ELECTRICAL RESISTIVITY MEASUREMENTS IN THE NEILLSVILLE AREA, WISCONSIN

By

H. Cecil Spicer and George J. Edwards

U. S. GEOLOGICAL SURVEY

Released to open files
August 31, 1955

U. S. DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

ELECTRICAL RESISTIVITY MEASUREMENTS IN THE NEILLSVILLE AREA, WISCONSIN

By

H. Cecil Spicer and George J. Edwards

Prepared in cooperation with

the Wisconsin Geological Survey

GEOPHYSICS BRANCH REPORT 55-2

Released to Open Files

AUG 31 1955

This report and accompanying illustrations are preliminary and have not been edited or reviewed for conformity with Geological Survey standards and nomenclature.

CONTENTS

ILLUSTRATIONS

TABLES

ELECTRICAL RESISTIVITY MEASUREMENTS IN THE NEILLSVILLE AREA, WISCONSIN

By

H. Cecil Spicer and George J. Edwards

ABSTRACT

Sixty-eight electrical depth profiles were completed in the vicinity of Neillsville, Wis. to obtain information on the water-bearing beds in the glacial moraine and consolidated sedimentary rocks in the area. No productive aquifers were found but the best areas for test drilling are described. The basic theory and interpretation procedures, together with a short description of field methods on electrical resistivity measurements are also presented.

INTRODUCTION

The Neillsville area, in west-central Wisconsin, has long been deficient in water. Most of the wells drilled so far in the area are either dry or yield insufficient water. As a part of the investigation of the ground-water resources of Wisconsin being made in cooperation with the Wisconsin Geological Survey, University of Wisconsin, a ground-water study of that area was undertaken. In connection with that study, an electrical resistivity investigation was made.

The primary purpose of the project was to obtain information on the occurrence of aquifers in the thick sandstone deposits of the area or in the terminal moraine southeast of Neillsville. Other objectives were to locate any gravel deposits present; to determine the character, depth, and thickness of such material beneath the surface; and to select promising sites for drilling test holes.

Neillsville is in the south-central part of Clark County, in west-central Wisconsin. The resistivity measurements were made in T.24 N., R. 2 W., of the 4th principal meridian, mainly in the northeastern part of the township (fig. 1).

Work on the project started July 23, 1950 and continued over a period of three weeks, ending August 11. The field measurements were made by George J. Edwards assisted by Herbert C. Spicer, Jr., and employees of the city of Neillsville. Preliminary interpretations of the apparent resistivity curves were made in the field to make it possible to choose the most favorable sites for drilling tests holes. The final interpretations were made and the report prepared by H. Cecil Spicer.

The assistance and cooperation extended to us by the city of Neillsville are gratefully acknowledged.

GEOLOGY OF THE AREA

The underlying rock of the area near Neillsville is either gneiss, gneissic granite, granite, or diorite. On the uneven, eroded surface of these crystalline rocks there was deposited marine sandstone to a depth of several hundred feet. After the area was uplifted from the sea, erosion removed much of the sandstone and valleys were cut which probably extended through the sandstone and into the crystalline rocks. The topography was again modified by glaciation and the surface was covered with drift varying in thickness from a few feet to more than 125 feet. Some of the hills of the area owe their relief to a rock core covered with thick terminal moraine. Numerous out-crops of crystalline rocks occur along both Black River and O'Neill Creek.

The ground water of this area has been found in only small quantities, inadequate for the growing needs of the area. The crystalline rocks of the area cannot be considered as possible aquifers. The sandstone above the granitic rocks was considered a possible aquifer because of its extent and thickness as well as the large amount of recharge possible from a considerable area of near-surface rock. The glacial drift is not a very promising source for an aquifer because of the large amount of clay contained therein. The best source for ground-water supplies would be in a deposit of outwash sand and gravel in a buried stream valley, if such could be located in the area.

Instrumentation and Field Methods

The Gish-Rooney type earth resistivity apparatus, with modifications by H. Cecil Spicer, was used to make the resistivity measurements. Vertical depth profiling was used throughout the study in order to obtain all the information possible about the materials beneath the surface. Electrodes were set in the earth according to the modification of the Wenner arrangement as proposed by F. W. Lee (1929). Measurements of potential were made by both the Wenner (1915) and Lee (1929) techniques thus giving three measurements at each interval. The apparent resistivities were computed by the Wenner (1915) formula $\rho_a = 2\pi a \frac{E}{I}$ for all the observations, thus giving three apparent resistivity curves which when plotted are spread on the chart thus making them more accessible for interpretation; however, the curve form remains the same. The three resistivity curves thus obtained are termed Full, P-1 and P-2. Bearings for the depth profiles are referred to true north and are given for the P-1 direction. Altitudes are expressed as heights above mean sea level.

INTERPRETATION OF THE RESISTIVITY CURVES

An apparent resistivity curve expresses graphically the behavior of an electrical field impressed on the earth. The curve by means of its slope, inflections, and other characteristics enables a determination to be made of the material beneath the surface of the earth.

