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STATE OF SOUTH DAKOTA
Sigurd Anderson, Governor

STATE GEOLOGICAL SURVEY
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REPORT OF INVESTIGATIONS

NO. 72

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ARTESIAN CONDITIONS IN AREA SURROUNDING THE SIOUX QUARTZITE RIDGE

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by

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TABLE OF CONTENTS

ARTESIAN CONDITIONS

IN

AREA SURROUNDING THE SIOUX QUARTZITE RIDGE

INTRODUCTION

Location and Area

The region covered in this report includes Buffalo, Brule, Jerauld, Aurora, Sanborn, Davison, Miner, Hanson, Lake, McCook, Moody, and Minnehaha Counties in South Dakota. The north county lines of Buffalo, Jerauld, Sanborn, Miner, Lake, and Moody Counties is the northern boundary, and the south county lines of Brule, Aurora, Davison, Hanson, McCook, and Minnehaha Counties is the southern boundary of the area. The region lies between the Missouri River, the western boundary, and the eastern boundary of the South Dakota and Minnesota state line.

In all, the area covers approximately 6900 square miles. Some of the largest towns and cities in the area include Sioux Falls, Flandreau, Madison, Howard, Salem, Mitchell, Woonsocket, Plankinton, Wessington Springs, and Chamberlain.

Purpose and Method of Investigation

The purpose of this investigation was to determine the static level, or height above sea level to which the artesian waters coming from the Dakota and Lakota formations would rise; and the rate and amount of decline of this water level in the past fifty years.

A second purpose of this project was to investigate the stratigraphy and structure of the area.

This survey was made by a two man party consisting of Fred V. Steece as assistant and the author as geologist.

An altimeter was used to determine the altitude above sea level of each well site, with levels carried from precise level bench marks near each well. A pressure gauge was used to determine the pressure on any well that was in good condition. The rate of flow was determined by observing the time required to fill a gallon measure, or where the flow was too great it was done mathematically by using a formula.

A well measured every three to six miles determined the gradient of the water level. Wherever possible, pressures were taken on wells that were in good condition. In certain parts of the area where there were no flowing wells, information was acquired from pumped artesian wells. A line was placed in a well to determine how far the water rose toward the surface. Where it was impossible to get a line through the pump into the well, the information came from the well owners.

Previous Investigations

The first investigation of artesian water in the region covered by this report was made by E. S. Nettleton[2], an engineer working for the U. S. Department of Agriculture. He made a general investigation to determine the depths, pressures, and flows of artesian wells in North Dakota and South Dakota during 1890 and 1891.

A more comprehensive study of the artesian basin in South Dakota was made for the United States Geological Survey by N. H. Darton[6] in 1896. Darton's preliminary report investigated the location of water-bearing beds and the limits of the territory in which artesian flows were expected in South Dakota and adjoining states. J. E. Todd[4b] made several investigations of the geology and underground water resources in the region covered by this present report. In 1909 Darton[1] wrote a second report for the United States Geological Survey on, "Geology and Underground Conditions of South Dakota." He investigated the geologic conditions bearing on the occurrence of artesian waters.

Comparing these investigations with the data of this survey made it possible to record the changes in head or water pressure during the past 60 years.

Acknowledgements

Mr. Bruno Petsch helped considerably with the report by doing most of the drafting and contributing electric well log data. Mr. Harold Erickson also assisted the author in the latter part of June before the regular field season started.

The author greatly appreciated the cooperation and information given by the well drillers and farmers operating in the area which helped make this report possible.

GEOLGOY OF THE AREA

PROCEDURES FOR OBTAINING STRATIGRAPHIC INFORMATION

Examination of Well Samples

The data obtained for making well logs of this area were interpreted from well samples and electric logs.

Cuttings collected from different wells were studied through a microscope to determine characteristics of formations. Each formation has definite lithologic characteristics, so the thickness and contacts can usually be identified accurately. A description of each formation according to the character and the fossils present is made visually and with the aid of a microscope. For example, the Greenhorn formation is identified as a limestone with many clam shells present.

Electrical Well Logging

Besides examination of cuttings there are other means of receiving stratigraphic information. The electric logger plays a great part in determining contacts and thicknesses of formations. For these purposes the State Geological Survey owns a 2000 foot electric logger to obtain accurate subsurface data.

Before the electric logging procedures start, the well must have good circulation to prepare the hole from obstructions. To log the well, a stationary electrode is placed at the surface, usually in the mud pit. A traveling electrode assembly at the end of a wire line spooled on a reel is lowered to the bottom of the hole. A recording of the well is made going down the hole and coming back up to obtain a double check. As the electrode assembly is lowered and raised in the hole, electrical currents are passed through the electrodes, and the electrical meter readings are automatically plotted against depths on the recording drum.

Some of the following fundamentals of the electric logger must be known in order to interpret the data.

In electrical well logging two electrical properties are measured in the bore hole: potential and resistance.

Potential

Potential is a measurement of the natural electrical potential between the surface electrode and one of the electrodes in the well. It is measured in millivolts, 1 millivolt being 0.001 volt. The electromotive force or potential gives rise to a current, which flows through permeable layers, then spreads into the adjacent formations, and returns through the mud filling the hole.

It has been observed that in a bore hole the electrical potential varies according to the nature of the beds traversed. For example, salt water sands and brackish water sands are usually more negative than the associated shale or clay. On the other hand, fresh water sands may be either more negative or more positive than the associated formations.

By making potential measurements in a bore hole and plotting them in terms of depths, a potential graph is obtained. From the graph it is possible to pick the boundaries of most beds and sometimes to have clues on the nature of some of the formations traversed. An idealized potential graph is represented on the left side of the Diagram No. 1.

Resistance

Electrical resistivity is that property which tends to impede the flow of electricity through a substance. This property can be measured in volume of rock having a unit of length and a unit of cross section. The resistivity of rocks is expressed in (ohms m^2/m) or ohmmeters. This has been found to be a convenient unit for practical purposes giving values between a fraction of an ohm and several thousand ohms.

The electrical conductivity of a bed is determined by the nature, quantity, and distribution of the water contained in the bed. Inasmuch as these factors vary appreciably from one bed to another, conductivity measurements made in a bore hole can be used to pick formation changes and sometimes to obtain some idea on the nature of the formations traversed. In practice it is not the conductivity but its reciprocal, the resistivity, or resistance, which is measured. The measurements are plotted in terms of depths and the resulting record is called a resistivity or resistance graph.

Electric Log

The combination of a potential graph and of a resistance graph placed side by side constitutes an electric log.

Application of Electric Logs

Electric logs give a detailed and continuous picture of the formations penetrated in the course of drilling, and they are, therefore, one of the most useful tools available at present for subsurface studies.

The principal applications of electric logs can be divided into the following classes, corresponding to the nature of the problems to be solved.

1. Geological problems
2. Investigations of water supplies
3. Data for surface exploration
4. Production problems

Geological Problems

The electrical properties of a bed are controlled primarily by the amount, composition, and geometry of the fluid, usually water, which it contains. Therefore, an electric log reflects the lithologic character of strata. Inasmuch as the electrical measurements are made with great detail in terms of depths, position and thickness of each of these strata can be determined with accuracy.

Since the average lithologic character of beds usually does not vary greatly over short distances, electric logs taken in neighboring wells which have traversed the same strata exhibit an almost identical pattern. The beds can, therefore, be correlated from well to well by comparing the electric logs obtained in these wells. From this data accurate geological mapping is possible.

If the wells are very shallow (seismograph shot holes, shallow core holes), a surface map or a shallow subsurface map can be established. This map will be of considerable value in exploration work when the surface geology reflects deeper structures. If the surface geology is not significant, deeper wells (core holes) will have to be drilled and logged for preparing a subsurface map from which the location of exploratory wells will be determined. Many other geological problems can frequently be solved with electric logs, such as bed identification, research on sedimentation, et cetera.

Investigation of Water Supplies

Inasmuch as the electrical characteristics of rocks are controlled by the amount and composition of the water which these rocks contain, electric logs are a useful tool for the investigation of the water supplies of an area. In particular they permit determining exactly the depth and thickness of fresh water bearing formation. They also furnish information regarding the quality of the water, such as fresh, brackish, or water high in salt content.[13]

STRATIGRAPHY

STRATIGRAPHIC SYSTEMS PRESENT

The rock formations which are exposed in this area belong to four geologic systems: the Quaternary, Tertiary, Cretaceous, and pre-Cambrian.

The Quaternary sediments, the youngest system exposed, cover most of the area under consideration. These sediments are mostly unconsolidated materials made up of glacial till, loess, sand, and gravel.

The Tertiary sediments, the next older, are ancient stream deposits of sands, gravels, and stratified quartzite. The Bijou Hills in the southern part of Brule County are capped with green quartzite of Miocene and Pliocene age.

The Cretaceous deposits include the Pierre, Niobrara, Carlile, Greenhorn, Graneros, Dakota, Fuson, and Lakota formations. The Pierre and the Niobrara are exposed along the Missouri River. The Niobrara and Codell sand member of the Carlile are exposed along Firesteel Creek, and the James River.

The oldest formation exposed is the Sioux Quartzite which is pre-Cambrian in age. It is exposed in spots in the area between Mitchell and Sioux Falls.

The geologic map of this area shows where these beds outcrop.

QUATERNARY SECTION

Pleistocene Deposits

Alluvium

Alluvial deposits composed of clay, silt, sand, and some gravel make up the flood plains of the Missouri, James, and Big Sioux Rivers, and the larger creeks.

Loess

Loess is a wind-blown deposit of fine clay, which makes a thin cover on some Missouri River terraces. The material is soft and unconsolidated, but well packed and held together by bentonite.

Glacial Deposits

Till or Boulder Clay

Glacial till is composed of a mixture of sands, clays, gravel, and scattered boulders. It is distinguished from ordinary stream deposits by its unassorted character and the absence of stratification.

The till or drift of this region exhibits the basin and swell surface in a mild degree. The drainage, which is very poor, is characteristic of the basin and swell surface and there are numerous small lakes and swamps.

The thickness of the till varies from a few feet to an average of 75 feet.

The terminal moraines are recognized by stony, knobby, hills mingled with circular and winding basins. The moraines usually present a large number of boulders, beds of gravel, and till mixed together.

In this area there is one principal moraine, the Gary Moraine, belonging to the Wisconsin stage. The name is derived from the town of Gary where it was first studied. It enters the west boundary of Firesteel Creek, near the north boundary of Jerauld County and continues southward along the east side of Firesteel Creek and follows in a southeasterly direction until it crosses the north line of Hutchinson County.[11]

Other prominent moraines in this area are the Pony Hills west of Woonsocket, and the White Lake moraine[14], approximately 2 miles in width, extending from the Wessington escarpment, 2 miles south of Wessington Springs, southwestward through the town of White Lake.

As the glacier retreated, great amounts of water released by melting of the ice left little evidence of its existence. A large part of it drained away over the surface cutting channels into the moraines. As the meltwater subsided, some of these channels were partially filled with sand and gravel.[14]

These channels vary in depth of 40 to 60 feet and in widths from half a mile to a mile. Along the James River older channels changed to terraces appear at different altitudes. East of Mitchell there are two old channels approximately 80 and 100 feet above the stream. The usual indication of such a terrace is a sharp, stony edge capping the river bluff and a generally flat surface extending for many rods.

"The best known channel in this area lies between Lane and Mitchell, and is occupied by the valley of Firesteel Creek. About the middle of its course this channel splits into three parts. Ten miles downstream the three channels again unite into a single one."[14]

TERTIARY SECTION

Bijou Formation

The Bijou formation was named by R. E. Stevenson for the type section capping the Bijou Hills in Brule County. It consists of gravels, sands, volcanic ash, bentonite, green quartzite, and conglomerate containing fossil mammals indicating upper Miocene and lower Pliocene in age.

"A section in the southwesternmost Bijou Hills is about 120 feet thick, consisting of a lower member of flesh-colored, sandy, and ashy silts separated by a thin green laminated bentonite from an upper buff, cross-bedded, fine grained sand. Irregular shaped limestone concretions occur throughout and there are petrified wood and mammalian bones."[16]

A typical section of the Bijou formation was measured by R. E. Stevenson in Gregory County.

