

GROUND-WATER RESOURCES OF THE SURREY AREA

WARD COUNTY, NORTH DAKOTA

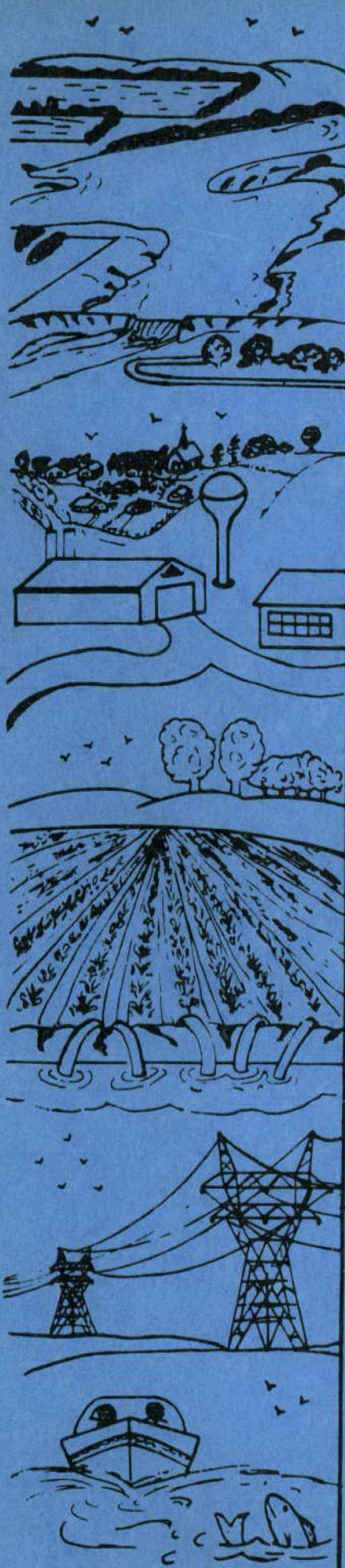
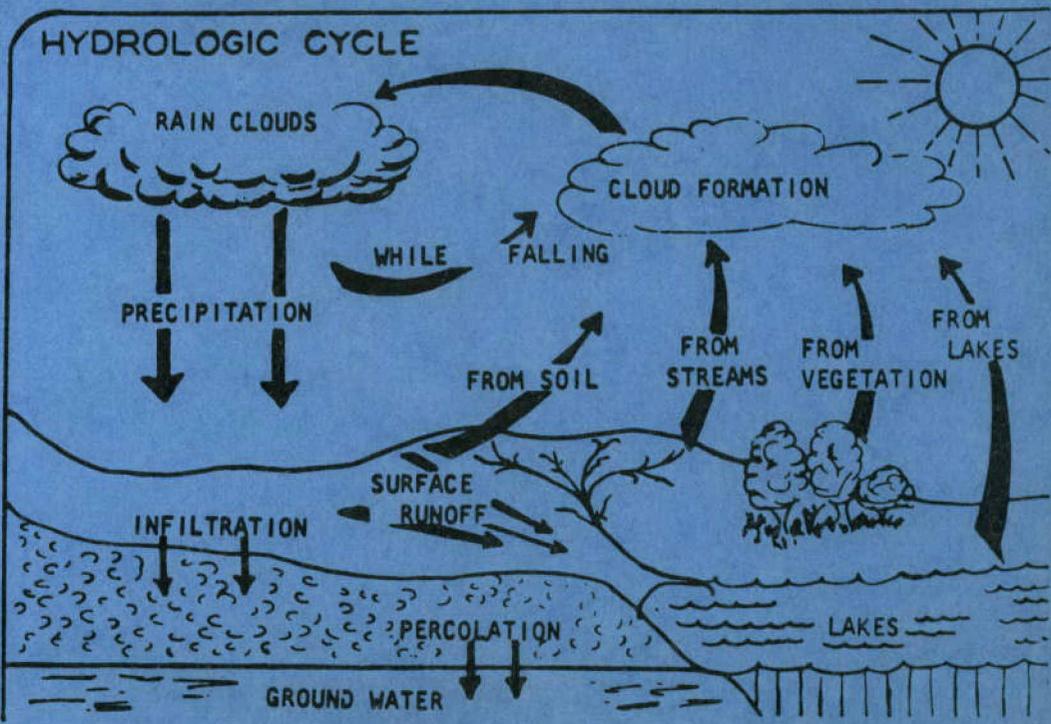
NORTH DAKOTA GROUND-WATER STUDIES
NUMBER 87

By

Allen E. Comeskey, Hydrologist
and Jon Reiten, Hydrologist
North Dakota State Water Commission

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State Office Building
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-1982-



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INTRODUCTION

On April 18, 1979, the Surrey City Council adopted a resolution to enter into an agreement with the State Water Commission to conduct a study to further evaluate the availability of ground water in the Surrey area to supplement their municipal water supply. The city of Surrey and the State Water Commission entered into agreement on August 17, 1979 beginning the study and sharing the estimated cost of \$8,300 equally. The field work for the study was accomplished from September 17 through 27, 1979, and October 6 through October 8, 1981.

The purpose of the study was to determine the areal extent, saturated thickness, water quality and water levels in an unnamed aquifer northeast of Surrey. These aquifer characteristics were assessed by means of data collected during the study. Data consisted of lithologic logs, geophysical logs, and measurements and samples from observation wells. The lithologic logs are written records of the materials penetrated by the drill and include classification and description, depth to and thickness of the geologic materials. These are determined from changes in drilling characteristics and the appearance of cuttings in the drilling fluid. More precise values for the depths and thicknesses are ascertained from the geophysical logs, which are graphs of changes in the electrical properties of the geologic materials. Observation wells are completed where a significant thickness of aquifer material is encountered. The wells are pumped and water samples collected for chemical analyses. They are then used for periodic measurements of water levels.

Location

The study area is located, generally, within the western lake section of the central lowlands in the southwestern corner of the Souris River Loop.

Specifically, it lies two miles north and three miles east of Surrey, North Dakota, Township 155 North, Range 81 West, Sections 2 through 16, and Township 155 North, Range 80 West, Sections 7, 8, 17 and 18 (fig. 1 and Plate 1).

Well Numbering System

The system for denoting the location of a test hole or observation well is based on the federal system of rectangular surveys of public land. (The first and second numbers indicate township north and range west of the 5th Principal Meridian and base line. The third number denotes the section. The fourth, fifth, and sixth letters refer to quarter sections, quarter-quarter sections, and quarter-quarter-quarter sections, lettered consecutively A through D in a counter-clockwise direction (fig. 2).

Present Water Supply

The city of Surrey presently obtains a portion of its municipal water supply from two wells located a mile north of town in 155-81-8cca (Plate 1). These wells are completed in sand and gravel in a surficial outwash channel. Well No. 1 was completed in 1967 in a section of sand and gravel from 4 to 23 feet and has a screened interval from 17 to 23 feet. Well No. 2 was completed in 1972 in a section of sand and gravel from 8 to 31 feet and has a screened interval from 15 to 25 feet. Surrey is presently allowed 60 acre-feet annually at a rate of 200 gpm.

This aquifer has recently been unable to supply the demands of Surrey. The water available is a finite amount which is received and stored from rain and snowmelt. This water remains in storage until moved by pumping. The water levels will decline if no precipitation occurs to replace that removed from storage. The amount of water in storage is related to the areal