The method of interpretation applies to resistivity curves of two, three, and more layers. The theory of images, as given by Jeans (1925) and others, is fundamental. Theoretical aspects relating to the application of images to resistivity curves are given by Hummel (1931). Two layer resistivity curves and as many methods of interpreting them will be found in papers by Roman (1931). Three layer resistivity curves will be found in an article by Wetzel and McMurry (1937), and the use of two-layer curves and Wetzel and McMurry three-layer curves to aid in the interpretation of three and more curves is completely explained by Watson and Johnson (1938). Assistance in understanding their treatment of image theory will be found in an article by Watson (1934). The method described by Tagg (1937) is useful at times for certain types of resistivity curves. Examples of its application will be found in the reference cited and in Heiland (1940) and in the present paper.

SUMMARY OF FIELD MEASUREMENTS AND INTERPRETATIONS

Sixty-eight depth profiles were completed in the Neillsville area. A few depth profiles were repeated in an attempt to get satisfactory measurements, but the cause of the erratic behavior was not always located. The centers of the depth profiles and the directions of the electrode lines are shown on figure 1, the circle representing the center and the line through the circle the direction. The filled circles on this figure indicate the location of wells or drill holes which were used in trying to correlate the resistivity interpretations with the geologic materials. Except for a few wells, the information is of little assistance because the descriptions on the well logs or drill logs were inadequate or missing. The complete listing of locations and descriptions of the drilling information is given in the appendix. Surface contours from a map by the Wisconsin Geological Survey are also given on figure 1.

Short depth profiles were completed on or just above outcrops of the rocks in the area. These are indicated by concentric circles designated T-1 to T-5 on figure 1. The computed resistivities obtained from these tests were used in correlating the interpretations obtained from the apparent resistivity curves with the geological materials. The following resistivities were obtained from measurements on the granite in a quarry: on the weathered surface, 55,800 ohm cms; weathered at shallow depth, 18,600 ohm cms; depth greater than 12 feet, 137,200 ohm cms; unweathered surface, 1,249,350 ohm cms. Tests on the sandstone gave the following resistivities: weathered surface, 21,200 ohm cms; depth greater than 10 feet, 212,000 ohm cms; unweathered surface, 105,200 ohm cms.

Interpretations of the resistivity curves giving a description of the materials and depths to each material will be found in the appendix. Altitudes on the surfaces of the sandstone and granite along with their thicknesses are given in Table 1. The altitudes on the sandstone surface are shown also on figure 2 for each resistivity depth profile; these altitudes are from table 1, column 3. Shown also on figure 2 are the wells and drill holes in which sandstone was reported.

TABLE 1

ALTITUDES ON SURFACE, SANDSTONE, AND GRANITE WITH THICKNESSES.

Resistivity depth profile	Altitudes in feet			Thickness in feet	
	Surface	Sandstone	Granite	Surface Materials	Sandstone
A-1	1,080	1,073	966	7	107
B-1	1,100	1,086	–	14	> 250
B-2	1,075	1,052	828	23	224
B-2E	1,100	–	–	–	–
B-3	1,050	1,044	998	6	46
B-4	1,020	–	1,014	6	–
B-5	1,066	–	1,059	7	–
B-6	1,100	–	1,084	16	–
C-1	1,075	1,050	909	25	141
C-2	1,038	990	728	48	262
C-3	1,030	–	1,015	15	–
C-4	1,042	–	1,039	3	–
C-5	1,082	1,078	997	4	81
D-1	1,100	1,093	825	7	268
D-1W	1,090	1,035	942	55	93
D-2	1,040	–	–	–	–
D-3	1,075	1,065	–	10	> 40
D-3W	1,033	1,005	930	28	75
D-3W2	1,045	1,036	–	9	–
D-3N	1,075	1,066	750	9	316
D-4	1,045	–	1,037	8	–
D-5	1,060	1,057	983	3	74
D-6	1,055	1,046	959	9	87
D-7	1,055	1,048	978	7	70
E-1	1,110	1,098	875	12	223
E-2	1,090	1,084	765	6	319
E-3	1,050	1,036	855	14	171
E-4	1,058	–	1,030	28	–
E-5	1,090	1,077	1,038	13	39
E-6	1,088	1,073	985	15	88
E-7	1,078	1,067	–	11	> 150
E-8	1,060	1,048	–	12	> 150
F-1	1,090	–	–	–	–
F-1W	1,095	1,068	–	27	> 250
F-2	1,110	1,100	845	10	255

TABLE 1
(Cont.)

Resistivity depth profile	Altitudes in feet			Thickness in feet	
	Surface	Sandstone	Granite	Surface Materials	Sandstone
F-3	1,040	1,036	988	4	48
F-4	1,040	-	1,028	12	-
F-5	1,080	1,067	978	13	89
F-6	1,120	1,106	-	14	> 250
F-7	1,093	1,080	-	13	> 200
F-8	1,075	1,069	1,018	6	51
G-1	1,100	1,092	1,011	8	81
G-2	1,100	1,098	1,018	2	80
G-3	1,080	1,048	870	32	178
G-4	1,025	-	1,011	14	-
G-5	1,100	-	1,089	11	-
G-6	1,130	1,100	-	20	> 300
G-7	1,120	1,106	945	14	161
G-8	1,100	1,086	945	14	141
H-1	1,100	1,089	1,015	11	74
H-2	1,100	1,057	-	43	> 200
H-3	1,022	1,002	972	20	30
I-1	1,100	1,058	993	42	65
I-2	1,125	1,098	870	27	228
I-3	1,090	1,082	1,003	8	79
I-4	1,055	1,035	-	20	> 250
I-5	1,100	1,078	-	22	> 200
I-6	1,060	1,050	964	10	86
J-1	1,050	1,043	988	7	55
J-2	1,038	1,028	980	10	48
K-1	1,100	-	-	> 23	-
K-1N	1,090	-	-	> 72	-
K-2	1,105	-	1,021	84	-
K-2W	1,105	-	943	163	-
K-3	1,100	1,088	975	12	113
L-1	1,135	-	927	208	-
L-2	1,130	--	965	165	-
L-3	1,162	-	1,012	150	-