Succession of Beds, Bijou Formation, Exposed
Gregory County, South Dakota
Composite Section
$SE\frac{1}{4}$, $NE\frac{1}{4}$, Sec. 30, T. 96 N., R. 67 W.

Bijou Formation

5. Irregular, lenticular, siliceous, coarse sandstone with green siliceous clay, cobbles and green sand - 4 ft.

4. Greenish, slightly lutaceous* sand of well rounded medium grained quartz - - - - - - - 11 ft.

3. Greenish, bentonitic clay - - - - - - - - - 8 ft.

2. Greenish, sandy, lutaceous siltstone, weathers pink, Ustatochoerus medius (Leidy)** - - - 11 ft.

1. Grey, lutaceous, fine sand - - - - - - - - - 20 ft.

* Cemented with clay
** Oreodont

The overlying green quartzite contains some black silicified wood, a few mollusk shells, locally small quartz, chert and feldspar pebbles, its sand grains varying from coarse to fine, somewhat cross-bedded with local lenses of unconsolidated sand.[16]

Dr. Joseph Gregory identified the following mammalian fossils collected by the South Dakota Geological Survey staff:

Fauna of the Bijou Formation in South Central South Dakota

Horses	Merychippus insignis Leidy M. republicanus Osborn Protohippus cf. P. perditus Pliohippus? sp. Neohipparion sp. Nannihippus retrusus Cope Hypohippus cf. H. equinus Scott Calippus cf. C. placidus
Camels	Procamelus cf. P. calcaneus Megatylopus sp. (may be Alticamelus sp.)
Deer	Blastomeryx sp. Dromomeryx? sp. Cranioceras? sp.
Antelope	Merycodus cf. M. furcatus Leidy
Peccaries (Pig family)	Prosthennops sp.
Rhinoceras	Teloceras? sp. Aphelops? sp.
Mustels (weasels, badgers, skunks, otters, etc.)	Brachypsalis modicus Matthew
Horned Rodents	Mylagaulid
Oreodonts	Ustachoerus medius Leidy
Mastadons	Gomphotheriidae

MESOZOIC SECTION

Pierre Formation

Distribution

The Pierre formation extends over the western part of the area thinning to the east and appearing along the bluffs of the Missouri Valley. Surrounding the Sioux quartzite ridge, the Pierre has been removed by erosion.

Character

The Pierre formation consists of a gray clay varying from light to dark with numerous bentonite beds and concretions scattered throughout.

Bentonite is a finely divided, altered volcanic ash that settled at various times during the geologic past in shallow interior seas. The volcanic ash was altered to bentonite by action of sea water.

The concretions are composed of hard limestone and iron carbonate, which vary from two to twelve inches in thickness.

In the Chamberlain area along the Missouri River, iron manganese concretions appear in the Oacoma member of the Pierre. An example of this condition can be seen north and south of Chamberlain along the Missouri River bluffs. A measured section south of the mouth of Crow Creek, Buffalo County, shows the characteristics of the Pierre formation in this area.[9]

Succession of Beds, Pierre Formation, Exposed
at and South of the Mouth of Crow Creek,
Buffalo County, South Dakota
Composite Section
Secs. 23 and 34, T. 106 N., R. 71 W.

Pierre Formation
Sully Member
Verendrye facies

12. Shale, gray, weathers to gumbo; contains large black sideritic concretions; not measured.

11. Shale, light gray, flaky.................. 7'

10. Shale, light gray......................... 2'

9. Shale, light gray, with rusty zone at top and two intermittent zones of white rusty lime concretions in lower 15 ft...29' 4"

8. Shale, light gray, with zone of white, rusty lime concretions at top, and two similar, intermittent zones near base..................................... 9'

7. Shale, gray to yellow gray, flaky; numerous iron manganese concretions and many bentonites.....................20' 1"

Lower Oacoma facies

6. Shale, dark gray, gummy, containing 3 thick bentonites and a few layers of concretions............................ 22' 3"

Crow Creek facies

5. Marl, light gray......................... 5'

4. Sandstone, brown, calcareous, slabby... 11"

Gregory Member

3. Shale, gray to brown, containing numerous flat, rusty-brown concretions. Some calcareous layers, including an intermittent 5"--6" impure marl lying 7 to 10 feet below the Crow Creek sand in some exposures on each side of the river in this immediate area.................................84'

Sharon Springs Member

2. Shale, dark gray to black fissile, contains fish fragments and numerous bentonite beds; selenitic at base - - - - - - 14'

Niobrara Formation

1. Chalk, impure, weathers yellow on outcrop.

Distinguishing and Drilling Characteristics

Since the Pierre is a soft, plastic clay that contains numerous bentonites in certain zones and layers of concretions, the formation drills easily, but the bentonites and concretions that occur in certain zones may cause some trouble. The bentonites have the property of absorbing large quantities of water causing heaving and swelling which might close the hole. The bentonites are useful in rotary drilling as they make their own drilling mud, saving the driller the expense and trouble of using prepared muds.

Fossils and Age

The most common fossils found in the Pierre are clam shells of the genus Inoceramus, identified by heavy corrugations of the shell. Micro-fossils of the order, Foraminifera, too small to detect without visual aid, can be identified under the microscope. Marine reptile bones can be found at the contact of the Verendrye and Oacoma facies of the Sully member. The age of the Pierre is upper Cretaceous and is the lower part of the Montana group.

Thickness

The Pierre formation varies greatly in thickness in the region between the James and Missouri Rivers in Buffalo, Brule, Jerauld, Aurora, Sanborn, and Davison Counties. Because it is the topmost of the bedrock formations, it has been subject to much erosion. The maximum thickness is in the western part of the area where 260 feet is recorded at the Knippling Ranch located in the NE$\frac{1}{4}$, Sec. 36, T. 108 N., R. 72 W.

Niobrara Formation

Distribution

The Niobrara is a conspicuous feature in the bluffs along the Missouri River as far north as Chamberlain. It underlies the Pierre over most of the area except where it underlies the drift close to the Sioux Ridge. Exposures are numerous along the James River, Firesteel Creek, Enemy, and Twelvemile Creeks southwest and south of Mitchell.

Character

The Niobrara is composed of a dark gray to blue chalk and marl. Under the microscope the chalk has a speckled appearance due to the micro-fossils which are made up of white calcite. The Niobrara grades into a marl and chalky marl in the Chamberlain area. There is an increase of argillaceous material with a decrease of $CaCO_3$ material towards the northern part of the state.[10]

In Kansas the Niobrara has been divided into two members on the basis of lithology. The upper part, called the Smoky Hill member, is softer and contains numerous bentonites. The lower part, called the Ft. Hayes member, is almost a limestone and has fewer bentonites.

In this area it is difficult to recognize a lithologic subdivision. "Since the main basis for subdivision is micro-paleontologic rather than lithologic, it remains very difficult if not impossible to distinguish between the two members in the field without additional laboratory study."[10]

The resistivity of the Niobrara is high which can be seen on an electric log. The contact of the Niobrara can easily be interpreted from electric log data.

Distinguishing and Drilling Characteristics

Weathered chalk appears buff or white, but unweathered or fresh chalk is a blue and speckled, and it is often mistaken for clay or shale. When a drop of hydrochloric acid is placed on the chalk, it will bubble or effervesce briskly releasing carbon dioxide, while the clay will not react to the acid.

The Niobrara drills quite easily and usually does not present any problem to the driller.

Fossils and Age

The most numerous fossils found in the Niobrara are micro-fossils called Foraminifera and Ostracods. Other prevalent fossils found are small, deep, cup-shaped oysters (Ostrea congesta) usually found in clusters and clam shells of the genus Inoceramus. Teeth of sharks, fish scales, and fish bones are abundant throughout the formation. The age of the Niobrara is upper Cretaceous placed in the Colorado group.

Thickness

The maximum thickness of the Niobrara is 150 feet recorded in Buffalo and Brule Counties. It thins to the east with a minimum of 40 feet recorded in Lake County. In Aurora, Jerauld, Sanborn, and Davison Counties the average thickness is 100 feet.

Carlile Formation

Distribution

The upper part of the Carlile, known as the Codell member, is exposed along the James River and Firesteel Creek in the vicinity of Mitchell. The Carlile underlies most of the area covered by this report except where it is wedged out against the quartzite.

Character

The Carlile formation varies from a light gray to dark and bluish gray clay. Calcareous concretions are more or less abundant throughout the deposit. The size of the concretions vary from 2 to 36 inches in thickness. A considerable amount of iron pyrite and gypsum is abundant in the formation. Shales or clays offer little resistance, so the resistivity "kicks" of the Carlile recorded on the electric log are very small. The Codell sand member can easily be interpreted because a sandstone or sand has more resistance than clays.

Codell Member

A horizon of sand and clay layers near the top of the Carlile is persistent over most of the area. The Codell consists of a fine angular to sub-angular quartz sand with some of the grains frosted or etched. In Brule and Buffalo Counties, the Codell grades into a clay. Part of the Codell exposed along Firesteel Creek is described below:

Succession of Beds, Codell Member
Exposed along Firesteel Creek
Davison County, South Dakota
NW$\frac{1}{4}$, Sec. 35, T. 104 N., R. 61 W.

6.	Loose sorted sand....................................	6"
5.	Hard layer consisting of reworked clay, coarse sand and pebbles. Abundance of sharks' teeth found in this layer........................	12"-16"
4.	Layer of clay with thin seams of melanterite.	3"
3.	Very loose sand with thin clay seams interspersed between..............................	6"
2.	Gray, loosely cemented sand consisting of a number of shale streaks....................	22"
1.	Loosely cemented sand with streaks of red clay	24"
	Total thickness of Section	6 feet ≠

Distinguishing and Drilling Characteristics

In the stratigraphic section, the Carlile lies conformably between the Niobrara and the Greenhorn. The Codell usually lies underneath the Niobrara and the first sign of sand indicates the contact.

The Carlile is a dark colored, soft, plastic clay that contains layers of concretions. It drills easily, but hard concretions may cause some drilling trouble. The Carlile can also be used as a drilling mud because it consists of a soft clay and contains scattered bentonites.

Fossils and Age

Fossils are very abundant in the formation, especially in the upper part. Fish remains are common throughout the formation. Other common fossils found are *Inoceramus* shells, previously described, and fossil oyster shells called *Ostrea congesta*. The age of the Carlile is Cretaceous and is the upper part of the Benton group.

Thickness

In the western part of the area the Carlile varies from 175 to 200 feet and in the eastern area it ranges from 70 to 150 feet.

Greenhorn Formation

Distribution

The Greenhorn lies beneath most of the area except where it is wedged out against the quartzite in the following counties: eastern Davison, Hanson, McCook, Minnehaha, Moody, southern Lake, and southern Miner.

Character

The Greenhorn is a fossiliferous chalk and limestone with an admixture of clay that occurs in thin, but distinctive beds. It consists of a lower member of bluish gray chalk containing thin seams of black shale and a few bentonites; a medial member of hard, shelly, thin bedded limestone containing numerous Inoceramus prisms separated by partings of clay; and a top member of light blue-gray chalk. Examination of the electric logs shows that the Greenhorn may grade more into a chalk towards the northern part of the area. Below is a section of exposed Greenhorn measured by E. J. Bolin and the author in February, 1952.

Succession of Beds in the Greenhorn Formation
Measured at Quarry 12.3 miles SE of
Westfield near Highway 12, Plymouth County, Iowa.

8.	Highly weathered, soft, buff and light blue-gray chalk.....................................	3 ft.
7.	Slabby thin-bedded, white limestone. Beds vary from ¼" to about 1" in thickness. Contains abundant Inoceramus fragments and has iron staining on surface......................	8.7 ft.
6.	Very hard, massive, white limestone. Contains abundant Inoceramus fragments and has iron staining on surface.......................	4.5 ft.
5.	Highly weathered, soft, buff and light blue-gray chalk. Contains a 1" seam of bentonite 2.45 ft. below top............................	3.72 ft.
4.	Black, slabby, calcareous shale.............	.4 ft.
3.	Chalk as above.................................	.3 ft.
2.	Shale as above.................................	.5 ft.
1.	Chalk as above - base of quarry............	3.14 ft.
	Total thickness of section	24.26 ft.