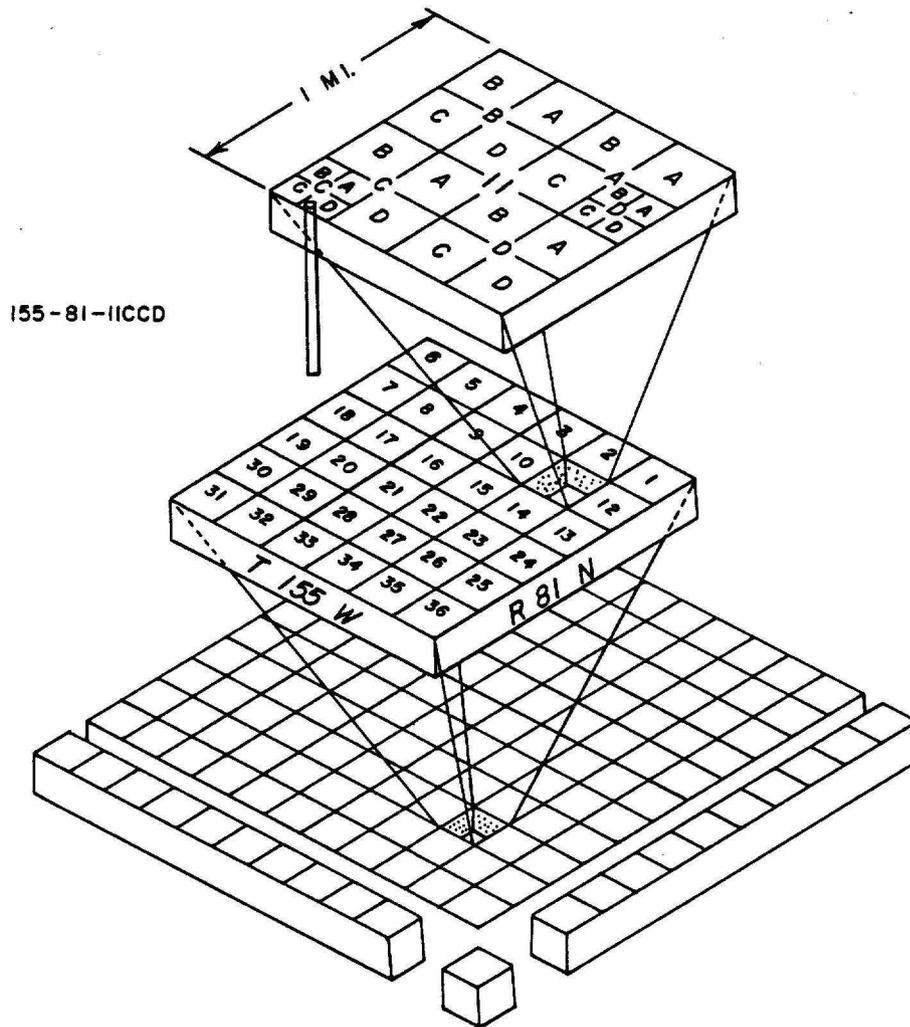


FIG. 2 WELL NUMBERING SYSTEM

extent and thickness of the aquifer. The aquifer is less than 1/8 mile wide with a saturated thickness of about 20' at the city wells thinning to about 6' towards the east. The areal extent and thickness of this aquifer are limited so the amount of water available is limited. As Surrey's population has increased its demands have correspondingly increased. These increased demands have exceeded the recharge in certain years resulting in a decline in the water level and making it necessary to acquire additional water from the North Prairie Rural Water Association starting in October 1975.

Previous Investigations

A general overview of the water resources of North Dakota is presented by Simpson, 1929, in USGS Water Supply Paper #598. On pages 250-262 and 304-305 he discusses the availability and quality of water contained within the glacial deposits and alluvium as underflow in the Souris River valley in the vicinity of Minot.

In USGS Professional Paper No. 325, Lemke detailed the geology of the Souris River loop near Minot. On pages 42, 84, 86, and 88 he mentions the bifurcating channels north of Surrey and discussed the age of the deposits and the depositional environment.

North Dakota Ground-Water Study No. 54 by LaRocque, Swenson and Greenman (1963a) is a study of the 4300 square miles of the Crosby-Mohall area of North Dakota which includes the Souris River loop. It provides a general overview of the occurrence of ground water in bedrock and glacial aquifers with no specific reference to the Surrey area. Plate 1 of the report displays the occurrence of flowing wells from 1911 to 1921 and includes those found in the Surrey area. LaRocque, Swenson, and Greenman (1963b) contains the tables of data collected during the study and is available for inspection at the

U. S. Geological Survey or the North Dakota State Water Commission, Bismarck, North Dakota.

In 1964, Froelich, North Dakota Ground Water Study #58, completed a survey of the ground-water resources of the Surrey area which resulted in the development of their present water supply. This study details the bifurcating channels around Surrey with emphasis on the geology and geomorphology of the glacial deposits. Much is presented on the depositional and erosional environment and the resultant areal extent, thickness and hydrologic characteristics of the deposits.

In North Dakota State Water Commission Ground Water Study No. 11, Pettyjohn and Hutchinson (1968, 1971) studies the ground-water resources of Renville and Ward Counties. The basic data report was compiled by Pettyjohn and published in 1968. The ground-water resources report was written by Pettyjohn and Hutchinson and published in 1971. In the discussion of the glacial deposits on pages 89-90, they mention the deposits near Surrey as ice marginal features.

Glacial Units

Lemke (1960) outlined the glacial deposits to be found east of Minot near the Surrey area. All deposits are resting on bedrock of the Tongue River member of the Fort Union Formation of Paleocene Age. These deposits are: ground moraine, ice-margin deposits, glacio-fluvial deposits and undifferentiated and Lake Souris deposits. Three advances of the Wisconsin ice sheet covered the area. The last either buried or eroded the previous two as it advanced from the northwest. The older deposits are exposed in the walls of the Des Lacs River and Souris River valleys. All surface deposits are assigned to the Mankato substage of the Wisconsin ice sheet.

The Surrey area is characterized by a maze of bifurcating meltwater channels. It is likely that the channels formed among several blocks of stagnant ice and carried meltwater from them. The channels have gently rounded bottoms that contain only 0'- 15' of outwash derived from the till and composed of clay, silt, and small patches of sand (Froelich, 1964).

Encountered in the area were the two glacial outwash materials described by Lemke (1960) mentioned above. A discontinuous surface gravel overlies a portion of the study area as noted in the test hole logs and cross sections (Tables 1 and 2). This outwash material is thin, ranging from 2 to 10 feet. Occasionally, the gravel is incorporated into the soil as observed by Lemke. The second outwash material encountered was the overridden ice marginal deposits. These are found as two relatively thick, confined sand and gravel deposits and numerous small confined sand lenses.

Availability of Ground Water

In the Surrey area both bedrock and glacial aquifers are utilized for domestic and stock needs. Froelich (1964) assessed the potential for development of the bedrock formations. The Pierre Formation and formations below it are considered unsuitable for a municipal supply due to poor chemical quality and economic reasons. The Fox Hills Formation is composed of sand, sandstone, lignite, and silty and sandy clay. Electric log interpretation indicates that the Fox Hills was encountered at a depth of 435 feet at Surrey. Oil test holes and state drilled test holes reveal a thickness of about 103 feet for the Fox Hills Formation in the Surrey area. It is likely the Fox Hills is under artesian conditions similar to those further west. The Hell Creek Formation possesses less potential for development and may only be suitable for domestic and stock applications. It is composed of bluish gray silty to

