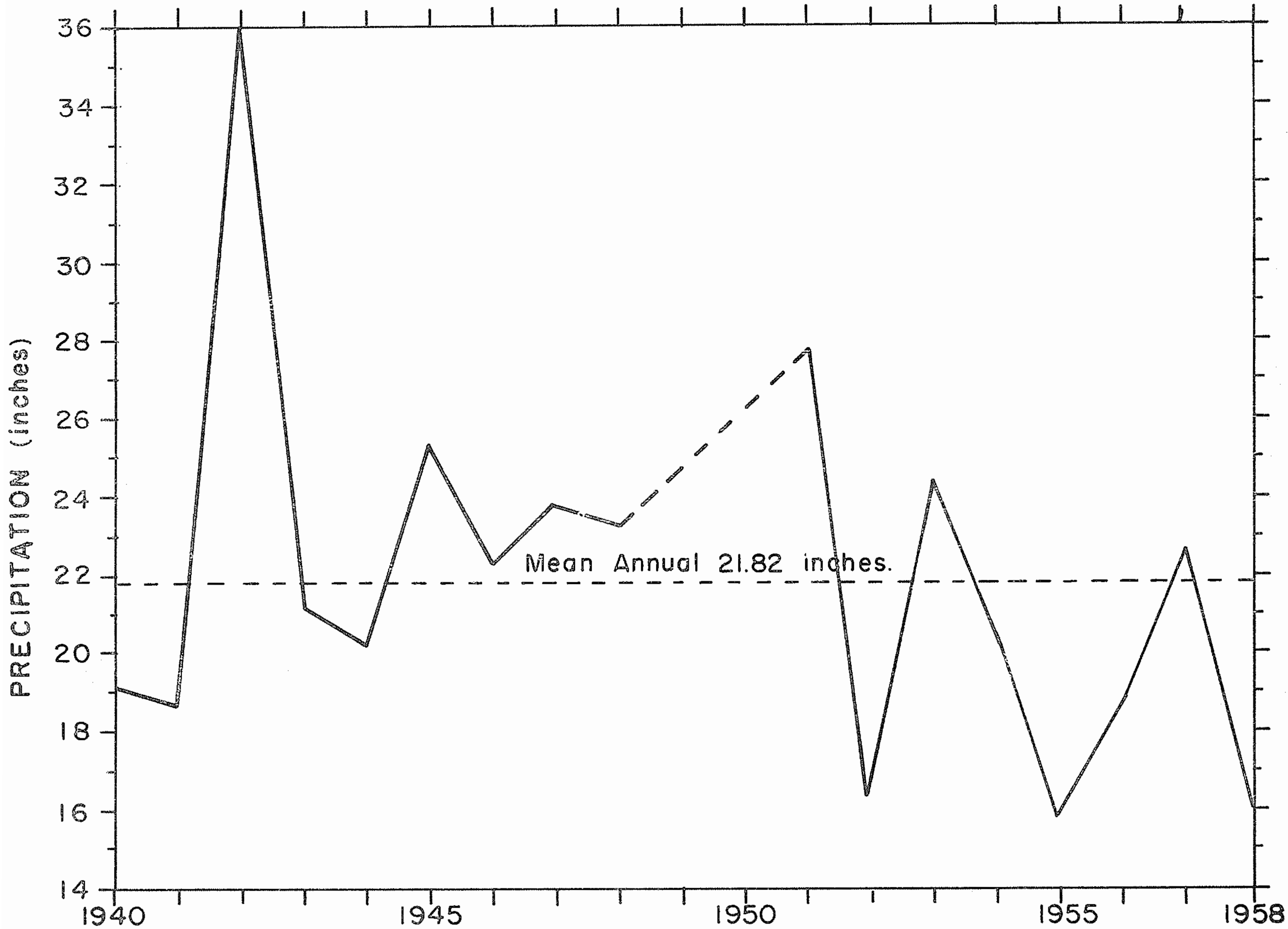


Figure 3 ANNUAL PRECIPITATION AT HOWARD, 1940—1958

GENERAL GEOLOGY

Surficial Deposits

The surficial deposits of the Howard area are nearly all the result of glaciation late in the Pleistocene Epoch. These deposits are collectively called glacial drift, which can be divided into till and outwash deposits. Till consists of boulders, pebbles, sand, silt, and clay which were carried by the ice itself. Outwash deposits of boulders, pebbles, and sand were deposited by meltwater streams of the glacier. Silt and clay are also present where they were not washed away by the stream water.

Alluvial material deposited by streams is present in a narrow strip along the West Fork of the Vermillion River (fig. 4). The alluvium consists of silt, clay, and small amounts of sand and gravel.

Subsurface Deposits

Beneath the surficial deposits lie stratified sedimentary rocks of Cretaceous age. The Cretaceous rocks beneath the Howard area in descending order are; Niobrara chalk and Carlile shale (fig. 5).

The Niobrara Formation consists of light- to medium-gray to blue-gray marl and chalk. The Niobrara chalk is not present everywhere in the Howard area because of erosion.

The Carlile Formation consists of medium- to dark-gray bentonitic shale with pyrite concretions, and fine to very coarse calcareous argillaceous sandstone.

"Wash" is present above the Sioux quartzitic sandstone, of Precambrian age, and beneath the stratified "bed rock" of Cretaceous age. The wash consists of a mixture of sand to pebble size fragments of Sioux quartzitic sandstone, and fragments of the overlying sandstone or shale. The "wash" in the Howard area is about 19 feet thick.

The Sioux Formation consists predominantly of sandstone that has been cemented very tightly with silica into a quartzite. The Sioux quartzitic sandstone forms a buried ridge, the surface of which slopes steeply to the north and northwest.