Distinguishing and Drilling Characteristics

The Greenhorn lies conformably under the Carlile and conformably over the Graneros. It can easily be recognized by numerous fragments of Inoceramus shells. On the resistivity graph the Greenhorn limestone shows the most resistance. The "kicks" on the graph are very prominent, easily distinguishing it from the other formations. It is a hard formation, and may slow the drilling time, but it is not too difficult to penetrate.

Fossils and Age

The Greenhorn is a shelly limestone that consists mostly of Inoceramus shells. Besides Inoceramus, the formation contains fish fragments, sharks' teeth, fish scales and Foraminifera. The age of the Greenhorn is Cretaceous and is part of the Benton Group.

Thickness

The thickness of the Greenhorn varies from 50 feet in the western part to 20 feet in the eastern part of the area. The Greenhorn thins to the east and is wedged out around the quartzite ridge.

Graneros Formation

Distribution

The Graneros lies beneath most of the area except where it is wedged out against the Sioux quartzite.

Character

The Graneros consists mainly of fine grained, dark-colored clay, with streaks of sand layers found interspersed through the formation. Concretions of iron carbonate varying from two to six inches in thickness occur at different horizons, and pyrite is abundant throughout the clay.

Distinguishing and Drilling Characteristics

The Graneros lies conformably between the Greenhorn and the Dakota. Pyrite streaks and layers of concretions sometimes make the Graneros difficult to drill. The Graneros, like the Pierre and the Carlile, can be used as a drilling mud because it consists of a soft, plastic clay.

Fossils and Age

Few fossils are found in this formation with the exception of some large reptile bones.[4a] The age of the Graneros is Cretaceous and it is the lower part of the Benton Group.

Thickness

The formation varies in thickness from one area to another. Four hundred thirty feet of strata logged at the Loring Well in Sanborn County is the thickest section. One hundred fifty feet of strata logged at the Biskeborn Well in Brule County is the thinnest section. Over most of the area the Graneros averages 200 feet in thickness.

Dakota Formation

Distribution

The Dakota underlies most of the area covered except where it is wedged out against the Sioux quartzite ridge.

Character

The Dakota formation is made up of sandstones with some thin interbedded clays, some of the features of which are given in the following exposed detailed section.

Succession of Beds in the Dakota Formation
Measured below the Mouth of Aowa Creek
Dixon County, Nebraska.[4a]

Sandstone, soft, porous, rust colored.........	10 ft.
Clay, dark with thin sandstone layers.........	2.5
Sandstone, nodular, rust colored..............	1
Clay, dark, sandy at base.....................	1
Sandstone, with layers of iron concretions....	4.5
Sandstone, dark, rust colored, with shaly layers.	25
Total exposed thickness	44 ft.

Diagram 1 shows the following intervals of sandstones and clays in the next section of the Dakota taken from a well.

Succession of Beds in the Dakota Formation
Electric Log of Fred Meyer Artesian Well
Sec. 22, T. 109 N., R. 63 W.,
Beadle County, South Dakota.

Top of Dakota formation	817 ft.
Sandstone..................................	3.5
Clay.......................................	6.5
Sandstone..................................	6
Clay.......................................	2
Sandstone..................................	2
Clay.......................................	7.5
Sandstone..................................	14
Clay.......................................	6.5
Sandstone..................................	5
Clay.......................................	4.5
Sandstone..................................	6
Clay.......................................	4
Sandstone..................................	4
Clay.......................................	5

Sandstone....................................	5 ft.
Clay...	1
Sandstone....................................	2
Clay...	2
Sandstone....................................	6
Clay...	3
Sandstone....................................	8.5
Total thickness of section	102 ft.

Distinguishing and Drilling Characteristics

The Dakota lies conformably between the Graneros and Fuson formations. Water well drillers have divided the Dakota into the first, second, third, and fourth flows. These flows are not persistent over an area, however, for there may be a number of flows separated by clay layers. As shown by Diagram 1, there may be as many as 12 or 13 sands separated by clay layers that contain water.

Fossils and Age

The formation contains numerous traces of plant life in the form of carbonaceous strata, bits of charcoal, root marks, and fragments of leaves. It is a fresh water deposit with a few animal fossils that occur rarely. The Dakota has yielded a large and characteristic flora consisting mostly of dicotyledonous plants, as well as a small molluscan fauna of fresh water types.[4a] The age of the Dakota formation is middle Cretaceous.

Thickness

The Dakota varies in thickness in different parts of the area. A thickness of four hundred fifteen feet was logged at the Biskeborn Well in Brule County. This is a tremendous thickness compared to other sections of the Dakota covering the area. An explanation for this thickness may be an old stream channel formed in the Dakota. The minimum thickness recorded at the Knippling Well is 80 feet. The average thickness ranges from 80 to 150 feet.

Fuson Formation

Distribution

The Fuson underlies most of the area except where it is wedged out against the quartzite.

Character

The Fuson formation consists of thin beds of fine grained sand and different light colored clays mixed with a great amount of bentonite.

Manganese pellets are found in great numbers throughout the formation, and are persistent from the Black Hills to the eastern part of the state. The manganese pellets vary in color from a light brown to deep purple.

Distinguishing and Drilling Characteristics

The Fuson serves as a good impermeable horizon between the Dakota and Lakota. The formation can be recognized in the cuttings because of numerous rounded manganese pellets that vary in color. The pellets can easily be mistaken for sand by the driller because of the similar size and shape of the grains. The Fuson is full of bentonite and slacks easily, so it should be cased as soon as possible.

Fossils

No fossils have been found in the Fuson in this area, but pieces of carbonized wood and thin streaks of lignite are commonly found.

Thickness

The Fuson ranges from 10 to 30 feet over most of the area.

Lakota Formation

Distribution

The Lakota underlies most of the area except where it is wedged out against the quartzite.

Character

The Lakota varies in texture from a gray, fine, angular, to a coarse, angular, subrounded, unsorted sand.

Distinguishing and Drilling Characteristics

The Lakota lies conformably under the Fuson and unconformably on the Sioux quartzite. The formation has the same drilling characteristics as the Dakota. There are some hard streaks in the Lakota that make it difficult for drilling.

Fossils and Age

Carbonized wood and seams of lignite are frequently found throughout the formation. Fossil fern trees called cycadeoids have been found in the Lakota formation north of Edgemont in the Black Hills region. The age of the Lakota is middle Cretaceous.

Thickness

There are no wells in this area to show the thickness of the Lakota.

PRE-CAMBRIAN SECTION

The largest extent of pre-Cambrian section, so far as known, consists of pink quartzite called the Sioux quartzite formation. Other types of pre-Cambrian found are igneous and metamorphic rocks.

Sioux Formation

Distribution

The Sioux quartzite forms a subsurface ridge that outcrops near Sioux Falls and extends west of Pierre for some distance. The known exposures in this area are in Minnehaha, McCook, and Hanson Counties. The areal extent of exposures in this area are shown on the outcrop map, and covers a belt approximately 70 miles long in an east-west direction and about 20 miles wide in a north-south direction. The western extent of the outcrops are 5 miles east of Mitchell, and the eastern extent are in the eastern part of Minnehaha County. The northern extent of the Sioux outcrops at Dell Rapids and the southern extent outcrops at the McCook-Turner County line along the East Fork of the Vermillion River.

The black areas on the outcrop map indicate the approximate location of the outcrops.

Character

"The Sioux quartzite is composed of fine, well sorted angular pink quartz grains that are tightly cemented. The rock has a characteristic greasy lustre due to the fact that it breaks through the quartz grains instead of around them. This quality of breaking identifies the rock as a quartzite and is the result of the compact cementation of quartz by silica. Although the greater part of the Sioux formation consists of fine grained quartzite, a number of outcrops show seams and beds of coarse grained quartzite."[3]

Distinguishing and Drilling Characteristics

The quartzite is a very hard formation which is too difficult to drill with the Jetting Machine and the Rotary Rig. The best method of drilling the quartzite is to use a heavy cable tool rig so that the formation can be smashed. Jetting tools will not break the quartzite and rotary bits, with the exception of the diamond bit, will wear out in a very short time trying to grind it.

Fossils and Age

The age of the Sioux quartzite cannot be determined directly because no fossils have been found in the formation, and the relationship with other formations is obscured by glacial debris.

On indirect evidence, the formation is probably pre-Cambrian in age. On the basis of lithology, absence of fossils and gentle structures, the formation has been correlated by some geologists with the Baraboo quartzite in Wisconsin, which is overlain directly and unconformably by upper Cambrian sediments.[3]

Thickness

The thickness of the formation is indeterminable with no known boring going through it.

Igneous and Metamorphic Rocks

Distribution

Granite has been reported in several wells in Hanson County and one well in Davison County. Granite was struck at a depth of 500 feet in Sec. 25, T. 103 N., R. 61 W. It has been struck in two or three wells about 5 miles north of Farmer.

The granite from wells north of Farmer, in Hanson County, is a fine grained, light gray rock predominant in transparent feldspar, while that from the wells southwest of Mitchell is darker and coarser. At Madison a black hornblende schist was reported at a depth of 1300 feet.[11]

It could be that the igneous rocks struck in these wells are dikes intruded through the quartzite similar to the dike consisting of diabase north of Corson, South Dakota.

Distinguishing and Drilling Characteristics

Igneous rocks present the same problems as the Sioux quartzite for drilling with the Jetting Machine and the Rotary Rig.

Thickness

Igneous rocks, which form the crust of continental area, have no known thickness.

STRUCTURAL CONDITIONS

Introduction

In the area covered by this report gentle folds, flexures, and troughs are the principal features showing structure. The general slope of the area, which is due to the north flank of the Sioux quartzite ridge, is to the north and the west. The Greenhorn slopes northwest approximately 8 feet to the mile in the western part of Lake County as far west as Jerauld County. A general dip of the Greenhorn slopes north 9 feet to the mile in the northern part of Davison and Aurora counties to the northern part of Sanborn and Jerauld counties.

The structure map is controlled from elevations on top of the Greenhorn formation. The elevations on top of the Greenhorn were determined by subtracting the depth to the Greenhorn from the surface elevation. The depths to the Greenhorn were calculated from electric well logs and sample logs.

Sioux Quartzite Ridge

The dominant structure is the Sioux quartzite ridge which rises to a crest up to 1000 feet above the surface of the metamorphic and intrusive rocks to the north. The ridge runs eastward across the state from a point northwest of Pierre southeastward through Sioux Falls and beyond into Minnesota.

Studies made by Brewster Baldwin[3] show that the sediments are laterally extensive and have been gently warped, tilted, and jointed at some period in the past. The amount of dip of the beds varies from 11 degrees at some exposures to flat lying at others, but averages about 3 or 4 degrees. The direction of dip also varies considerably. The direction of dip of the outermost exposures is toward the center of the exposure area. At Dell Rapids the dip is to the south and southwest, and at Parker the beds dip north.[3]

Very irregular topography on the north side of the ridge is evident by the difference in depth to quartzite. Buried hills and valleys are typical of the quartzite ridge.

Overlaps and Unconformities

During the time of deposition, stratigraphic overlaps were formed near the shoreline of the Sioux quartzite ridge which remained a high land until lower Cretaceous time. The oldest sediment known in this area is the Lakota formation which lies unconformably on the quartzite. It is possible that the Morrison formation and the Sundance formation, both of which are Jurassic in age, overlap unconformably on the quartzite into the northwestern part of Buffalo County.

The records of well logs show that the lower part of the Cretaceous including the Lakota, Fuson, and Dakota overlap on the Sioux quartzite ridge in the southeastern part of Sanborn County, southern Miner County, and southern Lake County. A boundary line of the Sioux quartzite near the surface is shown on the geologic map in back of the report.

Minor Flexures

Although the structure map shows folds and troughs, they are extremely gentle, suggesting compaction and settling on an irregular pre-Cambrian surface.