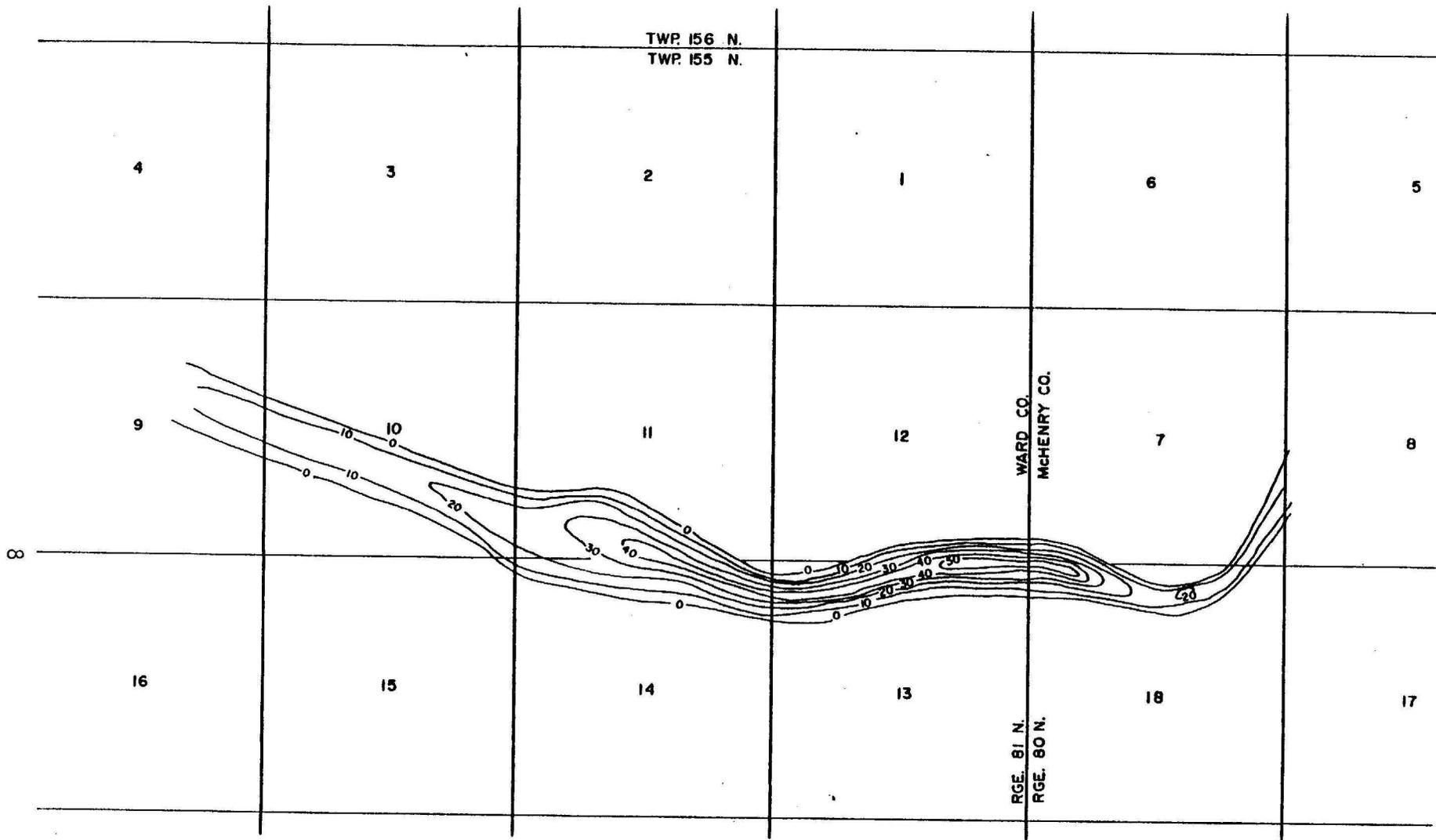


FIG. 3 AQUIFER BOUNDARY AND THICKNESS

sandy clay. The Cannonball Formation is predominantly composed of silty to sandy clay with only a few relatively permeable sandstones from which yields are expected to be low. Several wells utilize this formation for domestic and stock purposes but it was considered inadequate for municipal purposes. The most frequently utilized bedrock formation is the Tongue River which directly underlies the glacial drift. It is composed of silty and sandy clay with some shale, sandstone, lignite, and silt. Permeable strata are sporadic and fine grained and yields are adequate for domestic and stock applications only.

The unnamed glacial aquifer which is the subject of this study is located northeast of Surrey in Township 155 North, Range 81 West, Sections 9 through 14 and Township 155 North, Range 80 West, Sections 7, 8, and 18. Test drilling indicates it trends west from the McHenry County line along the north edge of Sections 13 and 14, across the southwest corner of Section 11, through the center of Section 10 into Section 19 where it either thins considerably or is truncated by erosion (fig. 3). It continues east from Section 13 into McHenry County into Section 18 where it rapidly thins and is truncated by erosion. The remnant of the aquifer crosses the southeast corner of Section 7 and passes into Section 8. This directional trend roughly corresponds to a bedrock topographic low revealed in test holes #11080, #11077, #1199, #11102, and #11759 (table 1 and 2). The aquifer generally occupies the deepest part of this structure except in test holes #11072, #9559, and #11071, where it drapes over the south flank of the trough.

Depth to the aquifer ranges from 18 to 82 feet. It ranges from 0 to 50 feet thick. It is predominantly composed of fine sand with thicker sections composed of fine sand to gravel and exhibiting cyclic graded bedding. Fig. 3

presents the areal extent and variation of thickness of the aquifer. The thickest section occurs along the McHenry County line then becomes thinner to the east and west. The aquifer usually directly overlies bedrock though there can be as much as 20 feet of intervening till.

An irrigation well located in 151-81-11cdc penetrates 25 feet of the aquifer and furnished some information on its water yielding characteristics. The well is 50 feet deep and is screened from $37\frac{1}{2}$ to 50 feet. When completed on May 4, 1975, it was test pumped at 500 gpm for 4 hours with a reported drawdown of 4 feet. The owner is presently allowed to appropriate 128 acre-feet/year at a rate of 500 gpm.

The hydrographs for the observation wells in 155-81-11CCC and 11CCD (fig. 4 and 5) show the effects of pumping from the irrigation well. The total water used each year is listed. The total monthly precipitation for each year is included in figs. 4 and 5. There appears to be no correlation between the precipitation and the water level fluctuations. It is not known how much water was used the first year or if this use resulted in the apparent water level change. The water levels for the following years exhibit a fairly consistent cycle of decline and recovery with a slight overall recovery due to a reduction in withdrawal.

The aquifer is confined within a relatively impervious clay till which allow only small amounts of water to percolate into the aquifer. Recharge through the till may be increased where surface gravels are present above the aquifer which retain precipitation and may increase the amount of water available for downward leakage. The aquifer may receive direct recharge from surface gravels, streams, and ponds if they intersect. Recharge is limited, but, as indicated by the hydrographs, is sufficient to replace the water withdrawn.