GEOLOGIC MAP OF THE HOWARD AREA

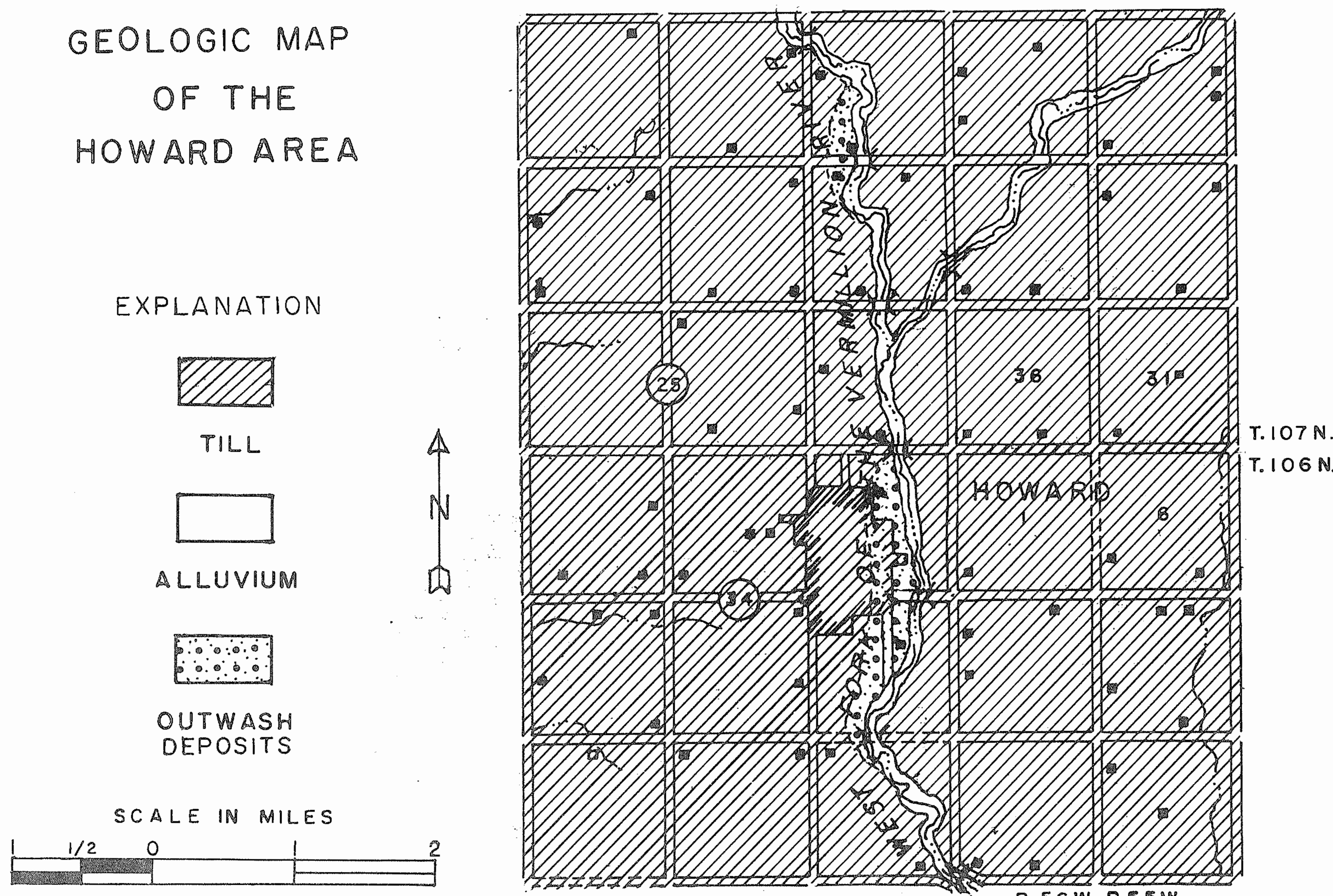
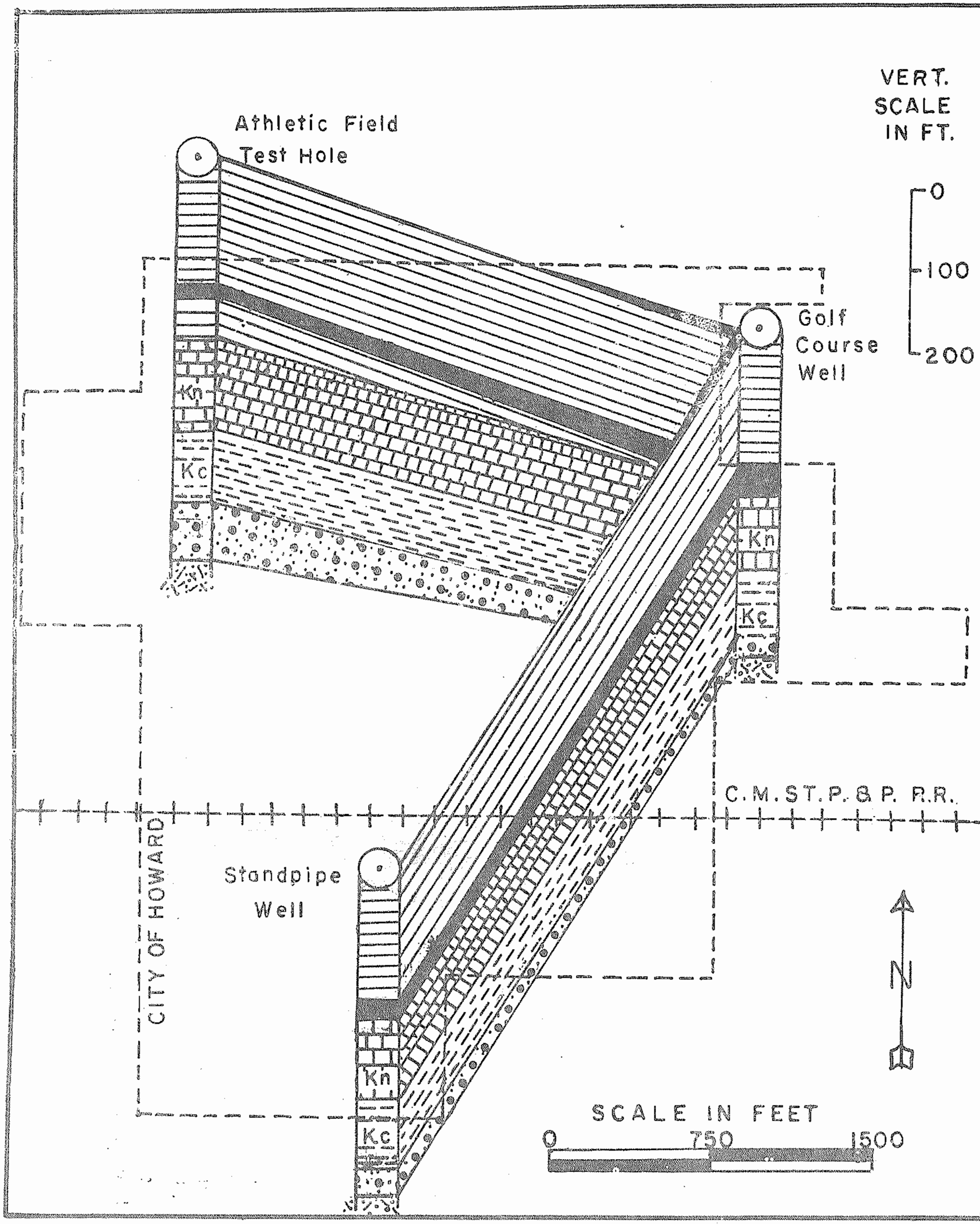