The thickness of the sandstone from the drilling information and the resistivity interpretations is shown on figure 3. These thicknesses are from table 1, column 6. It is evident from figure 3 that there are two areas where the sandstone has greater thickness than elsewhere and these areas are shown encompassed by dotted lines on this figure. Only four drill holes are reported to have penetrated through the sandstone to the granite in these areas.

Figure 4 shows the altitudes on the crystalline rocks and was prepared from the values of table 1, column 4. Information from twelve drill holes having no sandstone but giving the depths to granite is also included on the figure. It is apparent that the thick area of sandstone, particularly the easterly one shown on figure 3, is directly related to the depression in the granitic rocks, shown on figure 4. The shape of the thick sandstone mass of the westerly area is similar to that of the depression in the granite and, had there been more information about the depth to granite available, the two probably would have had the same appearance on both figures thus more completely establishing the same relationship which was found in the easterly area.

The appearance of the contours drawn on the bedrock surface and thickness of the sandstone above the bedrock are altered somewhat in the complete interpretations of the resistivity curves from those obtained by the preliminary ones which were made during the progress of the field observations.

On the basis of the preliminary estimates of the resistivity curves, two areas were selected as most promising for test drilling. One is in what appeared to be the area of thick sandstone and the other is in the moraine southeast of Neillsville. Such drilling would give much better information to correlate the geologic materials and the interpretations from resistivity measurements, and, furthermore, the areas chosen also appeared to be the most likely ones for obtaining water, but it was emphasized that they held little promise as adequate water-bearing areas.

Drill hole 48 was completed in the autumn of 1950. According to the sample log, see appendix, it had 32 feet of sandstone and the amount of water produced was unreported so it is presumed to be too small to be useful for a large-capacity well. This drill hole was put down near resistivity depth profile D-2. It was estimated, in the preliminary interpretations, that the sandstone would have a thickness of more than 200 feet there. The correlation between the drill log and the resistivity interpretations is definitely negative. No explanation for this situation can be offered other than the observer must have taken the measurements of resistivity over or alongside an apparently unnoticed and unreported buried conductor.

Drill hole 49 was completed in 1951 and was located near resistivity depth profile L-3. The correlation between the two sets of observations here is considered only fair. Interpretations of the resistivity observations show no evidence of sandstone, but the depth to granite is very close; 150 feet by resistivity and 152 1/2 feet by drilling. No water is reported in this well, but a well less than 1/4 mile NNW. from this drill hole, number 47, is stated to have water with a probable capacity of 100 gpm and, apparently, this water comes from a sand at a depth of 106 to 171 feet.

Well number 47 is located approximately midway between resistivity depth profiles K-3 and L-3 and only a short distance from drill hole number 44. The depth to granite at K-3 was 125 feet, at L-3 was 150 feet, and at number 44 was 154 feet, but at number 47 the granite was not reached at 171 feet. Consequently, it seems probable that a buried channel may be present near this drill hole and further exploration near it might discover a useful aquifer.

Another area appears in the completed interpretation to be a possible area for drilling to discover an aquifer. It is located in the northeastern part of section 1 near resistivity depth profiles I-1 and I-2. Unfortunately, these observations are at the northern most limits of the area investigated so it is not possible to estimate the extent of the gravels found there. These gravels may be associated with those known to be present in the gravel pit of SE 1/4 NW 1/4 section 1, and, if they are, a sizeable aquifer might be present.

The electrical-resistivity measurements made in this area were not successful in locating a productive aquifer in either the sandstone or the glacial moraine. Three areas, though, are pointed out as possibilities for drilling to discover an aquifer; one in gravels, one in sandstone, and one in the glacial moraine. However, the area is one where little ground water can be expected because the sandstone is of low porosity and in most places interbedded with shales; the gravel deposits are scarce and, insofar as found, mostly near the surface; and the moraine is largely composed of clay which makes it a poor to valueless material for an adequate aquifer.

LITERATURE CITED

Heiland, C. A., 1940, Geophysical exploration: p. 727-731, Prentice-Hall.

Hummel, J. N., 1931, A theoretical study of apparent resistivity in surface potential method: Am. Inst. Min. Metall. Eng. Tech. Pub. 418.

Jeans, J. F., 1925, Mathematical theory of electricity and magnetism: 5th ed., Cambridge Univ. Press.

Lee, F. W., Joyce, J. W., Boyer, P., 1929, Some earth resistivity measurements: U. S. Bureau of Mines Inf. Circ. 6171, 16 p.

Roman, Irwin, 1931, How to compute tables for determining resistivity of underlying beds and their application to geophysical problems: U. S. Dept. of Comm. Bur. Mines Tech. Paper 502.

Tagg, G. F., 1937, Interpretation of earth-resistivity curves: Am. Inst. Min. Metall. Eng. Tech. Pub. 755, 11 p.