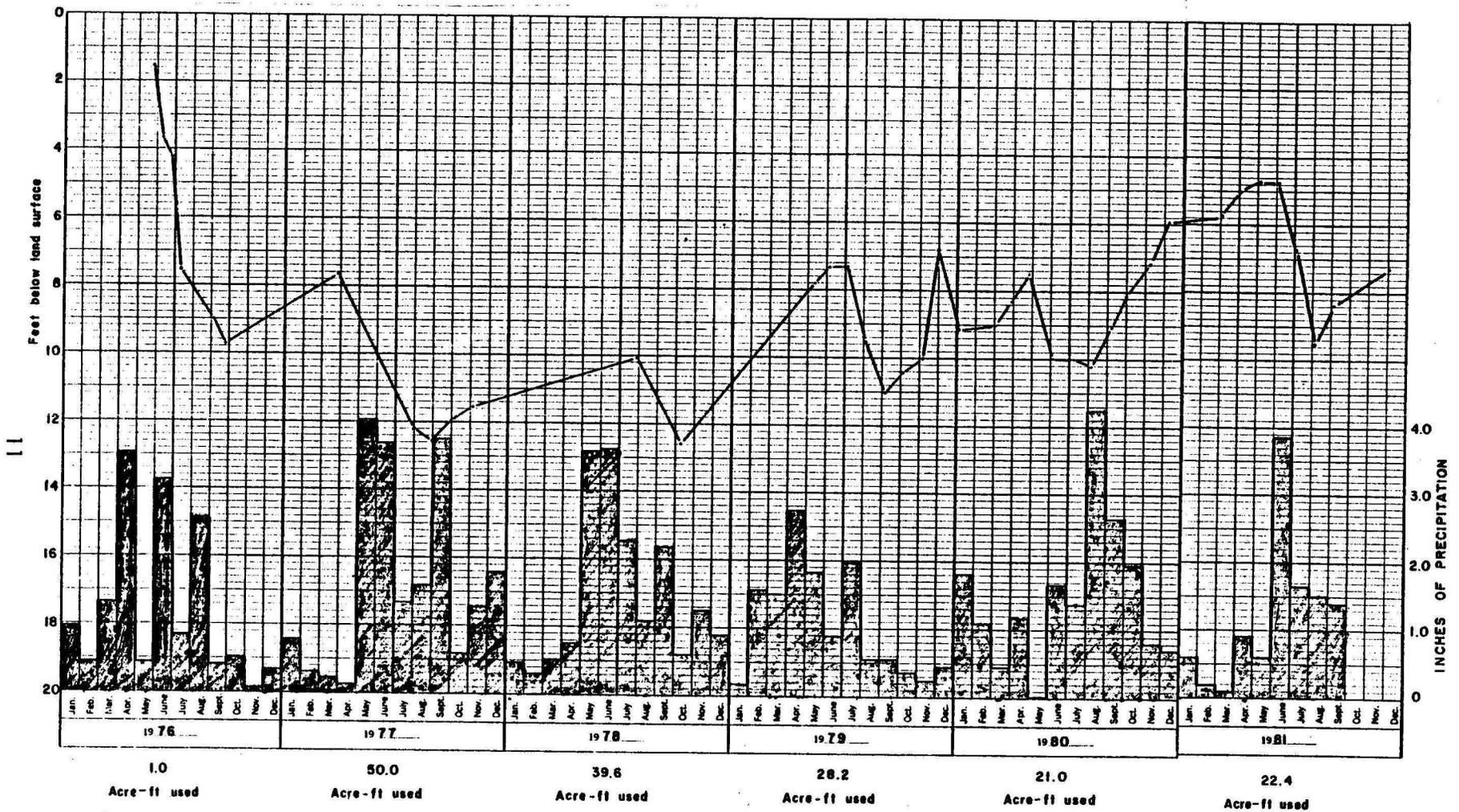


FIG. 4 - Hydrograph for 155-81-II ccc

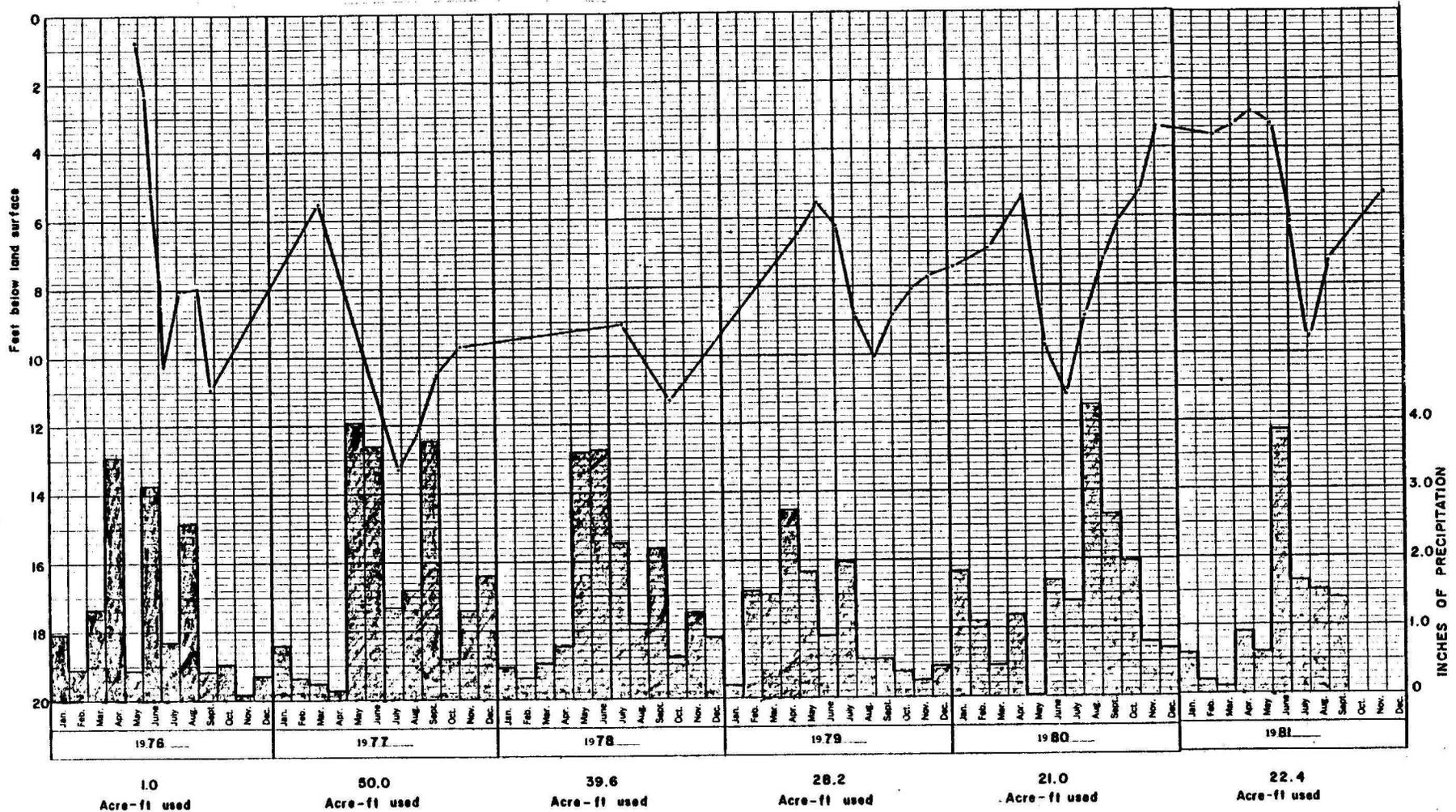


FIG. 5 - Hydrograph for 155-81-11 ccd

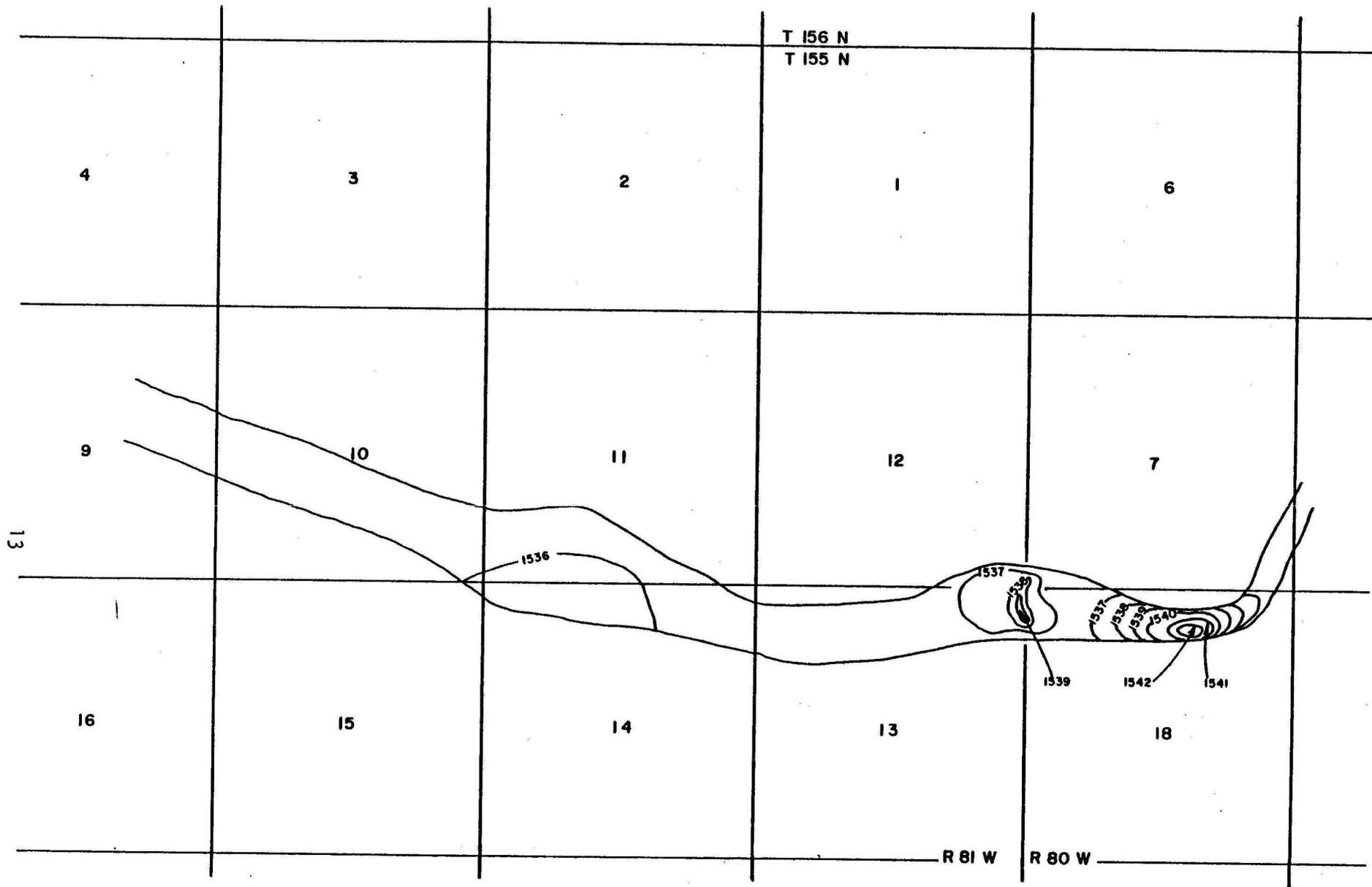


FIG. 6 POTENTIOMETRIC SURFACE MAP

The general direction of flow of the ground water is to the east. The potentiometric map (fig. 6) shows three anomalous areas which appear to be controlled by topography. The areas of high water levels are topographically high and the area of low water level is topographically low and contains a slough. Water levels in individual observation wells are noted on the logs of test holes (Table 1).

Water Quality

Water samples for chemical analyses were collected from the seven observation wells completed in the aquifer. The result of these analyses is shown in Table 3. An explanation of the significance of each constituent and how it may limit use of the water is shown in Table 4. The highest quality water available occurs in the vicinity of 155-81-13AAA. As the water moves from this area of high water levels to the areas of low water levels minerals are dissolved, decreasing the quality of the water. The poorest quality water available occurs in the vicinity of 155-81-11CCD, 155-80-18ABAD and 155-80-18ABCA.