A syncline extending from Brule County to the northern part of Jerauld and Sanborn Counties strikes to the northeast with a dip of 9 feet to the mile. The syncline may extend across the Missouri River where, according to Baker, the Niobrara chalk has its lowest altitude near the mouth of Elm Creek in Sec. 10, T. 101 N., R. 71 W. Though this is not seen too clearly on the structure contour map, a saddle or lobe of the trough goes across the river where there is not enough control to map.

A long nosed fold strikes to the west in Aurora and Brule Counties with the axis passing south of Platte Lake and Kimball. The slope is approximately 16 feet to the mile which is evident that the fold is due to the Sioux ridge.

The Medicine Butte Anticline[17] mapped on top of the Crow Creek sand near the bottom of the Pierre formation, is a long arch lying in the eastern part of Lyman County and trending roughly northwest by southeast between the Big Bend of the Missouri River and the Bijou Hills to the southeast in Brule County. This structure is evident in the northwestern part of the area under consideration.

In Buffalo and Brule Counties a gentle fold, which is nearly flat, strikes to the northeast with a dip 3 feet per mile. This fold does not trend in correspondence with the Medicine Butte anticline. More well logs will have to be collected from that area to plot a more accurate structure.

ARTESIAN WATERS

METHODS OF DETERMINING THE STATIC WATER LEVELS IN OBSERVATION WELLS

The pressure head above ground surface in flowing wells was determined by measuring the shut in pressure with a pressure gauge. The pressure gauge connected to a pitot tube is calibrated to measure the pressure in pounds per square inch. The pitot tube is a small tube which is bent at an angle of 90° near the lower end. When the tube is inserted in a pipe line under pressure, the water will rise a distance equal to both pressure and velocity head at the point where the tube is inserted.

Pressure head in a well is expressed as the height in feet of a column of water that can be supported by hydrostatic pressure. It has been proved mathematically that the hydrostatic head is equal to 1 lb./square inch x 2.3 feet. For example, a flowing artesian well that measures 8 lbs./ square inch pressure will support a column of water 18.4 feet above the ground level. Another way of measuring the hydrostatic head is to connect a hose to the outlet pipe and raise the open end until the water just ceases to flow. The hydrostatic level is obtained by measuring the vertical distance from the end of the hose to the ground.

A Paulin altimeter was used to determine the altitude on each well. The altimeter is an instrument graduated in feet which depends upon the variation of air pressure with altitude for its operation. The altimeter is so arranged that the force of air pressure required to bring the disks of the evacuated boxes back to their normal position is exactly recorded when the tendency is brought to its zero position. The altimeter was checked with known altitudes within short intervals to allow for sudden changes in pressure.

Draw-down

"In any artesian well that is yielding water, whether by pumping or by discharge through artesian pressure, there is invariably a draw-down, or a reduction in pressure of the water in the well. As soon as a well ceases to yield water there is a decrease in the amount of draw-down. An equivalent increase in the pressure is very rapid at first and then continues at a gradually diminishing rate until the normal static pressure of the water is reached. In any well that discharges by artesian pressure, this increase in pressure can be measured by means of a pressure gauge. The length of time required for complete recovery of the pressure will vary according to the permeability of the aquifier and the length of time the well has been yielding water. In some flowing wells the static pressure appears to be reached almost immediately after the well is closed; in others it may require several hours or days. Repeated measurements made in flowing wells after the flow has been shut off indicate that in wells drawing water from the Dakota sandstone recovery is relatively rapid."[5]

Atmospheric Pressure

A difference in pressure and water level that is due to atmospheric pressure can be seen. A noted change in water level occurs during winter and summer. During winter months the atmospheric pressure is higher, causing an increased pressure of the flowing wells. In the summer, the atmospheric pressure is lower causing a decreased pressure of flowing wells.

GENERAL GROUND WATER CONDITIONS

In this area there are three main artesian aquifiers. In the order of their depth, they are Codell, Dakota, and Lakota formations. These artesian aquifiers crop out in wide zones encircling the Black Hills uplift and have a steep outward dip that, within short distances, carries them far beneath the adjoining plains where they are buried under a thick body of impermeable shales and clays.

In the outcrop zones of the Black Hills, the sandstones receive water, part of which comes from rainfall and part from streams that flow across the outcrops. The Dakota may receive in part some head from the Sioux quartzite ridge. In general, the direction of movement of this water is outward from the Black Hills eastward across the state. It is believed that part of the supply of water from the Dakota and Lakota formations is connate, or water that remained in the formations after the deposition of overlying sediments. The accompanying maps show the approximate heads of the artesian water in the Dakota and Lakota formations in 1952 in the area covered by this report. The contour lines show the piezometric surface of the Dakota and Lakota formations. The head or piezometric level is the surface to which the water will rise in wells that tap these horizons. The movement of the artesian water is always in the direction that the piezometric surface slopes, from higher to lower levels.

ARTESIAN WATER IN THE CODELL MEMBER OF THE CARLILE FORMATION

Piezometric Surface of Codell

In the previous report,[12] it was mentioned that the Codell receives its head and source of water supply from the Sioux quartzite ridge. The Codell may receive some head from the quartzite ridge, but it may also receive a head from the elevated region of the Rocky Mountains in Colorado and the Black Hills region. According to Baker, the Codell is present in the form of a siltstone in the Marigold-Dunn well located in the NE$\frac{1}{4}$, Sec. 22, T. 1 N., R. 9 E., in Pennington County. This is good evidence that the Codell probably outcrops around the Black Hills. The Codell member can be traced from the type locality in Colorado through northwestern Nebraska, southern and eastern South Dakota.

It is fed also by the Missouri and James Rivers. At Fort Randall it is known that the Codell comes close underneath the base of the dam. Water probably seeps through cracks of the Niobrara and supplies water to the Codell sloping east. In Davison County the Codell outcrops several places along the James River and Firesteel Creek to receive more replenishment.

The number of flows from this formation are very few. Along the Missouri River and some of the larger creeks the Codell may flow. A flowing well located in Sec. 3, T. 102 N., R. 72 W., reported a depth of 200 feet to the flow. This well has very little pressure which indicated that it might come from the Codell. It was reported that this well contained some gas.

Quality of the Water in the Codell Member

The Codell, known as the "tubular horizon", is an important supply for pumped wells. It varies in different areas from soft to hard water. In the eastern part of Aurora County and the western part of Davison County, the water coming from the Codell is soft. In western Aurora County, the water coming from the Codell grades from soft to hard. Codell water is usually high in soda content which is not too desirable in some places. If a heavy clay or gumbo soil is saturated with Codell water a white alkali will be precipitated on the surface.

ARTESIAN WATER IN THE DAKOTA FORMATION

Piezometric Surface of the Dakota Formation

The location and numbers of all artesian wells for which information was collected are shown on the accompanying map and table.

From the contours on the map, the general slope of the piezometric surface is from west to east. The steepest gradient of the water level, which is 12 feet per mile, occurs in the eastern part of Jerauld and Aurora Counties. The piezometric surface becomes more level near the James River and rises again to 1400 feet above sea level in the northern part of Lake County.

The short contour lines in the eastern part of the area represent the limit of the Dakota formation which is "pinched out" by the Sioux quartzite ridge.

Decline in Head of the Dakota Formation

The greatest decline of head occurs near the Missouri River where more wild wells are located. Comparing the present survey to Darton's survey in 1908, the head has decreased as much as 200 feet in Buffalo and Brule Counties. Table No. 1 shows a rough comparison of Darton's survey in 1908 to the present survey in 1952. The greatest decline appeared in T. 102 N., R. 65 W., where a difference of 261 feet was recorded.

The following map, Table No. 1, compares Darton's piezometric head to the present piezometric head. To estimate roughly the difference in head, the present contour lines can be subtracted from Darton's contour lines.

Todd,[4a] as early as 1898, recommended that "a careful record be kept of the pressure in various artesian wells throughout the state." In 1916, H. M. Derr, State Engineer, made a report to the Governor on artesian conditions of the state. During the drouth, funds were appropriated in cooperation with the United States Geological Survey to investigate artesian conditions in west-central South Dakota. This work was done by E. P. Rothrock and T. W. Robinson, Jr.

During the past few years plenty of moisture has fulfilled the demands of water for many people, but when another drouth occurs, the underground water system will be drained more than ever.

Quality of the Water in the Dakota Formation

Two different kinds of water coming from the Dakota are present in the area of the following counties: the western part of Jerauld County, northeastern Aurora County, northern

Davison County, Sanborn County, northern Miner County, and northern Lake County. In this area, the soft water comes from the upper stratum of the Dakota. Under these conditions it is hard to explain the occurrence of soft water at the top of the formation.

"The water supplies from different parts of the Dakota formation differ greatly in their chemical character--that is, in the kinds and amounts of mineral matter that they hold in solution. They differ from place to place and in successive strata in the same place. In general, in North Dakota, South Dakota, and Minnesota the soft water occurs in the upper part and the hard water in the lower part of the Dakota sandstone."[5]

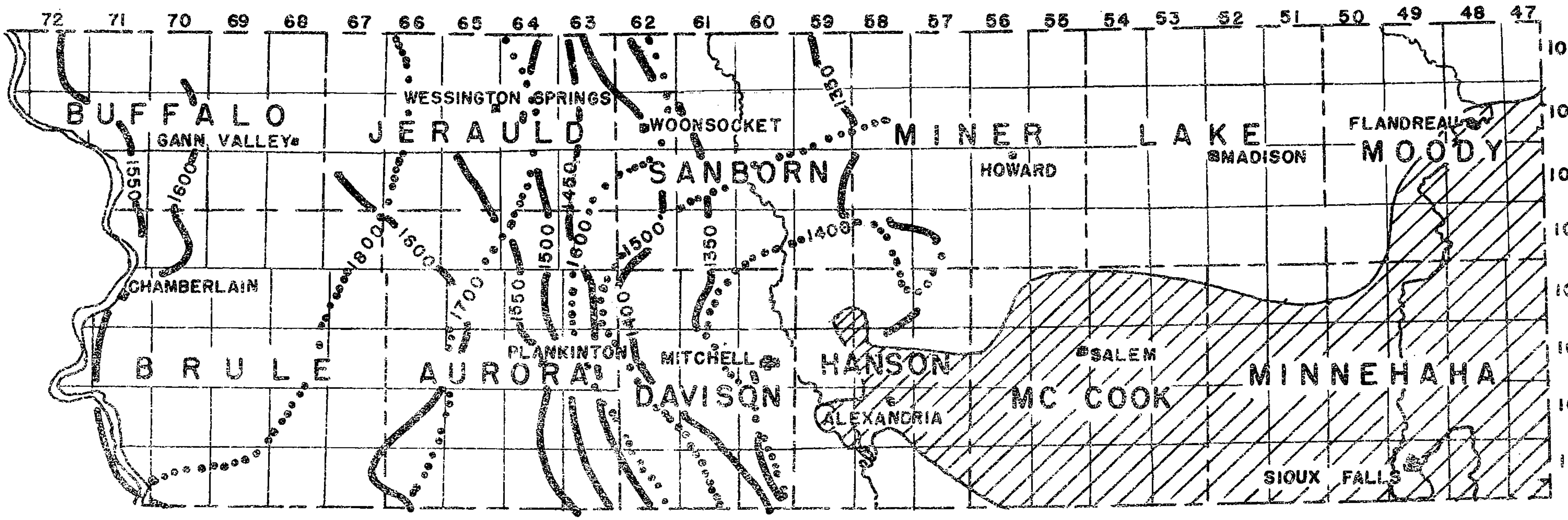
Samples of water collected from wells drilled to the Dakota and Lakota formations were analyzed by the State Chemical Laboratory.

A distinction can be made of the upper soft water horizon and lower hard water horizons of the Dakota. Table No. 3 shows a comparison of the different chemical constituents in the representative wells over the area.

The soft water is low in calcium and magnesium and high in sulfate material. The hard water is high in calcium, magnesium, and sulfate material.