Watson, R. J., 1934, A contribution to the theory of the interpretation of resistivity measurements obtained from surface potential observations: Am. Inst. Min. Metall. Eng. Tech. Pub. 518, 34 p.

Watson, R. J. and Johnson, J. F., 1938, On the extension of the two-layer methods of interpretation of earth resistivity data to three and more layers: Geophysics, v. 3, no. 1, p. 7-21.

Wenner, Frank, 1915, A method of measuring earth resistivity: Natl. Bur. Standards Sci. Paper 258, p. 469-478.

Wetzel, W. W. and McMurry, H. V., 1937, A set of curves to assist in the interpretation of the three-layer resistivity problem: Geophysics v. 2, no. 4, p. 329-341.

APPENDIX

Well Records in T. 24 N., R. 2 W.

See map for location

Well Number	Description
1	No information.
2	30 feet deep.
3	60 feet deep.
4	25 feet deep.
5	No data.
6	No data.
7	No data.
8	26 feet deep; 22 feet sandstone.
9	No data.
9A	12 feet deep; granite at 6 feet.
10	Granite at 10 feet.
11	Sandstone 30 feet.
12	125 feet deep; 12 feet to granite.
13	8 feet deep; hit granite.
14	32 feet deep; hit sandstone.
15	110 feet deep; 24 feet to sandstone; rest in sandstone.
16	22 feet deep; sandstone at 12 feet
17	64 feet deep.
18	14 feet deep.
19	18 feet deep, sandstone.
20	101 feet deep; no rock.
21	32 feet deep.
22	32 feet sandstone.
23	Sand at 32 feet.
24	12 feet deep; hit sandstone.
25	11 feet to sandstone.
26	70 feet deep; hit hard stuff.
27	12 feet deep; hit granite.
28	Sandstone at 26 feet.
29	12 feet deep.
30	24 feet deep; sandstone at 3 feet.
31	12 feet deep.

Well records continued

Well Number	Description
32	12 feet deep; hit granite.
33	10 feet to granite.
34	20 feet deep.
35	35 feet deep.
36	96 feet deep; 30 feet to sandstone.
37	15 feet deep.
38	Sandstone at 22 feet.
39	80 feet deep; struck sandstone.
40	33 feet deep; sandstone at surface.
41	30 feet deep; sandstone at 3 feet; granite at 30 feet.
42	55 feet deep.
43	40 feet to sandstone.

Well Logs

Well 44. 552 feet N., 12.5 feet E. of SW. corner sec. 13, T.24 N., R.2 W.

Description	Depth in feet
Till, brown	0 - 41
Till, gray	41 - 79
Mt. Simon sandstone	79 - 144
Sandstone	144 - 146
Conglomerate, small granite and quartz pebbles	146 - 154
Granite, disintegrated, harder below	154 - 157
42 feet of water	

Well 45. SE corner NE 1/4 NE 1/4 sec. 23, T. 24 N., R.2 W. SE. corner Clark County Fair Grounds.

Description	Depth in feet
Clay and "hardpan"; red brown till	0 - 27

Description	Depth in feet
Clay; sand, coarse	27 - 52
Gravel, fine stony	52 - 57
Till, pink calcareous	57 - 83
Till, gray	83 - 90
Sand, coarse glacial	90 - 95
Sandstone	95 - 155
Granite, pink	155 - 164

Well 46. At house 1/5 mile west of N. 1/4 cor. section 24.

Description	Depth in feet
Sand and gravel	0 - 140
26 feet of water	

Well 47. East of Neillsville on U. S. Highway 10 across road from Fair Ground.

Description	Depth in feet
Clay and boulder	106
Sand	106 - 171

Water table at 147 feet. Probable capacity of well 100 gpm with 8" - 10 ft. screen.

Well 48. SW. of center NW 1/4 sec. 12, T. 24 N., R. 2 W, 1950.

Description	Depth in feet
Silt, gray	0 - 5
Till, brown-gray	5 - 10
Sandstone, light gray	10 - 15
Shale, red	15 - 18
Sandstone, pink	18 - 21
Sandstone, light gray	21 - 42
Pre-Cambrian rock, decomposed, gray	42 - 47
Washed granite, light gray	47 - 51

Well 49. NW 1/4 NW 1/4 sec. 24, T. 24 N., R. 2 W. 1951.

Description	Depth in feet
Gravel	0 - 12
Till, brown-gray, gray	12 - 39
Sand, coarse to fine, light pink	39 - 48
Till, gray dolomitic or calcareous	48 - 95
Mt. Simon sandstone, light gray	95 - 106
Sandstone	106 - 119
Shale	119 - 125
Sandstone, light gray	125 - 127
Conglomerate	127 - 136
Granite, decomposed	136 - 152 1/2
Dark rock, ferromagnesian, diorite	152 1/2 -

Geologic Materials as Determined from Resistivity Curve Interpretations in T. 24 N., R. 2 W.

Line A-1. 550 feet E. of 1/4 line, 390 feet S. of NW. cor. SE 1/4 SW 1/4 sec. 12. Altitude 1,100 feet. P-1 N. 88° E.

Description	Depth in feet
Soil	0 - 7.2
Sandstone	7.2 - 28
Shale and sandstone	28 - 114
Granite	114 - 300

Line B-1. SE. cor. NW 1/4 SE 1/4 sec. 12. Altitude 1,100 feet. P-1 N. 77° E.