Pettyjohn and Hutchinson (1971) described the general water quality in the bedrock aquifers above the Pierre Formation in Ward County. No wells are known to be completed in the Fox Hills Formation. In southwestern North Dakota wells completed in the Fox Hills yield slightly to very saline water, soft, and generally high in fluoride. It is usually acceptable for domestic and municipal use. The Hell Creek Formation yields water that may be saline and has a high percent iron, sodium, and sulfate. The Cannonball and Ludlow Formations yield water of either the sodium chloride, sodium bicarbonate chloride, or sodium chloride bicarbonate type. The Tongue River Formation generally yields a sodium bicarbonate type water.

Summary

The aquifer was traced for a linear distance of about four miles. It ranges in width from $\frac{1}{2}$ mile to less than $\frac{1}{8}$ mile. Thickness ranges from less than 10 feet at the east and west extremes to 50 feet near the center. Water quality is extremely variable over a short distance, the best quality being found in the deepest section. Water levels appear to be controlled by topography, the highest water levels found where the aquifer is overlain by a topographically high area and the low water levels overlain by topographically low areas.

The limited areal extent, generally thin saturated thickness, and variable but generally poor water quality would exclude this aquifer as a potential municipal water supply. It is doubtful this aquifer could provide the sustained quantity and quality of water to meet Surrey's projected future needs and justify the costs of development.

Table 1 - Logs of Test Holes

The following test hole logs are compiled data of geologist's sample descriptions, driller's logs, and geophysical logs which include resistance and spontaneous potential. Grain-size classification throughout this report uses K. C. Wentworth's scale from Compton (1967). Color descriptions are of wet samples and are based upon color standards of the national research council (Goddard, et.al., 1948). Test holes completed as observation wells have surveyed elevations, all others are inferred from topographic maps published by the U. S. Geological Survey. Observation wells are composed of 1½" pvc plastic casing and screened bottoms. Well depths and screened producing intervals (S.I.) are also noted.

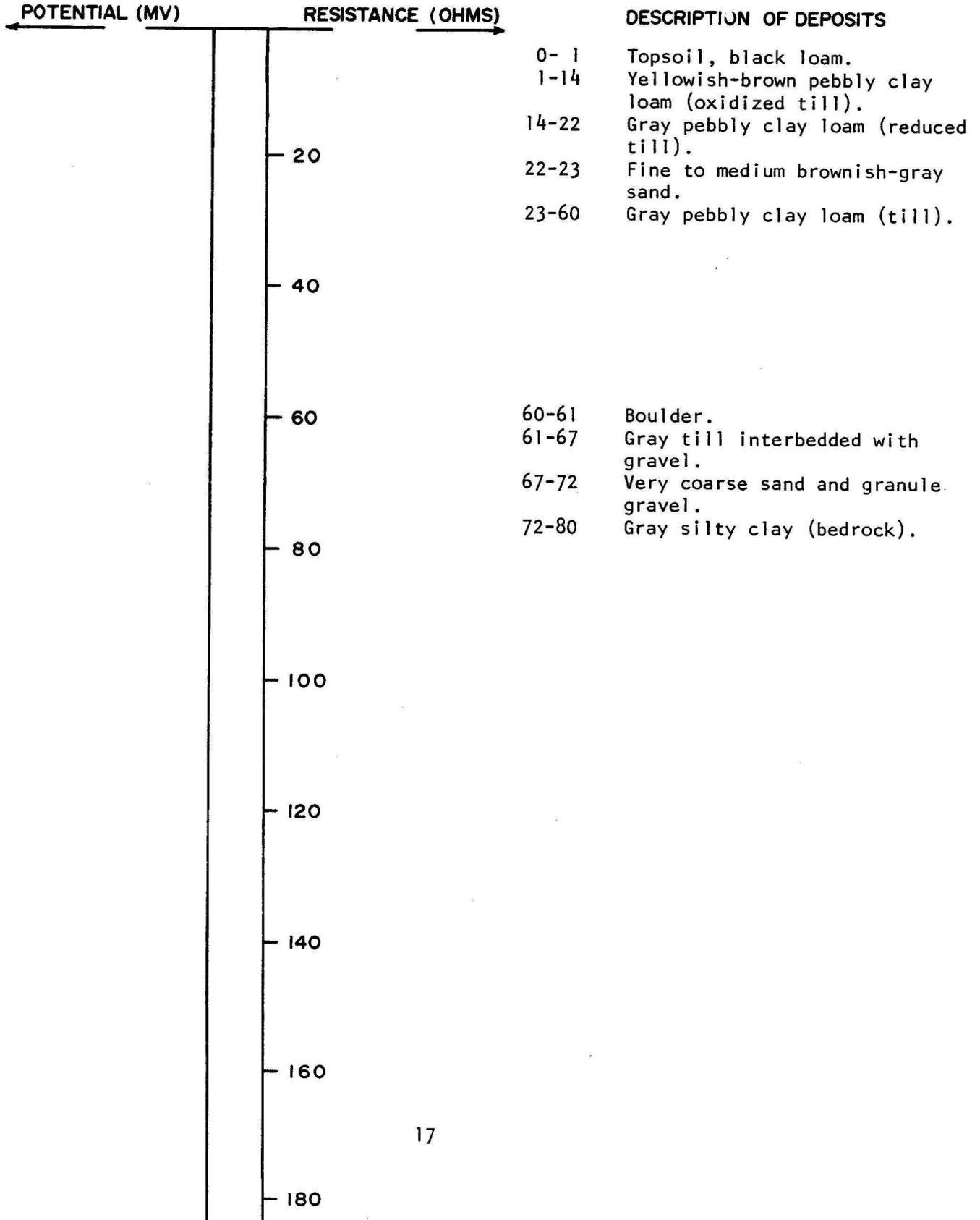
TEST HOLE 11779

LOCATION: 155-80-08CBBC

DATE DRILLED: 10/8/81

ELEVATION: 1540
(FT, MSL)

DEPTH: 80
(FT)