FIGURE 4



FENCE DIAGRAM SHOWING SUBSURFACE FORMATIONS AT HOWARD

EXPLANATION

TILL

GLACIAL SANDS AND GRAVELS

Kn NIOBRARA CHALK

Kc CARLILE SHALE

"WASH"

SIOUX QUARTZITIC SANDSTONE

(FOR INFORMATION ABOUT WELLS SEE APPENDIX)

FIGURE 5

OCCURRENCE OF GROUND WATER

Principles of Occurrence

Nearly all ground water is derived from precipitation. Rain or melting snow either percolates directly downward to the water table or drains off as surface water. Surface water evaporates, escapes to the ocean, or percolates downward to the ground water table. In general, ground water percolates downward from the ground surface to the water table, and then laterally down the hydraulic gradient. If the water is moving down the hydraulic gradient of the water table, it is said to be in transient storage.

Recharge is the addition of water to an aquifer (water-bearing material), and is accomplished in 3 ways:

1. Direct percolation derived from rain or snow melting on the ground surface.
2. Downward percolation from surface bodies of water.
3. Lateral underflow or water in transient storage.

Discharge or the removal of ground water is accomplished in 4 main ways:

1. Evaporation and transpiration by plants.
2. Seepage upward or laterally into surface bodies of water as by springs.
3. Lateral underflow of water in transient storage.
4. Pumping of water.

The volume of water capable of being stored in a saturated material is equal to the volume of voids or pore space of the material. A measurement of the capability of a material to store water is called porosity. Therefore porosity is the ratio of volume of voids in the material to the rock volume. The shape and arrangement of grains in a material affects the porosity greatly, but size of the grains has no effect. Therefore a container filled with sand and one filled with gravel, if the sand and gravel have the same shape and packing, would hold the same quantity of water. Sands and gravels usually have porosities that range from 20 to 40 percent. Sandstones normally have porosities of 15 to 25 percent; the lower porosity is due to closer packing and cementation.

The ratio of the volume of water that will drain from a material by gravity, to the volume of the material, is called specific yield. Values for specific yields vary from zero for plastic clays to nearly the value of the porosity for coarse sands and gravels.

The rate at which water will drain or pass through a material is a function of the permeability of the substance. Water will pass through a material with interconnected pores, but will not pass through a material with unconnected pores even if the latter material has a higher porosity. Therefore, permeability and porosity are not synonymous terms. As an example, till has high porosity but will yield little water because it has low permeability.

If a water-yielding formation (aquifer) dips below an impervious stratum, the water is no longer under normal water table conditions but is then under artesian conditions. Water under artesian conditions acts as water confined in a pipe, and will rise to the piezometric (pressure) water level if tapped, except for a decline caused by friction. Therefore artesian water can be compared to a water system using gravity pressure (hydrostatic pressure) from a stand pipe (water tower), to distribute water to a city.

Ground Water in Glacial Outwash Deposits

Outwash deposits occur as terraces along the West Fork of the Vermillion River (fig. 4). Because of their high porosity, such deposits hold large amounts of water when their base is below the water level as at the city of Howard. Unfortunately, these deposits at Howard have a high percentage of silt and clay (table 1); therefore they yield water very slowly. The terrace outwash deposits are recharged from precipitation directly, and by the river during periods of flood.

Table 1. --Comparative Size Analyses of the Two Types of Outwash Deposits

Test Hole No.	Depth in feet	(Sieve openings in inches) Cumulative Percent of Sample Retained on Each Screen .131	.093	.065	.046	.033	.023	.016	.012	.008	.006	% sand & silt before washing
15	44-49	0	0	0	0	0	7	21	51	76	91	17
35	29-34	0	8	17	34	52	71	84	93	97	--	32
35	39-44	0	0	14	30	47	63	76	85	91	95	48

Test Hole Locations

Older Outwash
Deposit #15 SW¼SW¼ sec. 23, T. 107 N., R. 56 W., Miner County.