Description	Depth in feet
Sandy clay soil	0 - 14.5
Shale and sandstone	14.5 - 29
Sandstone	29 - 400

Line B-2E. 67 feet E. of SW. cor. NE 1/4 SW 1/4 sec. 12. Altitude 1,100. P-1 N. 88° E.

Abandoned; interference from surface conductor.

Line B-2. NW cor. SW 1/4 SW 1/4 sec. 12. Altitude 1,075 feet. P-1 N. 87°E.

Description	Depth in feet
Sandy clay soil	0 - 5.7
Sand and gravel	5.7 - 23
Shale and sandstone	23 - 53
Sandstone, some shale	53 - 147
Granite	147 - 500

Line B-3. NE cor. SW 1/4 SE 1/4, 40 feet S. and 0.05 mi. W. of cor. sec. 11. Altitude 1,050 feet. P-1 N. 90° E.

Description	Depth in feet
Clay soil, gravel, sandstone boulders	0 - 5.8
Sandstone	5.8 - 12
Shale and sandstone	12 - 52
Granite	52 - 200

Line B-4. SE. cor. SW 1/4 NW 1/4 SE 1/4 sec. 10. Altitude 1,020 feet. P-1 N. 0° E.

Description	Depth in feet
Clay soil, sandstone and granite boulders	0 - 3.1
Clay	3.1 - 6.2
Granite	6.2 - 200

Line B-5. NE. cor. SE 1/4 SE 1/4 sec. 9. Altitude 1,066 feet. P-1 N. 0° E.

Description	Depth in feet
Sand	0 - 3.8
Sand, some clay	3.8 - 7.6
Granite	7.6 - 50

Line B-6. NE. cor. SW 1/4 SE 1/4 sec. 9. Altitude 1,100 feet. P-1 S. 45° E.

Description	Depth in feet
Sandy clay, boulders	0 - 3.9
Sandy Clay	3.9 - 15.6
Granite	15.6 - 300

Interference from power line evident.

Line C-1. NW. cor. NW 1/4 SE 1/4 sec. 12. Altitude 1,075 feet. P-1 N. 86°E.

Description	Depth in feet
Moist clay, and sand soil	0 - 6.3
Sand, gravel, boulders	6.3 - 25
Sandstone and shale	25 - 166
Granite	166 - 600

Line C-2. NW. cor. NE 1/4 NE 1/4 SE 1/4 sec. 11. Altitude 1,038 feet. P-1 N. 90° E.

Description	Depth in feet
Sand and gravel fill	0 - 4.8
Sand and gravel	4.8 - 18
Sand, gravel, clay (shale?)	18 - 48
Sandstone	48 - 310
Granite	310 - 600

Line C-3. 150 feet N. of SW. cor. SW 1/4 NE 1/4 sec. 11. Altitude 1,030 feet. P-1 N. 63° E.

Description	Depth in feet
Sandy soil	0 - 3.8
Clay or till	3.8 - 15
Granite	15 - 180

Line C-4. 57 feet W. of SE. cor. SW 1/4 NE 1/4 sec. 10. Altitude, 1,042 feet. P-1 N. 90° E.

Description	Depth in feet
Clay soil, granite boulders	0 - 3.4
Granite	3.4 - 100

Line C-5. NW. cor. SE 1/4 NW 1/4 SE 1/4 sec. 9. Altitude 1,082 feet. P-1 N. 72° E.

Description	Depth in feet
Sandy clay soil	0 - 4.4
Sandstone	4.4 - 85
Granite	85 - 100

Line D-1. SE 1/4 SW 1/4 NE 1/4 sec. 12, 800 feet N. of 1/2 line. Altitude 1,100 feet. P-1 N. 0° E.

Description	Depth in feet
Sandy clay soil	0 - 6.9
Sandstone	6.9 - 28
Sandstone, shale	28 - 275
Granite	275 - 600

Line D-1W. 216 feet E. of 1/4 line, 0.275 mile S. of road, NW. cor. SW 1/4 NE 1/4 sec. 12. Altitude 1,090 feet. P-1 N. 0° E.

Description	Depth in feet
Clay soil	0 - 5.5
Sandstone	5.5 - 32
Shale and sandstone	32 - 148
Granite	148 - 400

Line D-2. NW. cor. SE 1/4 sec. 12. Altitude 1,040 feet. P-1 N. 0° E. Interference from buried conductor evident on curve; interpretation impossible to correlate with log of well 48.

Line D-3. NW cor. SE 1/4 NE 1/4 sec. 12. Altitude 1,075 feet. P-1 N. 90° E.

Description	Depth in feet
Moist clay soil	0 - 2.4
Clay	2.4 - 9.6
Sandstone (?)	9.6

Observations taken over some undetermined buried conductor near P-2 end.

Line D-3W. 76 feet W. of SE. cor. NE 1/4 NW 1/4 sec. 11. Altitude 1,033 feet. P-1 N. 90° E.

Description	Depth in feet
Sandy clay soil	0 - 9
Sandstone	9 - 28
Shale and sandstone	28 - 103
Granite	103 - 250

Line D-3W2.

Description	Depth in feet
Sandy clay soil	0 - 8.6
Sandstone, dense	8.6 - 36
Shale and sandstone	36 -

Buried conductor must be present which ruined the observations.