"During the past few years it was found that too much fluoride in the water will cause mottling of the teeth in children under nine years. The maximum safety limit has been placed at about one part per million. Fluoride may be successfully removed from hard waters in the lime-soda softening process, and if water contains considerable magnesium, the cost need be only slightly more than for softening alone. The presence of magnesium seems to be essential according to present knowledge of the reactions. Soft artesian waters, having objectionable amounts of fluoride, have not been economically treated."[8]

A number of the wells that were analyzed during the course of investigation showed an objectionable amount of fluoride. The largest fluoride content was found to be 4.5 parts per million in a well located in the SW$\frac{1}{4}$, Sec. 4,



EXPLANATION

1700 Piezometric Head Surveyed by Darton in 1908

1600 Piezometric Head Surveyed in 1952

Sioux Quartzite Exposed or near Surface

COMPARISON OF DARTON'S SURVEY IN 1908 TO PRESENT SURVEY IN 1952

Location	DARTON'S SURVEY Depth (ft)	DARTON'S SURVEY Head (ft)	PRESENT SURVEY Depth (ft)	PRESENT SURVEY Head (ft)	Decline Since 1908
Brule County					
T101N-R67W	750-950	46-96	900	-30	76-126
T101N-R68W	815-960	27-57	885	-45	70-100
T102N-R67W	750-888	72	900	-18	110
T102N-R68W	800-1050	23	900	-70	93
T102N-R69W	900	92	860	-65	157
T102N-R70W	1000	92	870	-55	147
T105N-R68W	930	172	890	23	149
Jerauld County					
T106N-R63W	715-760	253	740	80	173
T106N-R64W	735-880	262	960	69	193
Aurora County					
T102N-R65W	850	126	900	-135	261
T102N-R64W	800	179	840	-50	229
T103N-R66W	863	80	888	69	11
T104N-R63W	523	80	----	46	34
Sanborn County					
T105N-R60W	360-630	80	540	27	53
T105N-R61W	348-670	184	843	69	115

T. 107 N., R. 64 W., Jerauld County. A majority of the wells contain 3 parts per million of fluoride which is over the safety limit.

Temperature of the Artesian Water in the Dakota Formation

In general, the temperature of the artesian water increases toward the western part of the area. The temperature ranges from 55° F. in Miner County to 79° F. in Buffalo County.

In Charles Mix County[4], at a well located in Sec. 16, T. 100 N., R. 71 W., a temperature of 90° F. was recorded. A careful check was made in Brule County to see if water at that temperature could be traced further north. In Gregory County, joining Charles Mix County to the west, some temperatures vary from 90° F. to 120° F. The temperatures of wells in Charles Mix and Gregory Counties indicate the edge of the hot water belt that extends northwest through Kadoka because of the corresponding temperatures recorded in various wells through that area.

ARTESIAN WATER IN THE LAKOTA FORMATION

Piezometric Surface of the Lakota Formation

The piezometric surface or water level of the Lakota formation is shown by contours on the accompanying map. From a general height of 1700 feet above sea level, located mainly in Buffalo County, the surface slopes toward the east. In the northern part of the area, mainly in Miner, Sanborn, and Jerauld Counties, the Lakota is controlled by the Sioux Ridge with the slope from north to south.

Decline in Head in the Lakota Formation

Inaccurate records in the past failed to separate the pressures of the Dakota and Lakota formations. It is difficult, therefore, to determine how far the water head in the Lakota has fallen. Darton's report[1] showed that a general high of 1800 feet above sea level existed in Buffalo, the western part of Jerauld, and most of Brule Counties. Probably some of the pressures from various wells in the area taken at that time came from the Lakota and, if this is true, the water level has dropped 100 feet or more.

Quality of Water in the Lakota Formation

In this area, the Lakota water does not differ much in chemical constituents and quality from Dakota water. The only difference is that in the area where the upper part of the Dakota produces soft water, there is a higher content of $CaCO_3$ in the Lakota. Taking an average of four Lakota waters and nine Dakota waters, it was found that the Lakota is slightly higher in most of the chemical constituents than the Dakota. (See the following averages of the Dakota and Lakota analyses).

AVERAGE OF LAKOTA ANALYSES

Total Solids	2209.5	ppm
Chlorides	110.5	"
Sulfates	1262.5	"
Silica	28.7	"
Calcium	326	"
Magnesium	81.5	"
Alkalinity		
Phenolphthalein	6.2	"
Methyl Orange	109	"
Total Hardness as $CaCO_3$	1148	"
Iron	33	"
Fluoride	2.7	"

AVERAGE OF DAKOTA ANALYSES

Total Solids	2175.7	ppm
Chlorides	94.2	"
Sulfates	1238	"
Silica	12.3	"
Calcium	251.7	"
Magnesium	62.8	"
Alkalinity		
Phenolphthalein	12.7	"
Methyl Orange	132.2	"
Total Hardness as $CaCO_3$	883.2	"
Iron	5.3	"
Fluoride	2.2	"

Temperature of Water in the Lakota Formation

The temperature of the water coming from the Lakota varies from 56° F. in Sanborn County to 72° F. in Buffalo County. In the rest of the area discussed here, a distinction of temperature change cannot be made between the Dakota and Lakota waters. The condition of temperature increase from east to west described for Dakota waters is the same for both formations.

WATER WASTAGE

Defective well construction and casing corrosion are the chief causes for underground leakage of wells. In some cases there has been a tendency to drill the hole too big for the casing. If the casing does not fit against the walls of the hole tightly, water will flow on the outside of the pipe to the surface or into other reservoirs.

Corrosion of metal casing is the biggest factor resulting in leakage and varies with the amount of corrosive constituents found in the water from one area to another. The principal cause of corrosion is an electro-chemical process, in which charged mineral particles tend to react on the iron of the casing. This is especially true where large pressures and flows tend to accelerate this reaction.

Copper casing or brass lined casing wears much longer because these metals are more resistant to chemical action. Plastic casing which is resistant to chemical action has been tested recently in some wells. Casing lined with cement is also resistant to chemical action.

DEVELOPMENT OF A WELL

The art of developing a suitable well sometimes is one of the main difficulties faced by a well driller. If the water-bearing sand is too fine and loose, the well has to be properly packed with gravel in order to eliminate trouble of pumping or flowing sand with the water. In flowing wells, where there is a considerable amount of flowing sand with the water, there is a chance for the well to clog shut. Sometimes it is hard for a driller to determine where to perforate the casing. In this area the Dakota is separated by clay layers in variable thicknesses. If the casing is perforated at the contact of the clay layers, a great amount of clay will come with the water. A well flowing in this condition may cave in and clog shut in a short time.

The well drillers can gain valuable information on the thickness and contacts of strata from an electric log. The log records exactly at what depths the different sand, chalk, limestone, and clay layers appear. With this data the driller knows where to perforate the casing or to place screens in a well.

WILD WELLS

In this area there are a few "wild wells" which flow unrestricted the year around. For all practical purposes these wells are too large for beneficial use, and some of them are not used at all.

The largest flows occur near the Missouri River which is the area of greatest decline in head, because many wells have been allowed to flow tremendous volumes for many years. The largest well flowing at the present time is located at Red Lake where it helps supply the lake. Undoubtedly this well has helped to decrease the water level in an area surrounding the lake.

DETERMINATION OF HEAD AT PROPOSED WELL SITES

The altitude to which the water from the Dakota and Lakota formations may be expected to rise is shown on the following map by contours of piezometric surface. This information can be very helpful to the farmer and well driller in the area where the proposed well is to be drilled. The depth at which the water will stand in a non-flowing well may be estimated by subtracting the altitude of the piezometric surface from the altitude of the land surface at the proposed site.

The piezometric map may deviate somewhat from the actual pressure or the level to which the water will rise, especially in localities far from wells on which measurements of head were obtained, because interpolation cannot always be exact. It should be remembered that the accompanying map represents the piezometric surface as it was in 1952. Therefore, forecasts made after a few years will have some error until the lowering of pressure through water wastes which have been described can be controlled.

TABLE NO. 3

ANALYSES OF WATER FROM WELLS IN THE AREA SURROUNDING THE SIOUX QUARTZITE RIDGE from State Geological Survey Files

County-Jerauld
Location-SW¼, Sec. 4, T. 107N, R. 64W
Owner-Maynard Shyrock
Date-9/12/52 Depth-841'

	Parts Per Million
Total Solids	2076
Chlorides (Cl)	65
Sulfates (SO_4)	1217
Silica (SiO_2)	31
Calcium	257
Magnesium (Mg)	68
Alkalinity	
Phenolphthalein	None
Methyl Orange	144
Total Hardness as $CaCO_3$	894
Iron (Fe)	0.7
Manganese (Mn)	None
Fluoride (F)	4.5

County-Jerauld
Location-SW¼, Sec. 2, T. 108N, R. 64W
Owner-Melvin Neumeyer
Date-9/12/52 Depth-921'

Total Solids	2132
Chlorides (Cl)	91
Sulfates (SO_4)	1245
Silica (SiO_2)	19
Calcium (Ca)	143
Magnesium (Mg)	48
Alkalinity	
Phenolphthalein	None
Methyl Orange	106
Total Hardness as $CaCO_3$	554
Iron (Fe)	2
Manganese (Mn)	None
Fluoride (F)	2.5

County-Jerauld
Location-SW$\frac{1}{4}$, Sec. 25, T. 108N, R. 62W
Owner-James Linefeller
Date-9/12/52 Depth-875'

	Parts Per Million
Total Solids	2131
Chlorides (Cl)	82
Sulfates (SO_4)	1252
Silica (SiO_2)	13
Calcium (Ca)	17
Magnesium (Mg)	5
Alkalinity	
Phenolphthalein	None
Methyl Orange	144
Total Hardness as $CaCO_3$	63
Iron (Fe)	None
Manganese (Mn)	None
Fluoride (F)	1.5

County-Buffalo
Location-North Well, NW$\frac{1}{4}$, Sec. 30, T. 107N, R. 71W
Owner-L. P. Christenson
Date-9/12/52 Depth-575'

Total Solids	3962
Chlorides (Cl)	2057
Sulfates (SO_4)	101
Silica (SiO_2)	15
Calcium (Ca)	48
Magnesium (Mg)	25
Alkalinity	
Phenolphthalein	16
Methyl Orange	312
Total Hardness as $CaCO_3$	223
Iron (Fe)	14
Manganese (Mn)	None
Fluoride (F)	1

County-Buffalo
Location-SW$\frac{1}{4}$, Sec. 22, T. 107N, R. 72W
Owner-W.O.Peck, Gov't Farm
Date-9/12/52 Depth-1350'

Total Solids	2191
Chlorides (Cl)	97
Sulfate (SO_4)	1248
Silica (SiO_2)	28
Calcium (Ca)	372

Magnesium (Mg)	88
Alkalinity	
Phenolphthalein	5
Methyl Orange	136
Total Hardness as $CaCO_3$	1290
Iron (Fe)	0.6
Manganese (Mn)	None
Fluoride (F)	3

County-Buffalo
Location-NE¼, Sec. 36, T. 108N, R. 72W
Owner-Knippling Brothers
Date-9/12/52 Depth-1150'

	Parts Per Million
Total Solids	2173
Chlorides (Cl)	105
Sulfates (SO_4)	1298
Silica (SiO_2)	15
Calcium (Ca)	416
Magnesium (Mg)	97
Alkalinity	
Phenolphthalein	None
Methyl Orange	140
Total Hardness as $CaCO_3$	1437
Iron (Fe)	1
Manganese (Mn)	None
Fluoride (F)	3

County-Buffalo
Location-South Well, NW¼, Sec. 30, T. 107N, R. 71W
Owner-L. P. Christenson
Date-9/12/52 Depth-775'

Total Solids	2006
Chlorides (Cl)	92
Sulfates (SO_4)	1115
Silica (SiO_2)	19
Calcium (Ca)	243
Magnesium (Mg)	59
Alkalinity	
Phenolphthalein	17
Methyl Orange	146
Total Hardness as $CaCO_3$	849
Iron (Fe)	38
Manganese (Mn)	None
Fluoride (F)	3

County-Miner
Location-NW$\frac{1}{4}$, Sec. 19, T. 105N, R. 5
Owner-Lloyd Schave
Date-9/12/52 Depth-365'