Main Outwash
Deposit #35 NW¼SE¼ sec. 2, T. 106 N., R. 56 W., (on golf course), Miner Co.

A small area of older outwash deposits in the SW¼ sec. 23, T. 107 N., R. 56 W., 2½ miles north of Howard (fig. 6), is unlike the other outwash deposits in the area as it consists of fine clean sand with little clay (table 1). This material is approximately 45 feet thick (fig. 6), and the lower 25 feet is water-saturated. This outwash deposit is similar to the others in being recharged by direct percolation from rainfall, laterally from the high water table along the river, and by downward percolation of surface water from the stream. Discharge is mainly by plant transpiration and by a small amount of evaporation.

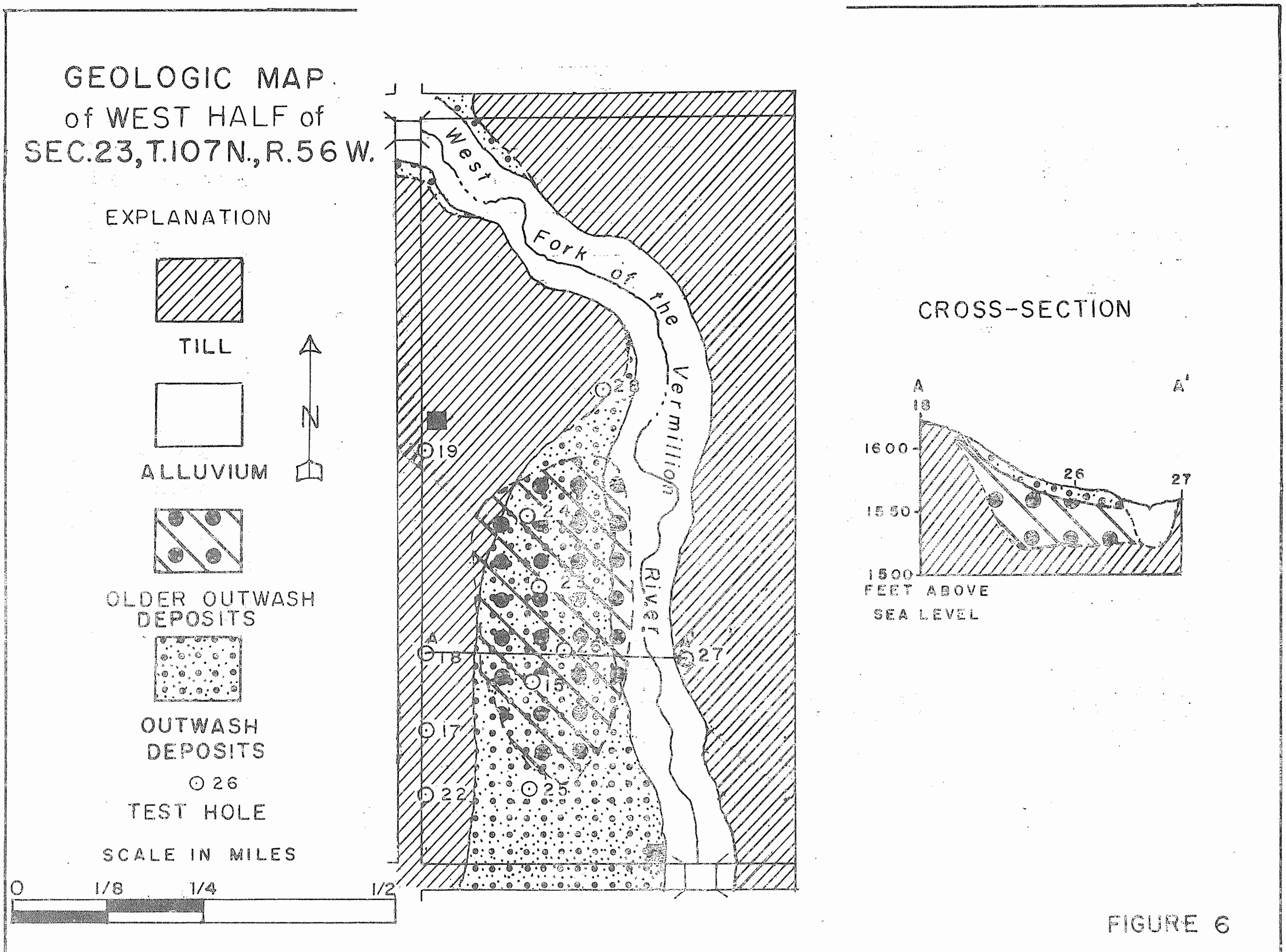

GEOLOGIC MAP
of WEST HALF of
SEC.23, T.107N., R.56W.
EXPLANATION
TILL
ALLUVIUM
OLDER OUTWASH DEPOSITS
OUTWASH DEPOSITS
⊙ 26
TEST HOLE
SCALE IN MILES
0
1/8
1/4
1/2
N
West Fork of the Vermillion River
19
18
17
22
25
15
27
26
24
CROSS-SECTION
A
A'
1600
1550
1500
FEET ABOVE
SEA LEVEL

FIGURE 6

Ground Water in Alluvium

Alluvium is present along the entire stream valley of the West Fork of the Vermillion River (fig. 4). The alluvial materials consist largely of clay and silt with minor amounts of sand and gravel. The alluvium holds large quantities of water, but yields water very slowly because of low permeability of the large silt and clay fraction. Recharge is due largely to direct precipitation and underflow of water into the reservoir. Discharge is due mainly to evaporation and underflow of water from the reservoir.