Line D-3N. 702 feet E. and 590 feet N. 22° W. of SW. cor. NE 1/4 NE 1/4 sec. 11. Altitude 1,075 feet. P-1 N. 22° W.

Description	Depth in feet
Clay soil, sandy	0 - 2.3
Clay	2.3 - 9.2
Sandstone, shale	9.2 - 325
Granite (estimated depth)	325

Line D-4. 384 feet W. of SE. cor. NE 1/4 NE 1/4 sec. 10. Altitude 1,045 feet. P-1 S. 87° E.

Description	Depth in feet
Wet clay soil	0 - 8
Granite	8 - 100

Line D-5. SW. cor. NW 1/4 NE 1/4 sec. 10. Altitude 1,060 feet. P-1 S. 77° E.

Description	Depth in feet
Sandy soil, boulders	0 - 3
Shale, sandstone	3 - 77
Granite	77 - 200

Line D-6. SW. cor. NW 1/4 NW 1/4 sec. 10. Altitude 1,055 feet. P-1 N. 0°E.

Description	Depth in feet
Sandy soil, boulders	0 - 2.2
Sandy clay	2.2 - 8.8
Sandstone	8.8 - 23
Shale	23 - 52
Sandstone, shale, weathered granite	52 - 96
Granite	96 - 400

Line D-7. NW. cor. SW 1/4 NE 1/4 sec. 9, 120 feet S. of creek. Altitude 1,055 feet. P-1 N. 0° E.

Description	Depth in feet
Clay soil and gravel	0 - 5.1
Clay	5.1 - 7
Sandstone	7 - 23
Shale and sandstone	23 - 77
Granite	77 - 325

Line E-1. NE. cor. SE 1/4 SW 1/4 sec. 1, 0.175 mile N. of road. Altitude 1,110 feet.

Description	Depth in feet
Sandy soil	0 - 9
Clay	9 - 12
Sandstone	12 - 52
Shale	52 - 85
Sandstone	85 - 235
Granite	235 - 600

Line E-2. NW. cor. NW 1/4 NW 1/4 sec. 12, 420 feet E. of 1/4 line and 0.05 mi. S. of road. Altitude 1,090 feet. P-1 N. 88° E.

Description	Depth in feet
Sandy clay soil	0 - 2.8
Clay	2.8 - 5.6
Sandstone	5.6 - 55
Shale and sandstone	55 - 85
Sandstone	85 - 145
Shale and sandstone	145 - 325
Granite	325 - 600

Line E-3. SE. cor. SW 1/4 SW 1/4 sec. 1, 100 feet N. and 27 feet E. of corner. Altitude 1,050 feet. P-1 N. 0° E.

Description	Depth in feet
Sandy clay soil	0 - 6.9
Clay and sand	6.9 - 14
Sandstone	14 - 125
Shale and decomposed granite	125 - 195
Granite	195 - 325

Line E-4. NE. cor. NW 1/4 NE 1/4 sec. 2. Altitude 1,058 feet. P-1 N. 90° E.

Description	Depth in feet
Clay, sand soil	0 - 7
Clay, some sand	7 - 28
Granite	28 - 100

Line E-5. SW. cor. SE 1/4 SW 1/4 sec. 3, 255 feet N. of corner. Altitude 1,090 feet. P-1 N. 90° E.

Description	Depth in feet
Clay soil, boulders	0 - 3.3
Clay, some sand	3.3 - 13.2
Sandstone	13.2 - 52
Granite	52 - 250

Line E-6. SE. cor. SW 1/4 SW 1/4 sec. 3. Altitude 1,088 feet. P-1 N. 90° E.

Description	Depth in feet
Sandy clay soil, gravel	0 - 3.7
Clay, sand	3.7 - 15
Sandstone	15 - 28
Sandstone, shale	28 - 103
Granite	103 - 500

Line E-7. 390 feet S. of road and NW. cor. NE 1/4 NW 1/4 sec. 9. Altitude 1078 feet. P-1 N. 90° E.

Description	Depth in feet
Clay soil, sand	0 - 2.7
Clay	2.7 - 10.8
Sandstone	10.8 - 200

Line E-8. 400 feet S. of NE. cor. NW 1/4 NW 1/4 sec. 9. Altitude 1,060 feet. P-1 N. 88° E.

Description	Depth in feet
Sandy clay soil, boulders	0 - 2.9
Clay	2.9 - 11.4
Sandstone	11.4 - 23
Shale and sandstone	23 - 112
Sandstone	112 - 450

Line F-1. NE. cor. SW 1/4 SE 1/4 sec. 1. Altitude 1,090 feet. P-1 N. 90° E. Abandoned because of interference from buried conductor.

Line F-1W. 200 feet W. of NE. cor. SW 1/4 SE 1/4 sec. 1. Altitude 1,095 feet. P-1 N. 90° E.

Description	Depth in feet
Sandy, soil	0 - 6.7
Clay, sand	6.8 - 27
Sandstone	27 - 400

Line F-2. 284 feet S. of NE. cor. SW 1/4 SW 1/4 sec. 1. Altitude 1,110 feet. P-1 N. 0° E.

Description	Depth in feet
Sandy clay soil	0 - 2.6
Clay	2.6 - 10.4
Sandstone	10.4 - 185
Shale and sandstone	185 - 265
Granite	265 - 600

Line F-3. SE cor. NW 1/4 SE 1/4 sec. 2. Altitude 1,040 feet. P-1 N 0° E.