	Parts Per Million
Total Solids	2246
Chlorides (Cl)	140
Sulfate (SO_4)	1224
Silica (SiO_2)	10
Calcium (Ca)	288
Magnesium (Mg)	74
Alkalinity	
Phenolphthalein	20
Methyl Orange	116
Total Hardness ($CaCO_3$)	1023
Iron (Fe)	0.5
Manganese (Mn)	None
Fluoride (F)	2

County-Sanborn
Location-SW$\frac{1}{4}$, Sec. 6, T. 108N, R. 62W
Owner-C.C. Jensen
Date-9/12/52 Depth-1200'

Total Solids	2201
Chlorides (Cl)	104
Sulfates (SO_4)	1249
Silica (SiO_2)	6
Calcium (Ca)	241
Magnesium (Mg)	69
Alkalinity	
Phenolphthalein	20
Methyl Orange	132
Total Hardness as $CaCO_3$	885
Iron (Fe)	1.4
Manganese (Mn)	None
Fluoride (F)	2

County-Sanborn
Location-SW$\frac{1}{4}$, Sec. 27, T. 108N, R. 61W
Owner-Mrs. Loring
Date-9/12/52 Depth-950'

Total Solids	2273
Chlorides (Cl)	136
Sulfate (SO_4)	1255
Silica (SiO_2)	66
Calcium (Ca)	275
Magnesium (Mg)	72

Alkalinity	
Phenolphthalein	None
Methyl Orange	129
Total Hardness as $CaCO_3$	982
Iron (Fe)	130
Manganese (Mn)	None
Fluoride (F)	3
Sodium & Potassium	216

County-Sanborn
Location-NW$\frac{1}{4}$, Sec. 1, T. 106N, R. 61W
Owner-Forestburg Well
Date-9/12/52 Depth-705'

	Parts Per Million
Total Solids	2082
Chlorides (Cl)	72
Sulfate (SO_4)	1222
Silica (SiO_2)	7
Calcium (Ca)	167
Magnesium (Mg)	49
Alkalinity	
Phenolphthalein	11
Methyl Orange	126
Total Hardness as $CaCO_3$	618
Iron (Fe)	0.4
Manganese (Mn)	None
Fluoride (F)	1

County-Aurora
Location-SW$\frac{1}{4}$, Sec. 25, T. 105N, R. 64W
Owner-Warren Larson
Date-9/12/52 Depth-750'

Total Solids	2181
Chlorides (Cl)	72
Sulfate (SO_4)	1249
Silica (SiO_2)	3
Calcium (Ca)	341
Magnesium (Mg)	82
Alkalinity	
Phenolphthalein	36
Methyl Orange	139
Total Hardness as $CaCO_3$	1188
Iron (Fe)	None
Manganese (Mn)	0.3
Fluoride	3

County-Aurora
Location-NW¼, Sec. 28, T. 104N, R. 63W
Date-9/12/52
Hoefort No. 1 Oil Test — Depth-1082'

	Parts Per Million
Total Solids	2385
Chlorides (Cl)	122
Sulfate (SO_4)	1319
Silica (SiO_2)	4
Calcium (Ca)	396
Magnesium (Mg)	88
Alkalinity	
Phenolphthalein	18
Methyl Orange	132
Total Hardness	1350
Iron (Fe)	4.6
Manganese (Mn)	0.4
Fluoride (F)	3

County-Aurora
Location-NW¼, Sec. 22, T. 103N, R. 65W
Owner-Robert Maine
Date-9/12/52 — Depth-320'

Total Solids	1671
Chlorides (Cl)	131
Sulfate (SO_4)	1049
Silica (SiO_2)	6
Calcium (Ca)	22
Magnesium (Mg)	8
Alkalinity	
Phenolphthalein	45
Methyl Orange	446
Total Hardness as $CaCO_3$	88
Iron (Fe)	1
Manganese (Mn)	None
Fluoride (F)	2

County-Aurora
Location-SW¼, Sec. 5, T. 102N, R. 66W
Owner-Ted Gillon
Date-9/12/52 — Depth-810'

Total Solids	2343
Chlorides (Cl)	112
Sulfate (SO_4)	1299
Silica (SiO_2)	5
Calcium (Ca)	414
Magnesium(Mg)	93

Alkalinity	
Phenolphthalein	13
Methyl Orange	137
Total Hardness as $CaCO_3$	1416
Iron (Fe)	1.7
Manganese (Mn)	None
Fluoride (F)	3

TABLE NO. 5

LOGS OF WELLS IN AREA SURROUNDING THE SIOUX QUARTZITE RIDGE

Brule County

NW$\frac{1}{4}$, Sec. 14, T. 103N, R. 71W..................Biskeborn Well
Altitude........1682 feet

	Feet
Glacial drift................	0-55
Pierre clay..................	55-280
Niobrara chalk...............	280-420
Carlile marl.................	420-476
Codell sand..................	476-605
Greenhorn limestone..........	605-665
Graneros clay................	665-815
Dakota sandstone and clays...	815-1335
Fuson clay...................	1335-1359
Sioux quartzite..............	1359-1400

Electric log by Bruno Petsch — Driller-Carl Meier
SE$\frac{1}{4}$, Sec. 3, T. 102N, R. 68W..............Carl Eckstum Well
Altitude........1685 feet

Casing set...................	0-342
Niobrara chalk...............	342-460
Carlile clay.................	460-670
Greenhorn limestone..........	670-710
Graneros clay................	710-890
Dakota sandstone and clay....	890-940

Electric log by Bruno Petsch — Driller-Jake Deisch
SW$\frac{1}{4}$, Sec. 8, T. 102N, R. 67W................F. H. Olson Well
Altitude........1637 feet

Casing set...................	0-380
Codell sand..................	380-392
Carlile clay.................	392-487
Greenhorn limestone..........	487-518
Graneros clay with streaks of sand..........	518-732
Dakota sandstone with clay streaks..........	732-865

Electric log by Bruno Petsch Driller-Carl Meier
SE$\frac{1}{4}$, Sec. 10, T. 105N, R. 67W......................Gould Farm
Altitude........1699 feet

	Feet
Glacial drift................	0-90
Pierre clay...................	90-350
Niobrara chalk...............	350-500
Carlile clay.................	500-646
Greenhorn limestone..........	646-740
Graneros clay................	740-905
Dakota sandstone.............	905-945

Buffalo County

Electric log by Bruno Petsch Driller-Carl Meier
NE$\frac{1}{4}$, Sec. 36, T. 108N, R. 72W................Knippling Ranch
Altitude........1633 feet

Casing set...................	0-390
Niobrara chalk...............	390-438
Carlile clay.................	438-650
Greenhorn limestone..........	650-740
Graneros clay and sandstone streaks.........	740-1035
Dakota sandstone and clay streaks..............	1035-1115
Fuson clay, Mn. pellets......	1115-1130
Lakota sandstone.............	1130-1154

Aurora County

Electric log by Bruno Driller-Carl Meier
Se$\frac{1}{4}$, Sec. 24, T. 105N, R. 66W....................Knigge Farm
Altitude........1614 feet

Casing set...................	0-290
Pierre clay..................	290-378
Niobrara chalk...............	378-480
Carlile clay.................	480-630
Greenhorn limestone..........	630-670
Graneros clay................	670-782
Newcastle sandstone ?........	782-798
Graneros clay................	798-908
Dakota sandstone and clay..................	908-957

Jerauld County

Electric log by Bruno Petsch Driller-Huron Drilling Co.
SE$\frac{1}{4}$, Sec. 3, T. 108N, R. 64W................Melvin Newmeyer
Altitude........1420 feet

	Feet
Glacial drift.................	0-60
Pierre clay..................	60-275
Niobrara chalk...............	275-440
Carlile clay.................	440-618
Greenhorn limestone..........	618-650
Graneros clay................	650-822
Dakota sandstone and clays.................	822-921

Sanborn County

Electric log by Bruno Petsch Driller-Kuborn Drilling Co.
SE$\frac{1}{4}$, Sec. 27, T. 108N, R. 61W..................Loring Farm
Altitude........1322 feet

Casing set....................	0-175
Niobrara chalk...............	175-235
Carlile clay and sand streaks..............	235-438
Greenhorn limestone..........	438-468
Graneros clay................	468-895
Dakota sandstone.............	895-950

Miner County

Electric log by Bruno Petsch Driller-Kuborn Drilling Co.
NW$\frac{1}{4}$, Sec. 19, T. 105N, R. 58W....................Shave Farm
Altitude........1308 feet

Glacial drift................	0-148
Carlile clay ?...............	148-234
Greenhorn limestone..........	234-247
Graneros clay................	247-270
Dakota sandstone and clays.................	270-350
Pink sandstone...............	350-365
Sioux quartzite..............	365----

Lake County

Electric log by Bruno Petsch Driller-Huron Drilling Co.
SW$\frac{1}{4}$, Sec. 15, T. 108N, R. 54W..................Carmody Farm

Altitude........1774 feet

	Feet
Glacial drift..................	0-80
Pierre clay....................	80-195
Niobrara chalk.................	195-248
Carlile clay...................	248-320
Greenhorn limestone............	320-345
Graneros clay..................	345-570
Dakota sandstone...............	570-682
Fuson clay.....................	682-702
Lakota sandstone...............	702-760

No.	Owner & Location	Date Drilled	Depth (ft)	M. P. Alt.*	Pressure (lbs)	Piez. Head	Rate Discharge Gal/Min
	Buffalo County						
188	E. A. Harris NE¼ S27-T106N-R69W	1947	960	1591	App. 50	1655	3
189	Leland Larson SE¼ S18-T106N-R70W		App. 950	1556	7	1572	6
190	Robert Krog SW¼ S8-T107N-R69W	1946	937	1603	2	1608	2
191	Knippling Brothers NE¼ S9-T107N-R70W	1949	1310	1681	None	1681	None
192	F. B. Cable SW¼ S30-T107N-R70W	1942	840	1465	40	1557	12
193	Les Christenson NW¼ S30-T107N-R71W	1947	575	1365	1	1367	1.6
194	Les Christenson NW¼ S30-T107N-R71W	1947	775	1350	App. 70	1511	90
195	Robert Stewart SW¼ S9-T107N-R72W	1949	App. 750	1466	30	1535	2.7
196	L. P. Christenson SE¼ S11-T107N-R72W	1948	975	1482	App. 30	1551	100
197	U. S. Gov't. Well SW¼ S22-T107N-R72W	1942	1350	1370	App. 200	1508	150
198	Hat Ranch - Knippling Bros. SE¼ S15-T108N-R71W	1948	1220	1703	10	1726	85
199	Bert Thompson SW¼ S3-T108N-R72W	1944	1271	1729	App. 4	1739	5
200	Geppert Estate NW¼ S8-T108N-R72W	New well	1300	1722	22	1773	20
201	L. E. Anderson SE¼ S10-T108N-R69W	1916	1280	1839		1605	
202	Willis Venekamp SE¼ S23-T108N-R72W		App. 1200	1728	8	1746	4.9
203	Robert Knippling SE¼ S24-T108N-R72W	1950	1050	1591	8	1609	3

No.	Owner & Location	Date Drilled	Depth (ft)	M. P. Alt.*	Pressure (lbs)	Piez. Head	Rate Discharge Gal/Min
204	Russel Kinsen SE¼ S31-T108N-R72W	Old well	App. 1000	1452	18	1493	8
205	Knippling Bros. NE¼ S36-T108N-R72W	1952	1150	1633	10	1656	25
	Brule County						
206	Jake Backus NW¼ S11-T101N-R67W	1940	1000	1631		1611	
207	Brumbaugh NE¼ S24-T101N-R67W	1909	821	1610		1603	
208	Karl Straub SW¼ S27-T101N-R67W	1928	900	1624		1594	
209	John Paulson SW¼ S1-T101N-R68W	App. 1922	App. 950	1664		1614	
210	Robert Novak NW¼ S21-T101N-R68W		800	1671		1626	
211	John Vasicka NW¼ S35-T101N-R68W	1942	885	1630		1595	
212	Joe Brtna SE¼ S25-T101N-R69W		950	1718		1671	
213	S. C. Kiehn SW¼ S17-T101N-R70W	1917	1160	1924		1664	
214	Gus Kiehn SE¼ S18-T101N-R70W	1948	716	1555			20
215	Joe M'lady NE¼ S23-T101N-R70W	1927	1040	1856		1656	
216	Carl Olson SE¼ S24-T101N-R71W	1944		1320	5	1332	20
217	Fred Olson SE¼ S8-T102N-R67W	1952	900	1644		1626	
218	John Chmella SE¼ S15-T102N-R68W	App. 1912	900	1704		1640	
219	Township Well NE¼ S16-T102N-R68W			1743		1633	