Ground Water in Stratified Sand Lenses

Stratified sand lenses in till will yield water quickly, but the quantity of water is limited because of the small size of the lenses and because they depend upon the till for recharge. However, in the Howard area there is a stratified sand and gravel deposit with lignite coal fragments near the bottom of the glacial material, which yields a moderate supply of water. This aquifer has a lateral extent of more than a mile in the western part of sections 2 and 11, and in the NW1/4 sec. 12, and contains a considerable amount of water; but, because it is only 17-20 feet thick, its drawdown is rapid when pumped.

Ground Water in the Dakota Group and "Wash"

The Dakota Group of sandstones and shales may be present in the northwestern corner of the mapped area. The sandstone layers of the Dakota are artesian water aquifers. The sandstones consist of predominantly quartz sand that has moderate permeability and porosity. The sandstone units yield a moderate supply of water.

The recharge for both probably comes from the Black Hills and Rocky Mountain areas where the Dakota Group is exposed at a higher elevation. Some recharge probably comes also from the buried Sioux Ridge, to the south. Discharge is due to springs, seepage, pumping and flowing wells.

Although the Dakota Group is not present at Howard, the porous and permeable "wash" directly overlying the Sioux quartzitic sandstone receives water from the Dakota where the latter directly overlies the Sioux quartzitic sandstone to the north; this water moves updip in the wash by artesian pressure. Therefore recharge and discharge of water in the "wash" is the same as recharge and discharge in the Dakota, except that where the Dakota is absent some sand lenses in the Carlile Formation which are also ground water aquifers probably add additional water to the wash at Howard.

The "wash" stores a large quantity of artesian water. The "wash" has variable porosity and permeability depending upon whether the overlying rock is sandstone or shale.

QUALITY OF GROUND WATER

Principles of Ground Water Quality

Precipitated water is nearly pure before it reaches the ground. After the precipitated water reaches the ground it comes in contact with many minerals, some of which are more soluble than others. Therefore the mineral content of the water depends upon the time and the solubility of the minerals with which the water comes in contact.

Quality of Water in the Outwash Deposits

The quality of water from the shallow, glacial outwash deposits along the West Fork of the Vermillion River is good (table 2).

The quality of the water from the older outwash materials in the SW1/4 sec. 23, T. 106 N., R. 56 W., is not known, because no wells penetrate this reservoir.

Quality of Water in the Stratified Sand Lenses

The water derived from the stratified sand lenses at the base of the drift is not of good quality, but is better than water from the "wash" or the upper sandstone of the Dakota Group (table 2).

Quality of Water in the Dakota Group and "Wash"

The quality of the water obtained from the "wash" and the sandstones of the Dakota Group is nearly identical, because the "wash" water is derived directly from the sandstone units. The quality of this water is not known specifically, but an analysis of mixed "wash" water and basal sand and gravel water indicates that this water is of slightly poorer quality than that in the basal sand and gravel (table 2).

Table 2.--Analyses of Water from Wells in the Howard Area

Sample No.	Source of Water	Total Solids (ppm)	Sulfate SO_4	Chloride Cl	Calcium Ca	Iron + Manganese Fe + Mn	Sodium Na	Magnesium Mg	Fluoride F	Arsenic As	Copper Cu	Zinc (Zn)	Lead Pb	Selenium Se	Hexavalent Chromium (Cr)	Nitrate (NO_3)	Hardness
1	Outwash Deposits	760	298	24	131	0	15	44									508
2	Basal sand and gravel	1488	811	30	179	0	210	34									35.5
3	Niobrara Chalk?	1860	1011	21	207	0	309	30									638
4	(Howard tap water) "wash" and basal sand	2094	1110	0	188	0	368	36									617
	U.S. Publ. Health Service Standard	500*	250	250	--	0.3	--	125	1.5	0.5	3.0	15	0.1	.05	.05	10	--

* Total solids may exceed 500 ppm to a maximum of 1000 ppm if the water having this concentration is the only water available.

Sample Locations

1. SW1/4NE1/4 sec. 11, T. 106 N., R. 56 W., Miner County
2. SW1/4NW1/4 sec. 12, T. 106 N., R. 56 W., Miner County
3. SE1/4SW1/4 sec. 35, T. 107 N., R. 56 W., Miner County
4. City of Howard, Miner County

All samples analyzed by State Chemical Laboratory, Vermillion, S. Dak., September, 1959.

CONCLUSIONS AND RECOMMENDATIONS

The possibility of developing a water supply in the outwash deposits along the West Fork of the Vermillion River at Howard appears unlikely because of the high clay and silt content of the deposits. If a location can be found where "clean" sand and gravel is present beneath the water table, then a properly constructed well or wells would probably yield an adequate quantity of water.

The older glacial outwash deposit 2½ miles north of Howard appears to be a good aquifer because of the thickness of water-bearing sand and its accessibility to recharge. It is impossible to determine accurately the quantity and quality of the water from this aquifer, unless a pump test is conducted on an existing well or on a test well constructed in the aquifer. It is suggested that a well at least 6 inches in diameter be drilled and cased, and that a 15-foot screen having the correct sieve openings be set on the bottom of the sand aquifer.

The basal glacial sand and gravel deposit beneath the city of Howard could yield considerably more water if another well was drilled into it, but the additional well must be located at a distance from the wells now pumping from this zone, because the interference due to drawdown would be large in an aquifer that is this thin.