Description	Depth in feet
Sandy clay soil	0 - 4.5
Sandstone	4.5 - 52
Granite	52 - 220

Line F-4. 376 feet E. of road, 0.15 mile to SW cor. sec. 2. Altitude 1,040 feet. P-1 N. 88° E.

Description	Depth in feet
Clay soil, boulders	0 - 12
Granite	12 - 240

Line F-5. NE. cor. SE 1/4 SE 1/4 sec. 3. Altitude 1,080. P-1 N. 90° E.

Description	Depth in feet
Sandy clay soil	0 - 17
Sandstone	17 - 42
Shale and sandstone	42 - 102
Granite	102 - 200

Line F-6. 15 feet N. of SW. cor. NW 1/4 SW 1/4 sec. 3. Altitude 1,120 feet. P-1 N. 90° E.

Description	Depth in feet
Sandy clay soil, boulders	0 - 3.6
Clay	3.6 - 14.5
Sandstone	14.5 - 300

Line F-7. 397 feet E. of SW. cor. NW 1/4 SE 1/4 sec. 4. Altitude 1,093 feet. P-1 N. 90° E.

Description	Depth in feet
Sandy clay soil, boulders	0 - 3.2
Clay	3.2 - 12.8
Sandstone	12.8 - 220

Line F-8. SE. cor. NE 1/4 SE 1/4 sec. 5. Altitude 1,075 feet. P-1 N. 90° E.

Description	Depth in feet
Clay soil, boulders	0 - 6.5
Sandstone	6.5 - 18
Sandstone and shale	18 - 57
Granite	57 - 300

Line G-1. 0.5 mile N. SE cor. sec. 1. Altitude 1,100 feet. P-1 N. 0° E.

Description	Depth in feet
Clay soil, sand	0 - 4
Clay, some sand	4 - 8
Sandstone	8 - 89
Granite	89 - 400

Line G-2. NE. cor. NE 1/4 SW 1/4 sec. 1. Altitude 1,100 feet. P-1 N. 90° E.

Description	Depth in feet
Sandy soil	0 - 2.2
Sandstone	2.2 - 82
Granite	82 - 400

Line G-3. SE 1/4 NE 1/4 sec. 2. Altitude 1,080 feet. P-1 N. 20° E.

Description	Depth in feet
Sand, gravel, clay	0 - 2.1
Sand, gravel	2.1 - 8.4
Clay, sand, gravel	8.4 - 32
Sandstone	32 - 135
Sandstone and shale	135 - 210
Granite	210 - 400

Line G-4. 195 feet S. of 1/4 line, 350 feet W. of NE. cor. NW 1/4 SE 1/4 sec. 2. Altitude 1,025 feet. P-1 N. 85° E.

Description	Depth in feet
Sandy clay soil, gravel	0 - 14
Granite	14 - 350

Line G-5. 325 feet S. of road and NE. cor. NW 1/4 SE 1/4 sec. 3. Altitude 1,100 feet. P-1 N. 0° E.

Description	Depth in feet
Sand, clay soil	0 - 2.6
Clay	2.6 - 11
Granite	11 - 200

Line G-6. 550 feet N. of SW. cor. SE 1/4 NW 1/4 sec. 3. Altitude 1,130 feet. P-1 N. 0° E.

Description	Depth in feet
Sandy clay soil	0 - 4.3
Clay	4.3 - 20
Sandstone	20 - 600

Line G-7. 566 feet S. and 173 feet E. of NW. cor. NE 1/4 SE 1/4 sec. 4. Altitude 1,120 feet. P-1 N. 0° E.

Description	Depth in feet
Sandy clay soil	0 - 10
Clay	10 - 13.5
Sandstone	13.5 - 115
Shale and sandstone	115 - 175
Granite	175 - 400

Line G-8. 219 feet S. of road and NW. cor. NE 1/4 SW 1/4 sec. 4. Altitude 1,100 feet. P-1 N. 90° E.

Description	Depth in feet
Sandy clay soil, boulders	0 - 3.1
Clay	3.1 - 14
Sandstone	14 - 155
Granite	155 - 500

Line H-1. 0.15 mile W. of road and NE. cor. NW 1/4 SE 1/4 NE 1/4 sec. 1. Altitude 1,100 feet. P-1 N. 90° E.

Description	Depth in feet
Sandy clay soil	0 - 2.7
Clay, some sand	2.7 - 11
Sandstone	11 - 62
Shale and sandstone	62 - 85
Granite	85 - 200

Line H-2. SE. cor. NW 1/4 NW 1/4 sec. 1. Altitude 1,100 feet. P-1 N. 0° E.

Description	Depth in feet
Sandy clay soil	0 - 2.3
Clay, sand	2.3 - 9.2
Gravel	9.2 - 23
Clay	23 - 43
Sandstone	43 - 300

Line H-3. NE. cor. NW 1/4 SW 1/4 NE 1/4 sec. 2. Altitude 1,022 feet P-1 S. 50° E.

Description	Depth in feet
Sandy clay soil, boulders	0 - 4.9
Clay	4.9 - 20
Sandstone	20 - 150
Granite	150 - 250

Line I-1. NE. cor. NE 1/4 on N. side of road. Altitude 1,100 feet. P-1 N. 90° E.