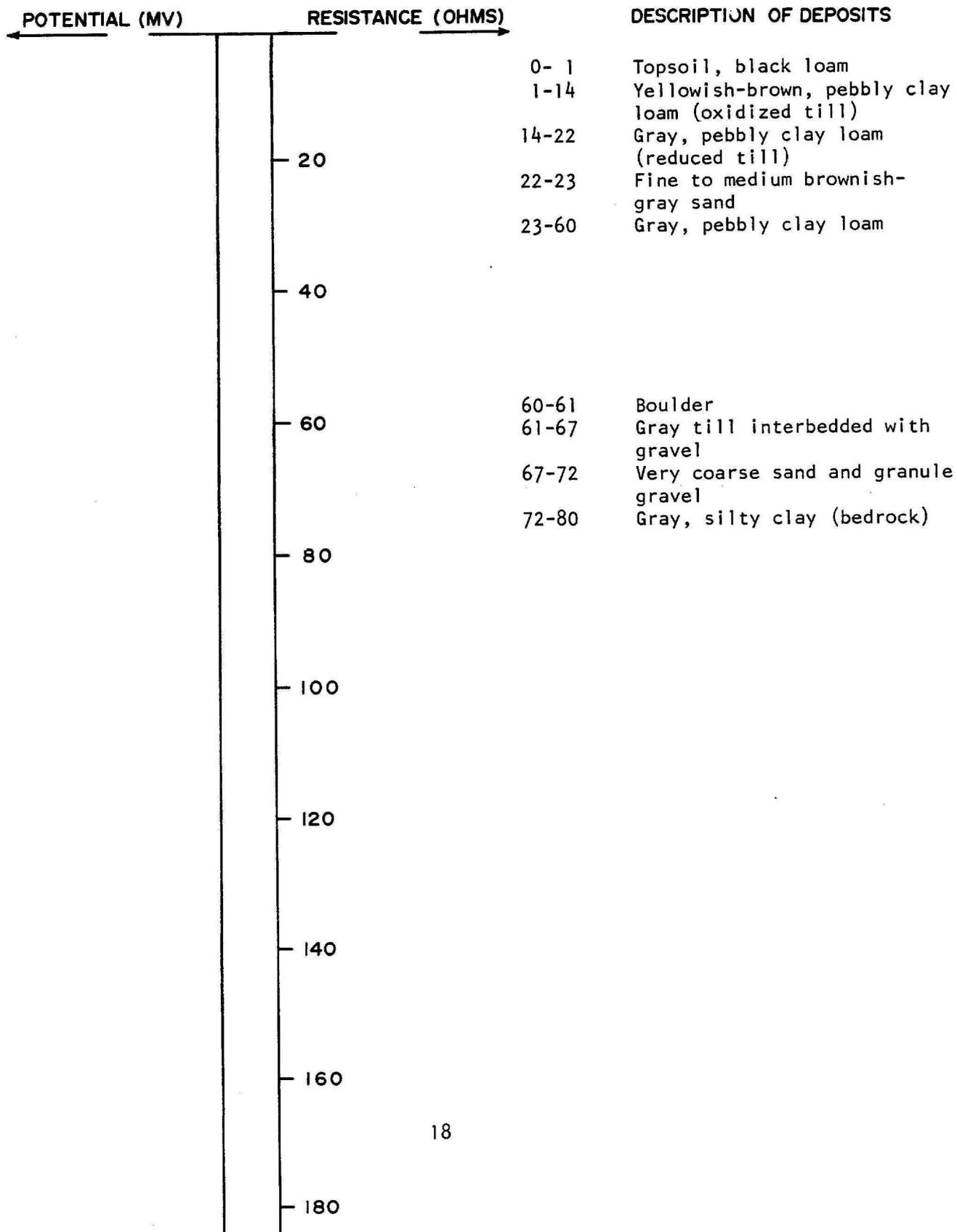
TEST HOLE 11779

LOCATION: 153-80- 8CBBC

DATE DRILLED: 10/8/81

ELEVATION: 1540
(FT, MSL)

DEPTH: 80
(FT)



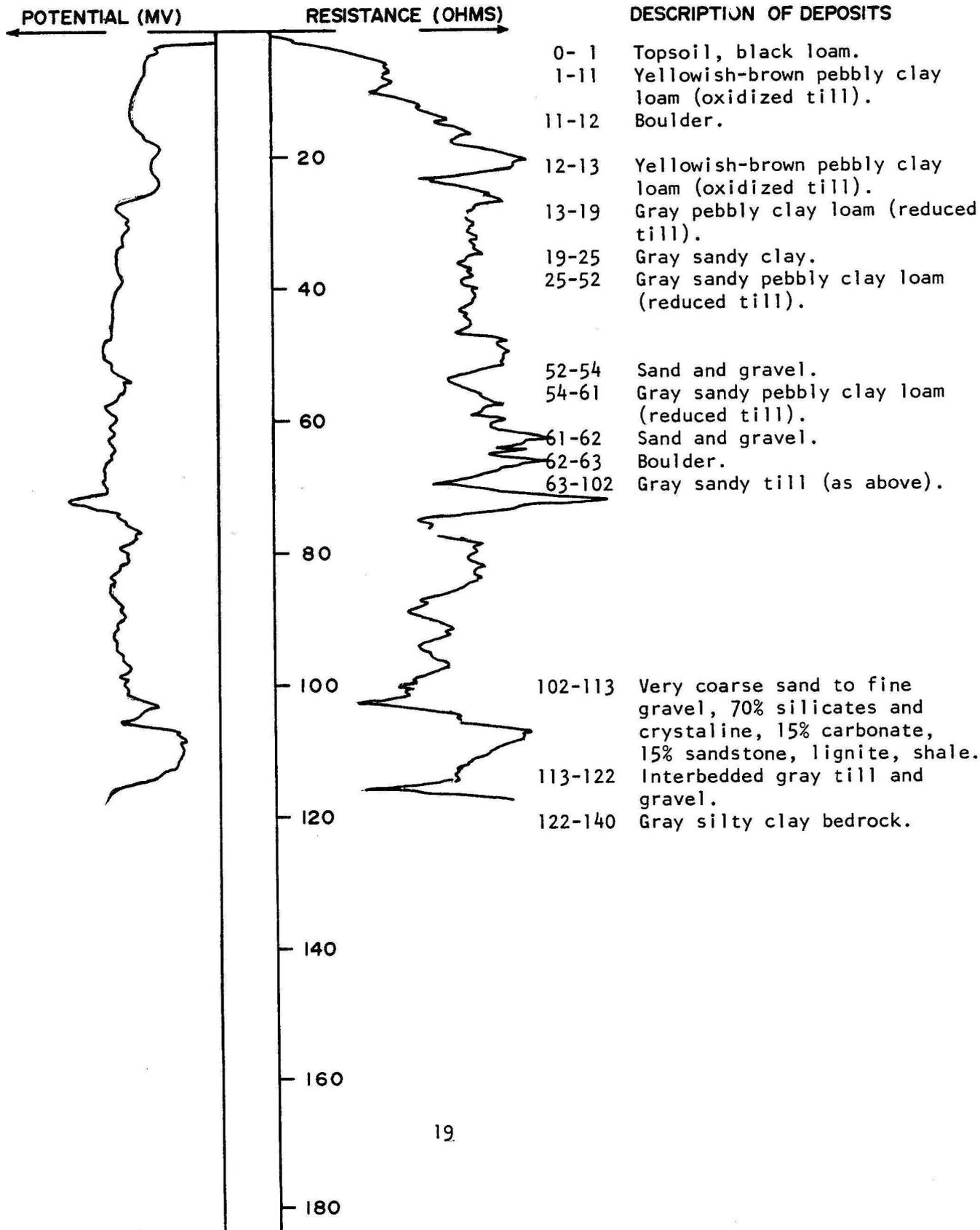
TEST HOLE 11774

LOCATION: 155-80-8CBC

DATE DRILLED: 10/8/81

ELEVATION: 1540
(FT, MSL)

DEPTH: 140
(FT)



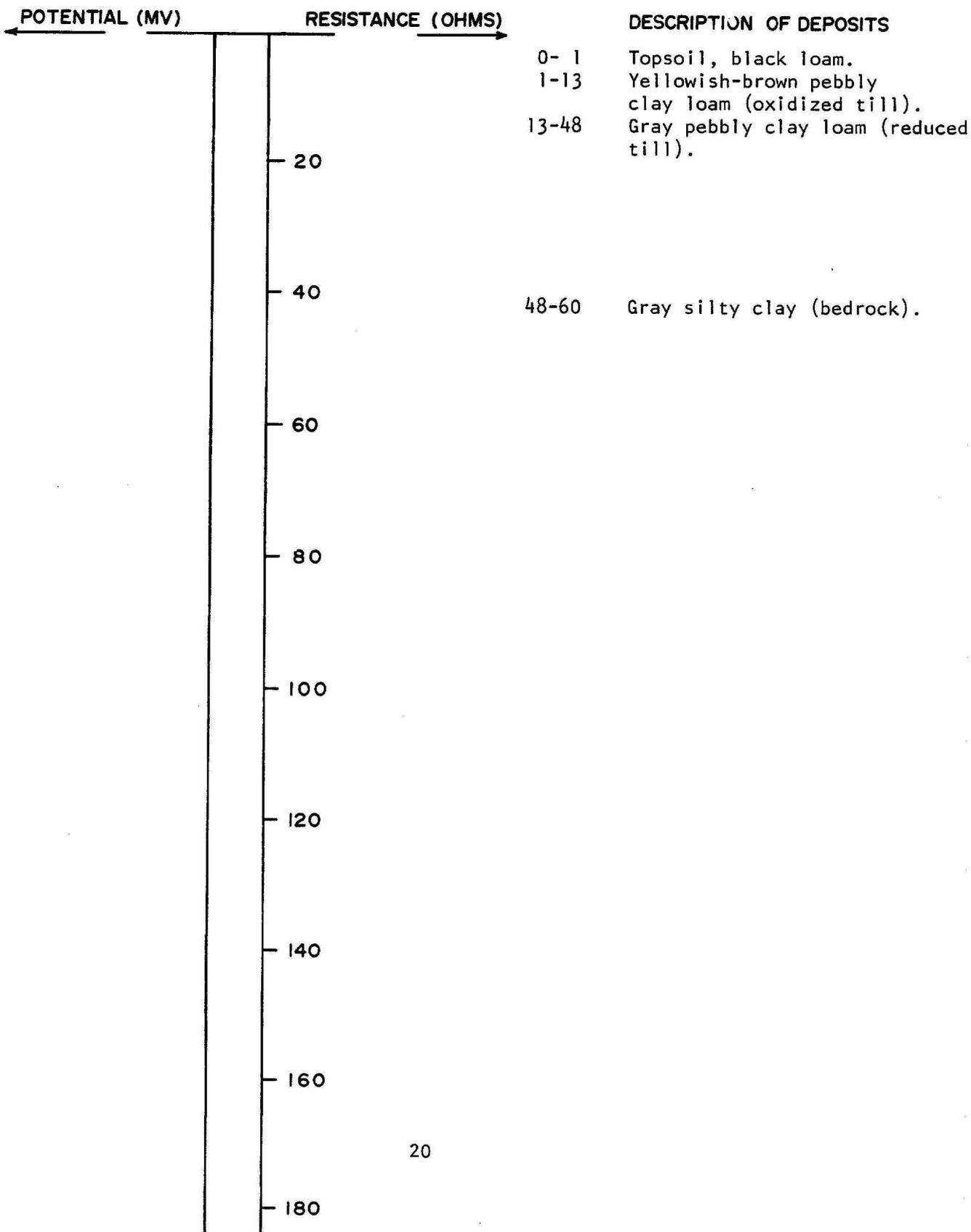
TEST HOLE 11773

LOCATION: 155-80-8CCBC

DATE DRILLED: 10/7/81

ELEVATION: 1545
(FT, MSL)