Additional water could also be obtained from the "wash" beneath the town, or from the sandstones of the Dakota Group nearby. The present well beneath the standpipe is drawing water from the "wash". If a water supply is desired from the "wash", then a well site at nearly any location beneath the city would be suitable; however, if the well is located in the northwestern corner of the city, it probably would yield more water than the present well yields because of the greater thickness of the "wash" at that location (fig. 5). If a water supply is desired from the Dakota sandstones, then the well would have to be located several miles north and northwest of the city. A well drilled into the Dakota sandstones or "wash" could be screened where the sand is soft and loosely consolidated.

The city should obtain a water permit from the State Water Resources Commission, and contact the State Board of Health as to the chemical and biological suitability of the water. It is recommended that the city contact a commercial well driller licensed by the State of South Dakota to do further test drilling, to find the most favorable site for a well or wells.

APPENDIX A

Logs of South Dakota Geological Survey Test Holes

Test Hole #1

Location: NW¼SE¼ sec. 2, T. 106 N., R. 56 W.
Elevation: 1554 feet
Total depth: 39 feet
Depth to water: 10.2 feet

Description	Depth (feet)
Clay, dark brown, and fine sand	0- 4
Clay, dark brown, and gravel	4- 9
Gravel and tan clay	9-10
Gravel, medium rounded	10-16
Clay, dark gray, and sand	16-39

Test Hole #2

Location: SW¼SE¼ sec. 2, T. 106 N., R. 56 W.
Elevation: 1546 feet
Total depth: 49 feet
Depth to water: 8.2 feet

Description	Depth (feet)
Clay, dark gray	0- 5
Clay, dark gray, and sand	5- 6
Gravel, unsorted, and clay	6-13
Clay, brown, and sand	13-15
Gravel, unsorted, and clay	15-20
Clay, brown, and sand	20-49

Test Hole #3

Location: NW¼SE¼ sec. 2, T. 106 N., R. 56 W.
Elevation: 1544 feet
Total depth: 44 feet
Depth to water: 10.7 feet

Description	Depth (feet)
Clay, dark gray	0- 4
Gravel, unsorted, and clay	4- 9
Clay, medium gray, and gravel	9-14
Clay, medium gray, with sand and gravel	14-39
Clay, medium gray	39-44

Test Hole #4

Location: NE¼SE¼ sec. 2, T. 106 N., R. 55 W.
Elevation: 1559 feet
Total depth: 75 feet
Depth to water: 17 feet

Description	Depth (feet)
Clay, dark gray, and sand	0-14
Clay, dark brown	14-24
Sand, medium	24-27
Clay, sand, and gravel	27-29
Clay, medium gray, and sand	29-34
Clay and sand	34-75

Test Hole #5

Location: NW¼NE¼ sec. 11, T. 106 N., R. 55 W.
Elevation: _______
Total depth: 40 feet
Water level: 12 feet

Description	Depth (feet)
Clay and sand	0- 4
Sand and gravel	4- 8
Clay and gravel	8-22
Sand, medium	22-39
Clay, gray	39-40

Test Hole #6

Location: SW¼NE¼ sec. 11, T. 106 N., R. 56 W.
Elevation: 1548 feet
Total depth: 45 feet
Depth to water: 8.7 feet

Description	Depth (feet)
Clay, with silt and fine sand	0- 11
Clay, brown, and sand	11- 16
Clay and sand	16-24
Clay, medium gray, with sand and gravel	24-45

Test Hole #7

Location: SW1/4NW1/4 sec. 2, T. 106 N., R. 56 W.
Elevation: 1559 feet
Total depth: 34 feet
Depth to water: 16 feet

Description	Depth (feet)
Clay, tan	0- 3
Gravel and sand	3-16
Clay, medium gray, and rock fragments	16- 17
Sand and clay	17- 19
Clay, medium gray, and rock fragments	19-29
Clay, medium gray	29-34

Test Hole #8

Location: SW1/4NW1/4 sec. 2, T. 106 N., R. 56 W.
Elevation: 1550 feet
Total depth: 54 feet
Depth to water: 22 feet

Description	Depth (feet)
Clay, black	0- 4
Clay, brown, and rock fragments	4- 9
Clay, medium gray, and sand	9-54

Test Hole #9

Location: SW1/4NE1/4 sec. 11, T. 106 N., R. 57 W.
Elevation: _____
Total depth: 54 feet
Depth to water: 26? feet

Description	Depth (feet)
Clay, dark gray	0- 4
Gravel and sand	4- 6
Sand and clay	6- 9
Sand and gravel	9-10
Gravel, medium	10-19
Gravel, medium, and clay	19-29
Sand and clay	29-34
Silt, sand, and clay	34-39
Silt, sand, clay, and gravel	39-44
Clay and gravel	44-54

Test Hole #10

Location: SW¼SE¼ sec. 2, T. 106 N., R. 56 W.
Elevation: 1543 feet
Total depth: 94 feet
Depth to water: 4.9 feet

Description	Depth (feet)
Clay, dark gray	0- 9
Clay, and gravel	9-34
Clay, and fine sand	34-39
Clay	39-94

Test Hole #11

Location: SW¼SE¼ sec. 2, T. 106 N., R. 56 W.
Elevation: 1545 feet
Total depth: 49 feet
Depth to water: 10.0 feet

Description	Depth (feet)
Clay, dark gray	0- 4
Clay, gravel, and sand	4- 9
Clay, sandy	9-24
Clay	24-29
Clay, sandy	29-49

Test Hole #12

Location: SW¼SE¼ sec. 2, T. 106 N., R. 56 W.
Elevation: 1544 feet
Total depth: 39 feet
Depth to water: 8.0 feet

Description	Depth (feet)
Clay, dark gray, and silt	0- 9
Clay, dark gray, with sand and gravel	9-14
Gravel, medium, with sand and clay	14-26
Sand, coarse, and clay	26-29
Sand, medium, and clay	29-34
Clay, medium gray	34-39