Description	Depth in feet
Clay soil, sand and gravel	0 - 7.5
Gravel	7.5 - 42
Gravel and clay or sandstone and shale	42 - 107
Granite	107 - 400

Line I-2. NE cor. NE 1/4 NW 1/4 sec. 1, N. side of road. Altitude 1,125 feet. P-1 N. 90° E.

Description	Depth in feet
Sandy clay soil, some gravel	0 - 7
Gravel or sandstone	7 - 27
Gravel and clay or sandstone and shale	27 - 42
Shale and sandstone	42 - 255
Granite	255 - 600

Line I-3. 300 feet S. of NW. cor. NW 1/4 NW 1/4 sec. 1. Altitude 1,090 feet. P-1 S-87° E.

Description	Depth in feet
Clay soil	0 - 8
Sandstone	8 - 27
Shale and sandstone	27 - 87
Granite	87 - 400

Line I-4. Opposite NW. cor. NE 1/4 NW 1/4 sec. 3. Altitude 1,055 feet. P-1 N. 0° E.

Description	Depth in feet
Moist sand	0 - 10
Clay	10 - 20
Sandstone	20 - 300

Line I-5. 305 feet W. and 196 feet S. of NE. cor. NW 1/4 NE 1/4 sec. 4. Altitude 1,100 feet. P-1 N. 85° E.

Description	Depth in feet
Sand and boulders	0 - 5.5
Clay and sand	5.5 - 22
Sandstone, shale	22 - 46
Sandstone	46 - 250

Line I-6. 218 feet N. of NE. cor. NW 1/4 NW 1/4 sec. 4. Altitude 1,060 feet. P-1 S. 80° E.

Description	Depth in feet
Moist sand, some clay	0 - 2.5
Clay, some sand	2.5 - 10
Sandstone	10 - 22
Shale, some sandstone	22 - 96
Granite	96 - 200

Line J-1. 0.35 mile W. of NE. cor. SE 1/4 sec. 13. Altitude 1,050 feet P-1 N. 90° E.

Description	Depth in feet
Sandy soil, boulders	0 - 1.9
Sandy clay	1.9 - 7.4
Sandstone	7.4 - 19
Shale and sandstone	19 - 62
Granite	62 - 350

Line J-2. 0.85 mile W. of NE. cor. SE 1/4 sec. 13. Altitude 1,038 feet. P-1 N. 90° E.

Description	Depth in feet
Clay, sand soil	0 - 7.7
Clay	7.7 - 10.4
Sandstone	10.4 - 22
Shale, sandstone	22 - 58
Granite	58 - 400

Line K-1. NW. cor. SE 1/4 SE 1/4 sec. 13. Altitude 1,110 feet. P-1 N. 90° E.

Description	Depth in feet
Sandy clay soil	0 - 5.7
Sand and gravel	5.7 - 23
Clay	23 -

Interference from a buried conductor spoiled the observations.

Line K-1N. 486 feet S. of road and NE. cor. NW 1/4 SE 1/4 sec. 13. Altitude 1,090 feet. P-1 N. 2° W.

Description	Depth in feet
Clay, sand soil	0 - 8.3
Clay, some sand and gravel	8.3 - 72
Granite	72 - 200

Line K-2. NW. cor. SW 1/4 SE 1/4 sec. 13. Altitude 1,105 feet. P-1 N. 0° E.

Description	Depth in feet
Sandy clay soil	0 - 5
Clay	5 - 15
Clay, some sand and gravel	15 - 84
Granite	84 - 250

Line K-2W. 90 feet E. of SW. cor. NE 1/4 SW 1/4 sec. 13. Altitude 1,105 feet. P-1 N. 90° E.

Description	Depth in feet
Sandy clay soil	0 - 3.2
Clay, some sand	3.2 - 13
Sand and gravel	13 - 18
Clay, sand, gravel	18 - 162
Granite	162 - 250

Line K-3. 210 feet N. 45° W. of SE. cor. NE 1/4 SE 1/4 sec. 14. Altitude 1,100 feet. P-1 S. 45° E.

Description	Depth in feet
Sandy clay, boulders	0 - 3.7
Clay, some sand	3.7 - 12
Sandstone	12 - 48
Shale and sandstone	48 - 125
Granite	125 - 300

Line L-1. SE. cor. SE 1/4 SE 1/4 sec. 13. Altitude 1,135 feet. P-1 N. 90° E.

Description	Depth in feet
Clay, sand soil	0 - 2.5
Clay, some sand and gravel	2.5 - 38
Clay, sand, gravel	38 - 108
Granite	108 - 400

Line L-2. NE. cor. NE 1/4 NW 1/4 sec. 24. Altitude 1,130 feet. P-1 N. 90° E.

Description	Depth in feet
Clay soil	0 - 7
Sand, gravel, clay	7 - 70
Clay, sand, gravel	70 - 165
Granite	165 - 500

Line L-3. 685 feet S. of road and NW. cor. NW 1/4 NW 1/4 sec. 24 Altitude 1,162 feet. P-1 N. 0° E.

Description	Depth in feet
Sandy clay soil	0 - 1.6
Clay, some sand	1.6 - 6.7
Sand, gravel, some clay	6.7 - 27
Clay, sand, gravel	27 - 150
Granite	150 - 350