No.	Owner & Location	Date Drilled	Depth (ft)	M. P. Alt.*	Pres-sure (lbs)	Piez. Head	Rate Discharge Gal/Min
220	Ed Pospichal SE¼ S13-T102N-R69W	1924	860	1700		1635	
221	W. G. Andera SE¼ S2-T102N-R70W	1918	826	1691		1685	
222	Frank Hrabe SE¼ S25-T102N-R70W	1929	929	1710		1656	
223	George Boyer #1 NW¼ S5-T102N-R71W	Before 1930	750	1375			60
224	George Boyer #2 NW¼ S6-T102N-R71W	1940	780	1395			
225	Ivan Eastmen NW¼ S12-T102N-R71W	1907	1118	1760		1760	
226	Wyman Randal SE¼ S14-T102N-R71W	1947	1090	1737		1656	
227	Alton Creamer NE¼ S2-T102N-R72W	Before 1930	775	1390			
228	Al Urban SW¼ S13-T103N-R68W	1913	960	1753		1620	
229	Pierce Bros. SE¼ S27-T103N-R68W	1930	960	1722		1656	
230	Charlie Helma NE¼ S26-T103N-R69W		960?	1715		1628	
231	Lou Kaufmen NW¼ S28-T103N-R70W	1907	956	1616	8	1634	12.1
232	Ronald Feltman NW¼ S32-T103N-R71W	App. 1922	970	1652		1627	
233	Art Martin NW¼ S13-T103N-R71W	1950	App. 1000	1630	2	1634	3.7
234	Lake Brothers SW¼ S9-T104N-R69W	1915	860	1589	15	1624	4.6
235	Garnet Ashley NE¼ S15-T104N-R69W	1915	Over 800	1611	None	1611	1
236	Lake Brothers NE¼ S17-T104N-R69W	1921	App. 850	1591	18	1632	3

No.	Owner & Location	Date Drilled	Depth (ft)	M. P. Alt.*	Pressure (lbs)	Piez. Head	Rate Discharge Gal/Min
237	G. T. Purcell SW¼ S26-T104N-R69W	1943	856	1626	None	1626	
238	Kenneth Sabin NE¼ S17-T104N-R70W	Old well	App. 900	1583	11	1608	1.8
239	Iden B. Meyer SE¼ S28-T104N-R70W	1950	1030	1624	None	1619	
240	John Glaus NE¼ S32-T104N-R71W	1940	900	1743		1683	
241	Raymond Young SE¼ S8-T105N-R67W	1950	980	1615		1614	
242	Clarence Viereck NW¼ S7-T105N-R68W	1913	App. 900	1600	16.5	1639	4
243	[illegible]n Heath SE¼ S31-T105N-R68W	1940	840	1626	10	1648	5.8
244	Kenneth Berchan SW¼ S33-T105N-R68W	1941	890	1614	10	1637	5.8
245	Ike Sorenson SW¼ S15-T105N-R69W	Old well	App. 1000	1580	33	1656	8.3
246	Warren Dusseau NW¼ S13-T105N-R70E	1949	1108	1635	30	1704	30
247	Everett Duval NE¼ S13-T105N-R70W	1949	1033	1621	25	1679	50
248	Virgil Rose SW¼ S10-T105N-R71W	1947	900	1447			130
249	Kenney Dusal SE¼ S11-T105N-R71W	1950		1474	App. 40	1566	10
250	Eldon Shive SE¼ S14-T105N-R71W	1950		1430	50	1545	12
	Jerauld County						
251	Murshitz SE¼ S24-T108N-R65W			1490	16	1527	2
252	Melvin Neumeyer SE¼ S3-T108N-R64W	1952	921		40		8.5

No.	Owner & Location	Date Drilled	Depth (ft)	M. P. Alt.*	Pressure (lbs)	Piez. Head**	Rate Discharge Gal/Min
253	Jake Heuther- Elbert Wenz-Renter SW¼ S13-T108N-R64W	1944	782	1394	40	1486	20
254	Otto Bathke SW¼ S21-T108N-R64W	1948	860	1452	30	1521	20
255	Edwin Bauer SE¼ S6-T108N-R63W	1920	800	1387	16	1425	1.3
256	John Ollinger SE¼ S34-T106N-R63W		740	1338	35	1418	6
257	Otto Krueger SW¼ S10-T106N-R64W	1951	961	1473	30	1482	12
258	Eldon Beckman NE¼ S29-T106N-R64W	1915	975	1552		1534	
259	Bernard Wills SW¼ S26-T106N-R67W	1939	1100	1670		1630	
260	M. A. Zinc NW¼ S7-T107N-R63W	1951	780	1387			
261	A. T. Weir NW¼ S24-T107N-R63W	1916	756	1344	40	1432	4
262	John Klemm SW¼ S31-T107N-R63W	1929	800	1372	40 or 60	1464	5
263	Nielson SW¼ S36-T107N-R63W	1942	680	1320	60	1412	7.8
264	Delbert Shyrock SW¼ S4-T107N-R64W		841	1495	14	1527	6
265	John Waybright SW¼ S10-T107N-R64W	1922	900	1463	9	1484	4
266	Lester W. Scheel NW¼SW¼ S29-T108N-R63E	1951	765	1371	40	1463	15
267	Skinner SW¼ S24-T108N-R63W	1926	600?	1321	20	1385	2.6
268	James Linefeller SW¼ S25-T108N-R63W	1907	875	1320			

No.	Owner & Location	Date Drilled	Depth (ft)	M. P. Alt.*	Pressure (lbs)	Piez. Head**	Rate Discharge Gal/Min
	Aurora County						
269	John Peters SW¼ S6-T101N-R66W	1944	840	1586		1561	
270	Peter Dockendorf NE¼ S29-T101N-R66W	1932	927	1578	10	1601	1.5
271	Donald Hanes NE¼ S1-T102N-R63W			1437		1437	
272	Phil Asmus SW¼ S32-T102N-R64W	1908	840	1600		1550	
273	Beckman NW¼ S17-T102N-R65W	1917	900	1644		1509	
274	Ted Gillon SE¼ S5-T102N-R66W	1951	810		45		50
275	Frank Ries NW¼ S35-T102N-R66W	1948	835	1621		1571	
276	Robert Maine NW¼ S35-T103N-R65W		900-1000	1589			
277	Claude Glisendorf SW¼ S19-T103N-R66W	1952	888	1605	30	1674	20
278	Harvey Johnson SE¼ S13-T104N-R63W		408	1373	7	1390	4
279	Oil Test NW¼ S28-T104N-R63W			1404	20 or more	1450	100
280	Dan Thayer NE¼ S10-T104N-R64W		540	1445	App. 2	1450	1.25
281	Harold Boyd SW¼ S24-T104N-R64W	1940		1468	10	1491	1.7
282	Carl Pfeifer SE¼ S34-T104N-R65W	1946	800	1584	5	1596	1.5
283	Henry Bisenius SW¼ S17-T104N-R66W	1952	825	1590	5	1607	6
284	T. Asbenson SW¼ S12-T105N-R63W	1948	App. 500	1361	7	1377	2

No.	Owner & Location	Date Drilled	Depth (ft)	M. P. Alt.*	Pressure (lbs)	Piez. Head**	Rate Discharge Gal/Min
285	Otto Schmidt SW¼ S18-T105N-R63W	1942	740	1414	App. 10 or 12		25
286	D. A. Spencer NE¼ S19-T105N-R64W	1952	875	1549	2	1554	1
287	Vernon Niles NW¼ S35-T105N-R65W	1939	870	1563	App. 10	1586	2
288	Morris Swenson NW¼ S24-T105N-R66W	1951	1000	1632		1592	
	Sanborn County						
289	Alexander-Rented from Johnson NW¼ S1-T105N-R59W	1952	475	1326	10	1349	6
290	Ben Kolp NE¼ S18-T105N-R59W	1950	590	1304	20	1368	15
291	E. H. Hewer SW¼ S18-T105N-R60W	1949	500	1316	9½	1338	5
292	Walligan-Mitchell SE¼ S20-T105N-R60W	1951		1310	15	1344	15
293	Vernon Amick SW¼ S6-T105N-R61W	1942	843	1320	30	1389	12
294	Forestburg Well Co. NW¼ S1-T106N-R61W	1952	705	1276	25	1333	77
295	Alec Vetter NE¼ S21-T106N-R62W	1940	580	1294	55	1420	50
296	Sam Floholm SE¼ S7-T107N-R59W	1945	App. 600	1300	5½	1313	1
297	William Ischen SW¼ S26-T107N-R59W		App. 720	1322	App. 5	1333	1.5
298	SW¼ S8-T107N-R60W	App. 1914	App. 700	1291	5	1302	3
299	Frank Ferguson S½ S34-T107N-R60W	1950	902	1281	25	1338	20
300	Robert Underbruner SW½ S5-T108N-R59W	1952	740	1317	10	1340	4

No.	Owner & Location	Date Drilled	Depth (ft)	M. P. Alt.*	Pres- sure (lbs)	Piez. Head**	Rate Discharge Gal/Min
301	Jerome Kemp SW¼ S35-T108N-R59W	1950	926	1333	30	1402	30
302	George Rhodes NW¼ S9-T108N-R60W	1951	965	1323	35	1403	90
303	Otto Brveske SE¼ S4-T108N-R61E	1949	720	1297	15	1332	4
304	Mrs. Loring SE¼ S27-T108N-R61W	1952	950	1322	35	1402	42.8
305	Loring SE¼ S27-T108N-R61W	App. 1902	750	1322	8	1340	.5
306	C. C. Jensen SW¼ S6-T108N-R62W	1948	1200	1300	50	1415	12
307	John Sims SE¼ S14-T108N-R62W	1952	750	1310	13	1339	6
	Miner County						
308	W. G. Henry NW¼ S31-T105N-R56W	1950	130	1388	App. 3	1394	10
309	Neal Oswald SW¼ S33-T105N-R56W	1952	96	1474			
310	Leonard Krouse W½ S7-T105N-R57W		207	1360	2	1362	.75
311	Ben Sieverding SW¼ S29-T105N-R57W	1902	400	1354		1336	
312	Nick Muller NW¼ S11-T105N-R58W	1944	606	1362	10	1385	10
313	Forrest Johnston NE¼ S12-T105N-R58W	1942	209	1352	10	1375	5
314	Lloyd Schave NW¼ S19-T105N-R58W	1952	365	1308	11	1333	5
315	George Kennedy SW¼ S23-T105N-R58W	1932	205	1318	1	1320	.20
316	James Hanson NE¼ S10-T106N-R57W	1917	519	1418		1397	

No.	Owner & Location	Date Drilled	Depth (ft)	M. P. Alt.*	Pressure (lbs)	Piez. Head**	Rate Discharge Gal/Min
317	William Neises NW¼ S34-T106N-R57W	1949	93	1387	1	1389	1.5
318	Ed Banks NW¼ S32-T106N-R58W	1940	600	1320	6	1334	3
319	C. O. Bamsey NW¼ S21-T107N-R56W	1910	530	1535		1405	
320	Melvin Windendahl NE¼ S9-T107N-R57W		456	1446		1436	
321	Dahms NE¼ S30-T107N-R57W	1951	407	1426		1376	
322	Seth Hall SE¼ S4-T107N-R58W	1908	App. 900	1384	3	1391	3
323	M. Thomas SE¼ S21-T107N-R58W			1380	3	1387	2
324	Ray Davids NW¼ S34-T107N-R58W	1951	370	1368	1	1369	2
325	A. R. Cross SW¼ S27-T108N-R56W	1922	609	1574		1538	
326	Carthage SW¼ S8-T108N-R57W	1949	1070	1440		1422	
327	Don Amsbury NE¼ S12-T108N-R57W	1906	1000	1548		1494	
328	A. J. Windendahl NE¼ S32-T108N-R57W	1936	450	1452		1402	
329	Russell Swanson NW¼ S18-T108N-R58W		App. 800	1368	3	1375	2
330	Fish Brothers NW¼ S24-T108N-R58W		App. 450	1356	10	1379	2.5
331	C. McGuire NW¼ S25-T108N-R58W	1948	806	1400	3	1411	2