Test Hole #13

Location: SW1/4SE1/4 sec. 2, T. 106 N., R. 56 W.
Elevation: 1548 feet
Total depth: 150 feet
Depth to water: 18.5 feet

Description	Depth (feet)
No sample	0- 4
Clay, sandy	4- 9
Clay	9- 14
Silt and gravel	14 - 24
Clay, sandy	24- 39
Clay, and medium-coarse sand	39- 44
Clay, sandy	44-150

Test Hole #14

Location: SW1/4SE1/4 sec. 26, T. 107 N., R. 56 W.
Elevation: 1550 feet
Total depth: 49 feet
Depth to water: 8.0 feet

Description	Depth (feet)
Clay, dark gray	0- 4
Clay, sandy	4- 9
Clay and gravel	9-14
Gravel	14-19
Clay, with sand and gravel	19-24
Sand	24-29
Clay, sandy	29-49

Test Hole #15

Location: SW1/4SW1/4 sec. 23, T. 107 N., R. 56 W.
Elevation: 1572 feet
Total depth: 64 feet
Depth to water: 13.0 feet

Description	Depth (feet)
Gravel and clay	0- 9
Gravel and sand	9-27
Sand, medium and fine	27-64

Test Hole #16

Location: NE¼NW¼ sec. 35, T. 106 N., R. 56 W.
Elevation: 1562 feet
Total depth: 29 feet
Depth to water: ____

Description	Depth (feet)
Clay, tan, with rock fragments	0-14
Clay, blue gray, with rock fragments	14-29

Test Hole #17

Location: SW¼SW¼ sec. 23, T. 107 N., R. 56 W.
Elevation: 1584 feet
Total depth: 59 feet
Depth to water: ____

Description	Depth (feet)
Clay, brown, with pebbles	0-24
Clay, blue gray, with pebbles	24-44
Sand, very fine	44-59

Test Hole #18

Location: NW¼SW¼ sec. 23, T. 107 N., R. 56 W.
Elevation: 1622 feet
Total depth: 24 feet
Depth to water: ____

Description	Depth (feet)
Clay, brown, with scattered pebbles	0-24

Test Hole #19

Location: SW¼NW¼ sec. 23, T. 107 N., R. 56 W.
Elevation: 1574 feet
Total depth: 84 feet
Depth to water: 37 feet

Description	Depth (feet)
Clay, brown, with pebbles	0-17
Sand, fine	17-39
Sand, fine-medium	39-64
Clay and fine sand	64-84

Test Hole #20

Location: NE¼NE¼ sec. 22, T. 107 N., R. 56 W.
Elevation: 1570 feet
Total depth: 14 feet
Depth to water: ____

Description	Depth (feet)
Clay, brown	0- 9
Clay, blue	9-14

Test Hole #21

Location: SE¼SE¼ sec. 22, T. 107 N., R. 56 W.
Elevation: 1573 feet
Total depth: 34 feet
Depth to water: 25 feet

Description	Depth (feet)
Clay and dark sand	0- 15
Clay, blue gray	15-34

Test Hole #22

Location: SW¼SW¼ sec. 23, T. 107 N., R. 56 W.
Elevation: 1585 feet
Total depth: 36 feet
Depth to water: ____

Description	Depth (feet)
Clay, brown	0-36

Test Hole #23

Location: NW¼SW¼ sec. 23, T. 107 N., R. 56 W.
Elevation: 1571 feet
Total depth: 69 feet
Depth to water: 10.8 feet

Description	Depth (feet)
Gravel, sand, and clay	0- 10
Sand, clean	10-39
Sand and clay	39-44
Clay and sand	44-69

Test Hole #24

Location: NW1/4SW1/4 sec. 23, T. 106 N., R. 56 W.
Elevation: 1568 feet
Total depth: 64 feet
Depth to water: 13.7 feet

Description	Depth (feet)
Clay, dark gray	0- 3
Gravel	3- 11
Clay and gravel	11-17
Sand, medium, clean	17-44
Sand and clay	44-64

Test Hole #25

Location: SW1/4SW1/4 sec. 23, T. 107 N., R. 56 W.
Elevation: 1573 feet
Total depth: 29 feet
Depth to water: _____

Description	Depth (feet)
Clay, brown	0- 5
Gravel and clay	5- 9
Clay, gray, and pebbles	9-29

Test Hole #26

Location: NW1/4SW1/4 sec. 23, T. 107 N., R. 56 W.
Elevation: 1567 feet
Total depth: 64 feet
Depth to water: 10.2 feet

Description	Depth (feet)
Clay, dark gray	0- 2
Gravel and sand	2- 11
Clay, medium gray, and pebbles	11-21
Sand, medium and fine	21-49
Sand, fine-medium, and clay	49-54
Clay and fine sand	54-64

Test Hole #27

Location: NE1/4SW1/4 sec. 23, T. 107 N., R. 56 W.
Elevation: 1558 feet
Total depth: 50 feet
Depth to water: 8.0 feet

Description	Depth (feet)
Clay, dark gray	0-15
Gravel and clay	15-19
Clay and pebbles	19-50

Test Hole #28

Location: SE¼NW¼ sec. 23, T. 107 N., R. 56 W.
Elevation: 1559 feet
Total depth: 49 feet
Depth to water: 12 feet

Description	Depth (feet)
Clay, dark gray and pebbles	0- 4
Clay and gravel	4- 5
Clay and coarse sand	5- 9
Clay	9-49

Test Hole #29

Location: NW¼NW¼ sec. 14, T. 106 N., R. 56 W.
Elevation: 1516 feet
Total depth: 29 feet
Depth to water: 8.0 feet