DEPTH: 60
(FT)



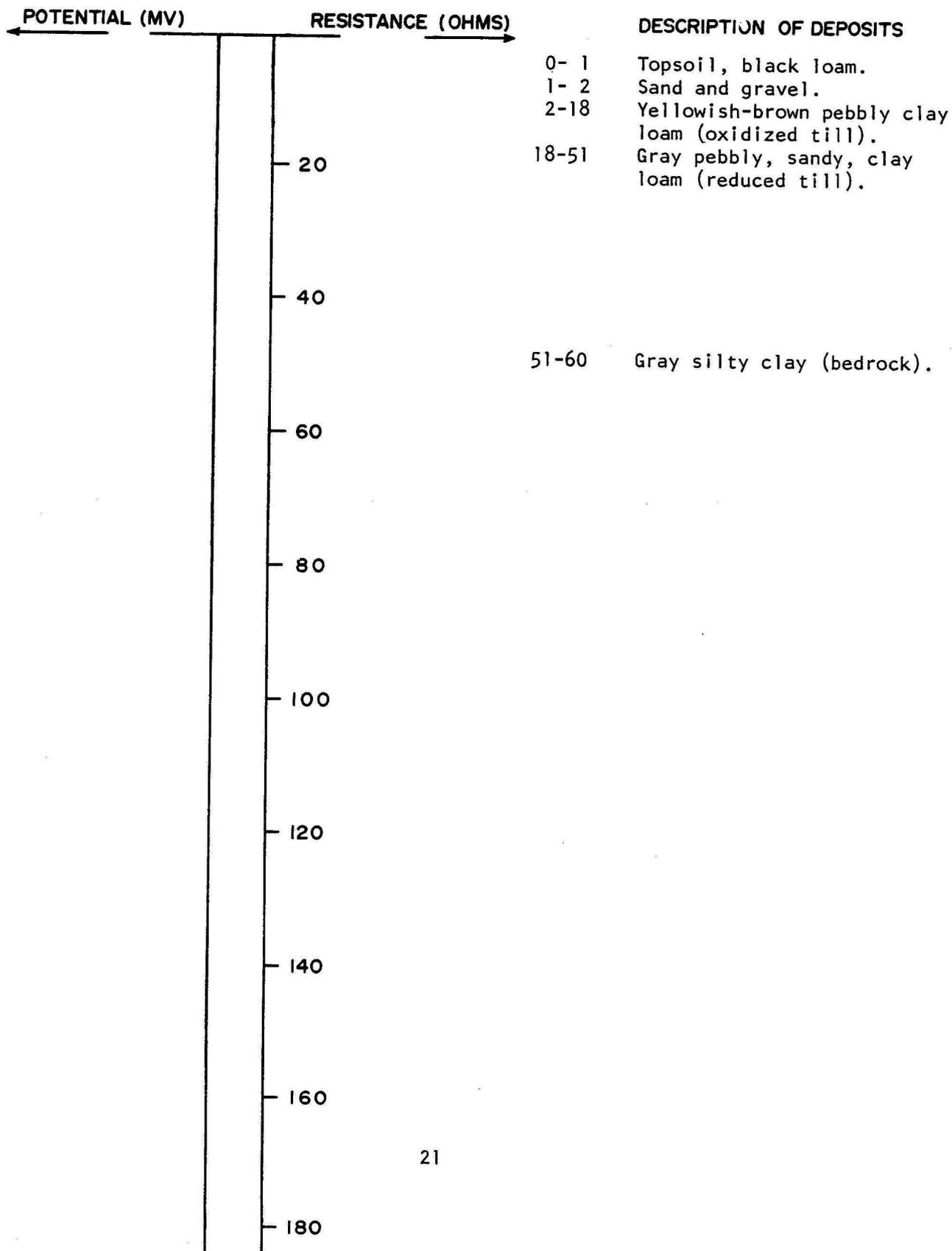
TEST HOLE 11775

LOCATION: 155-80-8DAA

DATE DRILLED: 10/8/81

ELEVATION: 1535
(FT, MSL)

DEPTH: 60
(FT)



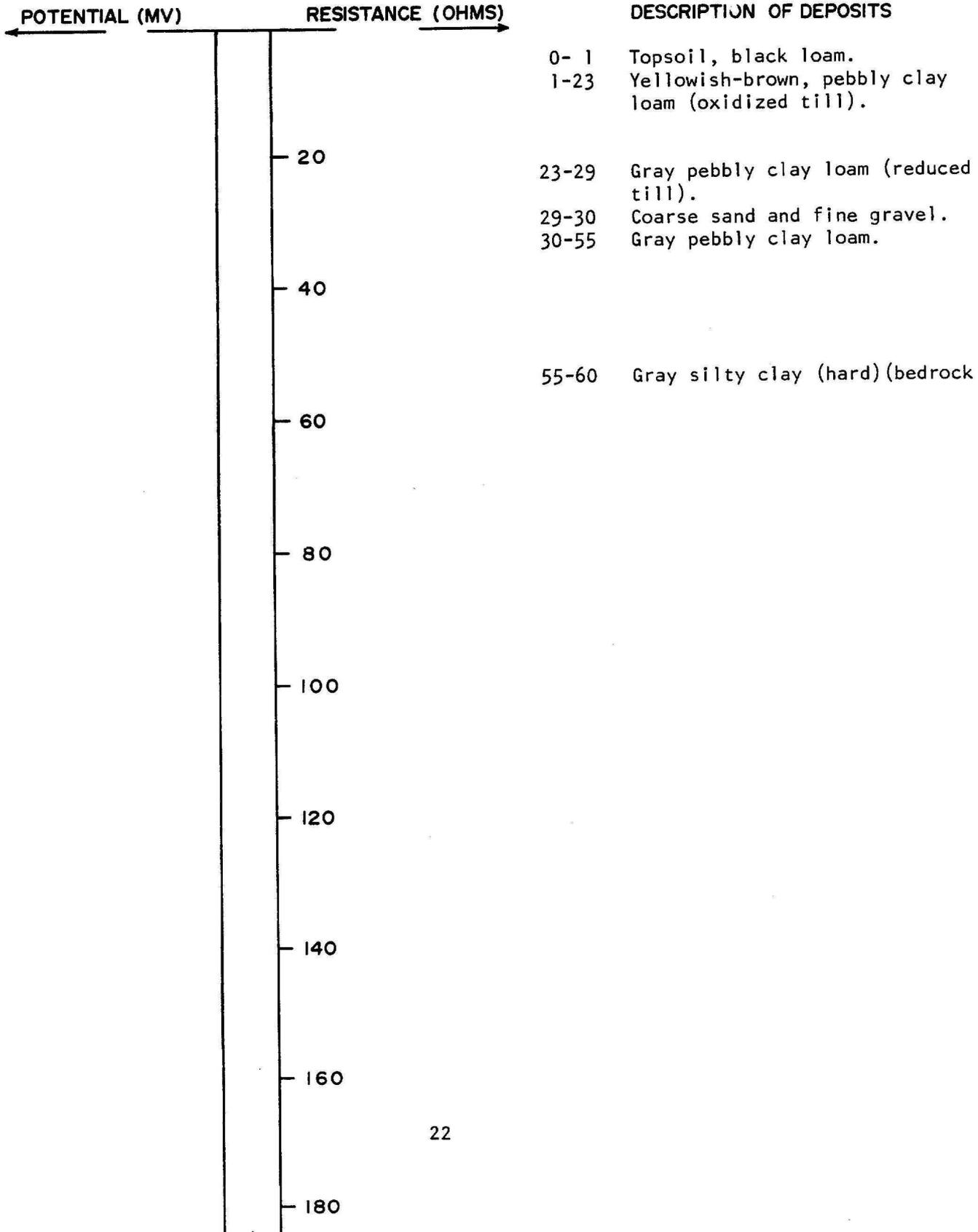
TEST HOLE 11776

LOCATION: 155-80-8DDA

DATE DRILLED: 10/8/81

ELEVATION: 1547
(FT, MSL)