Davison County

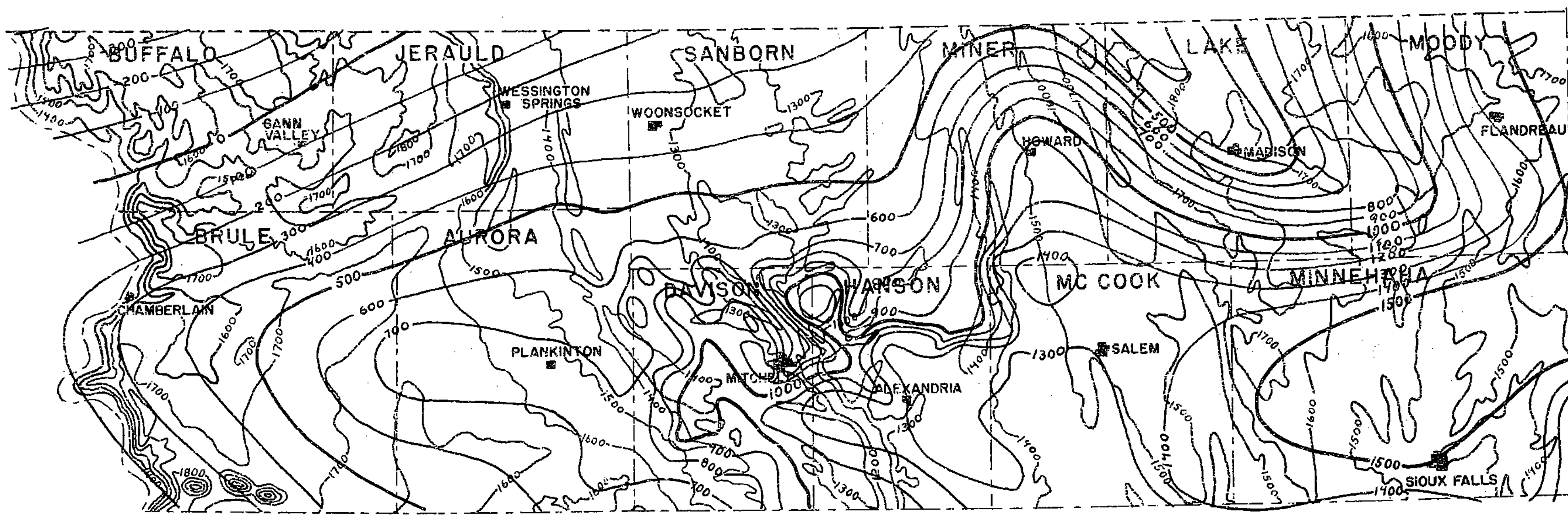
No.	Owner & Location	Date Drilled	Depth (ft)	M. P. Alt.*	Pressure (lbs)	Piez. Head**	Rate Discharge Gal/Min
332	Erpenbach SW¼ S1-T101N-R60W	1942	225	1326	2	1331	6

No.	Owner & Location	Date Drilled	Depth (ft)	M. P. Alt.*	Pressure (lbs)	Piez. Head**	Rate Discharge Gal/Min
333	Ross Henglefelt SW¼ S25-T101N-R60W	App. 1902	413	1372			
334	Will Schoenfelder NE¼ S21-T101N-R61W	1937		1441	App. 5-10	1446	4
335	Paulis SW¼ S30-T102N-R61W	1902		1300	App. 5	1312	10
336	Miller SW¼ S33-T102N-R61W	1948	334	1400	5	1412	10
337	Snyder SE¼ S34-T102N-R61W	1931	410	1390	App. 2	1394	.5
338	John Jorgenson NW¼ S9-T103N-R62W			1378	12	1406	4
339	Wallace Scott SW¼ S12-T103N-R62W	1940	390	1390	2	1395	2.5
340	Morrison Brothers SW¼ S15-T104N-R60W	1950	480	1305	1.5	1308	30
341	James Fraser SW¼ S3-T104N-R61W	1940	600	1312	20	1358	12
342	A. K. Koempke SW¼ S17-T104N-R61W	Recased in 1939	575	1338	9	1359	4
343	SW¼ S31-T104N-R61W			1370	7	1386	3
344	Burchfield SE¼ S34-T104N-R61W	1911	350	1323	1	1325	2
345	Lundgren SE¼ S16-T104N-R62W			1357	12	1385	3
	Hanson County						
346	George Heiman SE¼ S7-T101N-R59W	1947	300	1318	1.5	1322	3
347	Urban Weiland SW¼ S18-T101N-R59W	1948	270	1328		1328	
348	John E. Baxter SW¼ S27-T101N-R59W		285	1336		1266	

No.	Owner & Location	Date Drilled	Depth (ft)	M. P. Alt.*	Pressure (lbs)	Piez. Head**	Rate Discharge Gal/Min
349	Gardner SW$\frac{1}{4}$ S19-T103N-R58W		125	1400	1	1403	2.5
350	Norman Jorgenson SW$\frac{1}{4}$ S4-T103N-R59W	1945	158	1206	10	1229	6
351	Eugene Doering NW$\frac{1}{4}$SE$\frac{1}{4}$ S8-T103N-R59W	1952	194	1215	6	1228	2
352	Tom Green NW$\frac{1}{4}$ S18-T103N-R59W		320	1220	8	1238	6
353	Irving Eich NW$\frac{1}{4}$ S10-T104N-R57W		400	1364	1	1366	.5
354	Dissing NW$\frac{1}{4}$ S28-T104N-R57W	1950	312	1360		1245	
355	C. A. Moe SE$\frac{1}{4}$ S2-T104N-R58W	1948	470	1320	9	1341	30
356	Edgar Dewald SE$\frac{1}{4}$ S13-T104N-R58W	1944	565	1348	6	1362	2
357	Dale Nopens NE$\frac{1}{4}$ S23-T104N-R58W	1951	402	1350	1	1352	.20
358	Robert Heisinger NE$\frac{1}{4}$ S6-T104N-R59W	1952	100	1305	.5	1306	1.25
359	Ewing NW$\frac{1}{4}$ S19-T104N-R59W	1912	105	1315		1307	
360	Oscar Rongsted SE$\frac{1}{4}$ S24-T104N-R59W	1948	165	1280	1	1280	.5
	Lake County						
361	Ben Abraham NE$\frac{1}{4}$ S15-T107N-R54W	1902	744	1824		1544	
362	Raymond Carmody SW$\frac{1}{4}$ S15-T108N-R54W	1952	762	1774		1519	
363	Ole Dahl NE$\frac{1}{4}$ S27-T108N-R62W		734	1792		1512	
364	Floyd Kirsten SW$\frac{1}{4}$ S15-T108N-R53W		840	1767		1507	

No.	Owner & Location	Date Drilled	Depth (ft)	M. P. Alt.*	Pres-sure (lbs)	Piez. Head**	Rate Discharge Gal/Min
365	Fred Miller SW$\frac{1}{4}$ S15-T107N-R51W		626	1690		1440	
366	Leonard Crow SE$\frac{1}{4}$ S16-T107N-R52W	1948	660	1705		1405	
	McCook County						
367	Earl Boggs NW$\frac{1}{4}$ S20-T104N-R56W	1940	190	1380	4	1389	.33

* Measuring Point Altitude Above Sea Level
** Height of Piezometric Head Above Sea Level



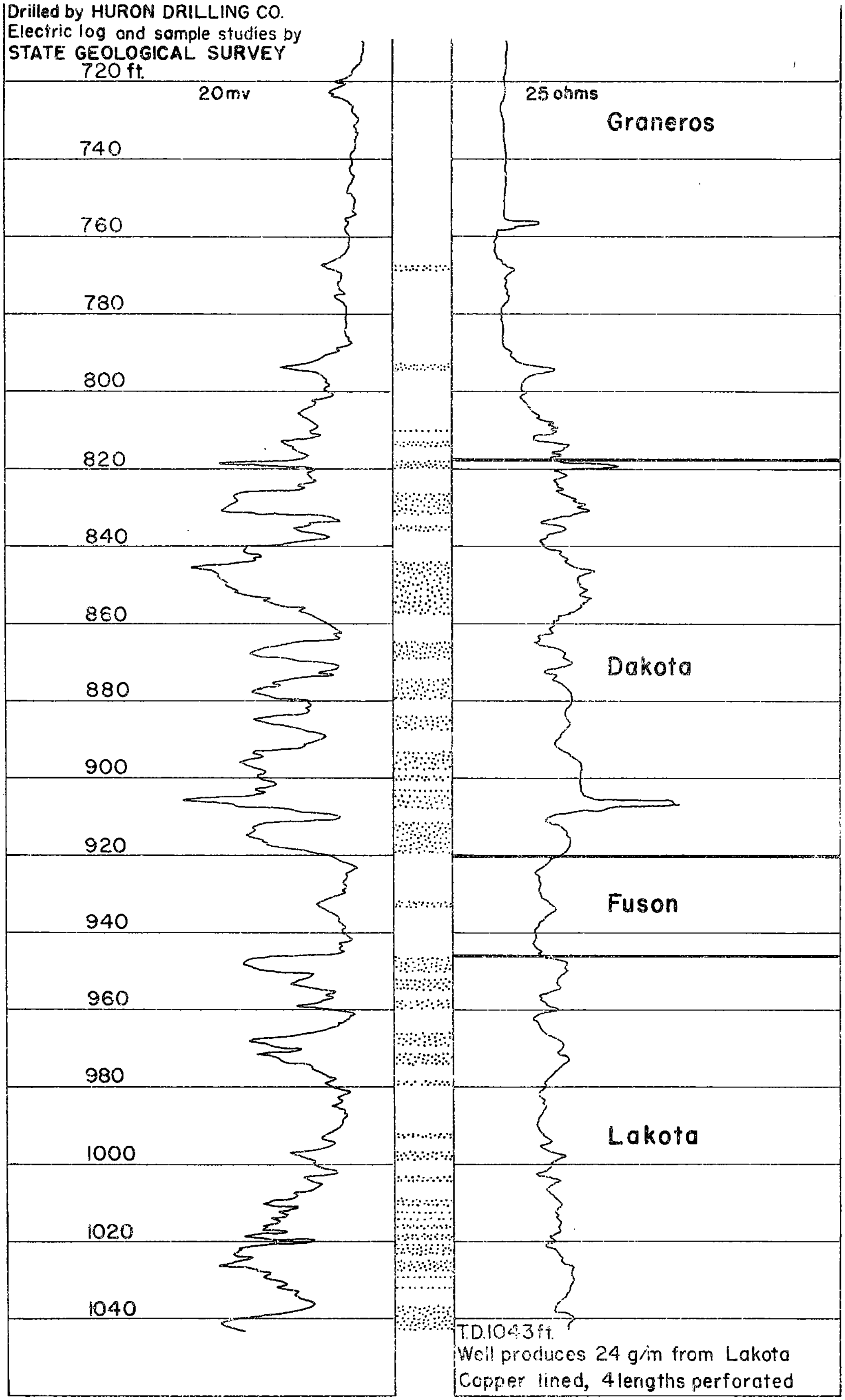
Map showing Topography and Pre-Cambrian suface

EXPLANATION

1500 — contour on topographic surface
1000 — contour on Pre-Cambrian surface
— — — State boundry
— — — County boundry

To find approximate depth to Pre-Cambrian (granite or quartzite) take the difference between the suface and the Pre-Cambrian contours at any point.

ELECTRIC LOG
FRED MEYER ARTESIAN WELL
Sec 22 T109 N. R.63 W.
BEADLE COUNTY



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