Description	Depth (feet)
Clay, dark gray and gravel	0- 4
Clay, sandy	4- 9
Clay	9-14
Clay, sandy	14-39

Test Hole #30

Location: NE¼NW¼ sec. 14, T. 106 N., R. 56 W.
Elevation: 1539 feet
Total depth: 49 feet
Depth to water: 7.0 feet

Description	Depth (feet)
Clay and gravel	0- 9
Clay, sandy	9-24
Gravel, fine, and clay	24-39
Sand, fine, and gray clay	39-49

Test Hole #31

Location: SE¼SW¼ sec. 11, T. 106 N., R. 56 W.
Elevation: 1527 feet
Total depth: 19 feet
Depth to water: _____

Description	Depth (feet)
Gravel and clay	0- 7
Clay, brown, and pebbles	7-19

Test Hole #32

Location: SE¼SE¼ sec. 11, T. 106 N., R. 56 W.
Elevation: 1516 feet
Total depth: 24 feet
Depth to water: 4.2 feet

Description	Depth (feet)
Clay, brown	0- 5
Clay and sand	5-24

Test Hole #33

Location: SE¼SW¼ sec. 9, T. 106 N., R. 56 W.
Elevation: 1512 feet
Total depth: 44 feet
Depth to water: _____

Description	Depth (feet)
Clay, brown, and fine sand	0-44

Test Hole #34

Location: SW¼SW¼ sec. 2, T. 106 N., R. 56 W.
Elevation: 1571 feet
Total depth: 49 feet
Depth to water: _____

Description	Depth (feet)
Clay, brown	0-24
Clay, brown, and sand	24-49

Test Hole #35

Location: SW¼NE¼ sec. 2, T. 106 N., R. 56 W.
Elevation: 1560 feet
Total depth: 54 feet
Depth to water: 5.4 feet

Description	Depth (feet)
Clay and gravel	0-24
Clay with gravel and sand	24-29
Clay with decreasing amount of sand with depth 25	29-54

APPENDIX B

Logs* of Deep Wells and Test Borings at Howard

Howard Town Well

Location: (at stand-pipe) NW1/4NE1/4 sec. 11, T. 106 N., R. 56 W., Miner Co., South Dakota
Elevation: 1572 feet
Total depth: 402 feet
Date drilled: May, 1953
Source of data: S. Dak. Geol. Survey files

Depth	Formation and Remarks
0- 20	Till, poorly sorted yellow sand, calcareous sandy clay with gypsum fragments.
20- 50	Sand, poorly sorted, with clay
50- 60	Sand with medium gray clay and sandy clay.
60-150	Sand and gravel poorly sorted with clay as above.
150-170	As above but with much lignite.
170-180	Gravel, pebble and granule size.
180-190	Gravel and sand with much lignite.
190-200	Niobrara Formation, marl, light gray, with abundant small white chalk spots, also lignite which may be cavings.
200-260	Chalk and spotted marl as above.
260-270	Same as above with scattered *Inoceramus* prisms and shell fragments.
270-280	Chalk-spotted marl as above, with some lignite.
280-290	Same as above.
294	(Carlile Formation top E. L.)
290-300	Sand, fine to very coarse grained, angular to subrounded, poorly sorted, loose and calcareous argillaceous sandstone.
300-320	Sand, and sandstone as above and medium dark gray bentonitic shale with pyrite.
320-340	Siltstone, yellow-brown and sandy siltstone concretions, some slightly calcareous.
340-350	Shale, micaceous, sandy, medium dark-gray; some fine-grained sandstone.
350-360	Sandstone, white, fine-grained, calcareous, micaceous, glauconitic lignite.
360-370	Shale, medium dark-gray.
370-380	Shale, dark gray.
380-400	Sand, fine-grained with bentonite.
400-402	Sioux Formation, well cemented, siliceous quartzose sandstone.

* Formation Tops picked by Electric Logs

Howard Test Well

Location: (South end of Athletic Field) NW¼ sec. 2, T. 106 N., R. 56 W., Miner County, S. Dak.
Elevation (G. L.): 1583 ± 3 feet
Total depth: 500½ feet
Date drilled: May 9, 1957
Source of data: Frederickson's Inc., Hutchinson, Minnesota

Depth	Formation and Description
0- 2	Topsoil, black
2- 70	Clay (till?) brown
70- 85	Sand, coarse
85-152	Clay, dark gray (blue)
152-154	Sand
154-158	Clay, blue
158-161	Sand
161-175	Sand with clay ("dirty")
175-200	Clay, medium gray
200-244	Clay, dark gray
240	Niobrara Formation top from E. Log
244-340	Shale (marl?) light gray
340	Carlile Formation top from E. Log
340-478	Shale, gray
478-480	Sand
480-500	Shale lensed with sand
500-500½	Sioux Formation, well cemented siliceous sandstone.

Howard City Well

Location: (NW¼ of golf course) SW¼NE¼ sec. 2, T. 106 N., R. 56 W., Miner County, S. Dak.
Elevation (G. L.): 1562 feet
Total depth: 405 feet
Date drilled: May 15, 1957
Source of data: Frederickson's Inc., Hutchinson, Minnesota

Depth	Formation and Description
0- 3	Topsoil, black
3- 18	Sand, coarse, brown with clay
18-170	Clay, dark gray, with sand
170-175	Sand with clay ("dirty")
175-182	Sand
182-184	Clay, dark gray
184-198	Sand, coarse with silt and clay
198-226	Shale (marl?), dark gray
200	Niobrara Formation top from E. Log
226-274	Shale, sandy, gray
274-344	Shale, gray
294	Carlile Formation from E. Log
344-380	Shale, hard, gray
380-405	Shale, gray and dark gray
405	Sioux Formation, well cemented, siliceous quartzose sandstone.