DEPTH: 60
(FT)



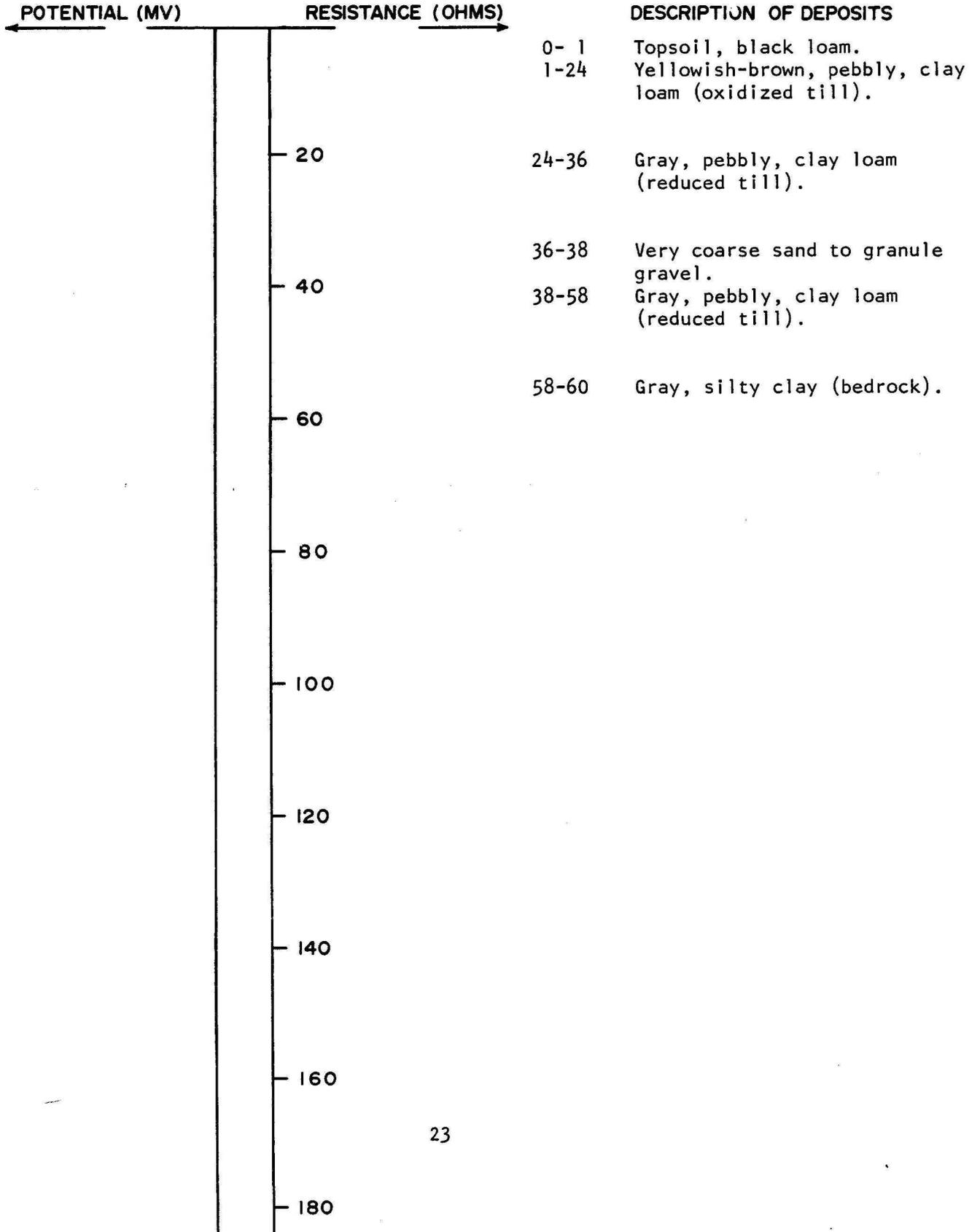
TEST HOLE 11777

LOCATION: 155-80-8DDD

DATE DRILLED: 10/8/81

ELEVATION: 1546
(FT, MSL)

DEPTH: 60
(FT)



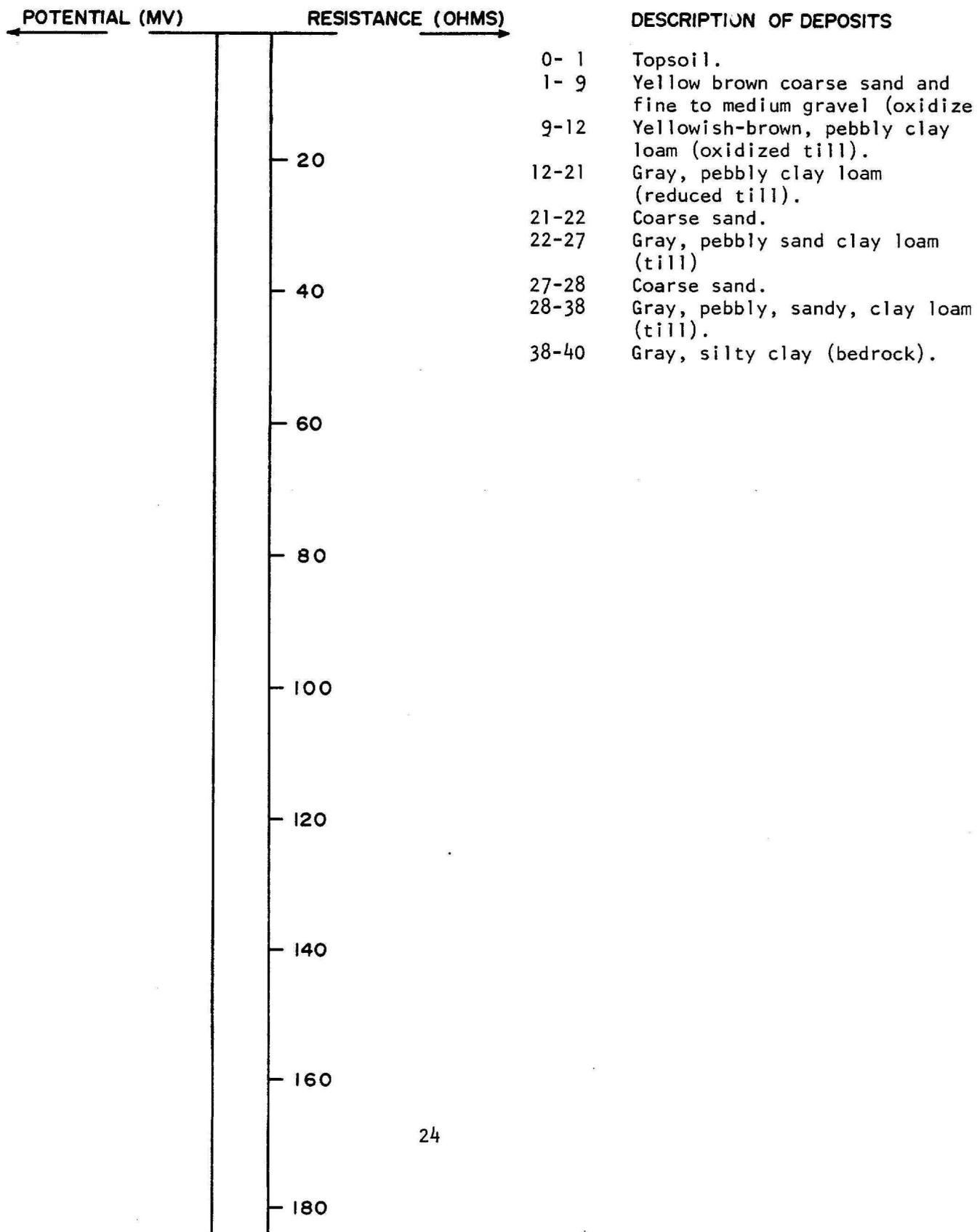
TEST HOLE 11778

LOCATION: 155-80-17AAD

DATE DRILLED: 10/8/81

ELEVATION: 1537
(FT, MSL)

DEPTH: 40
(FT)



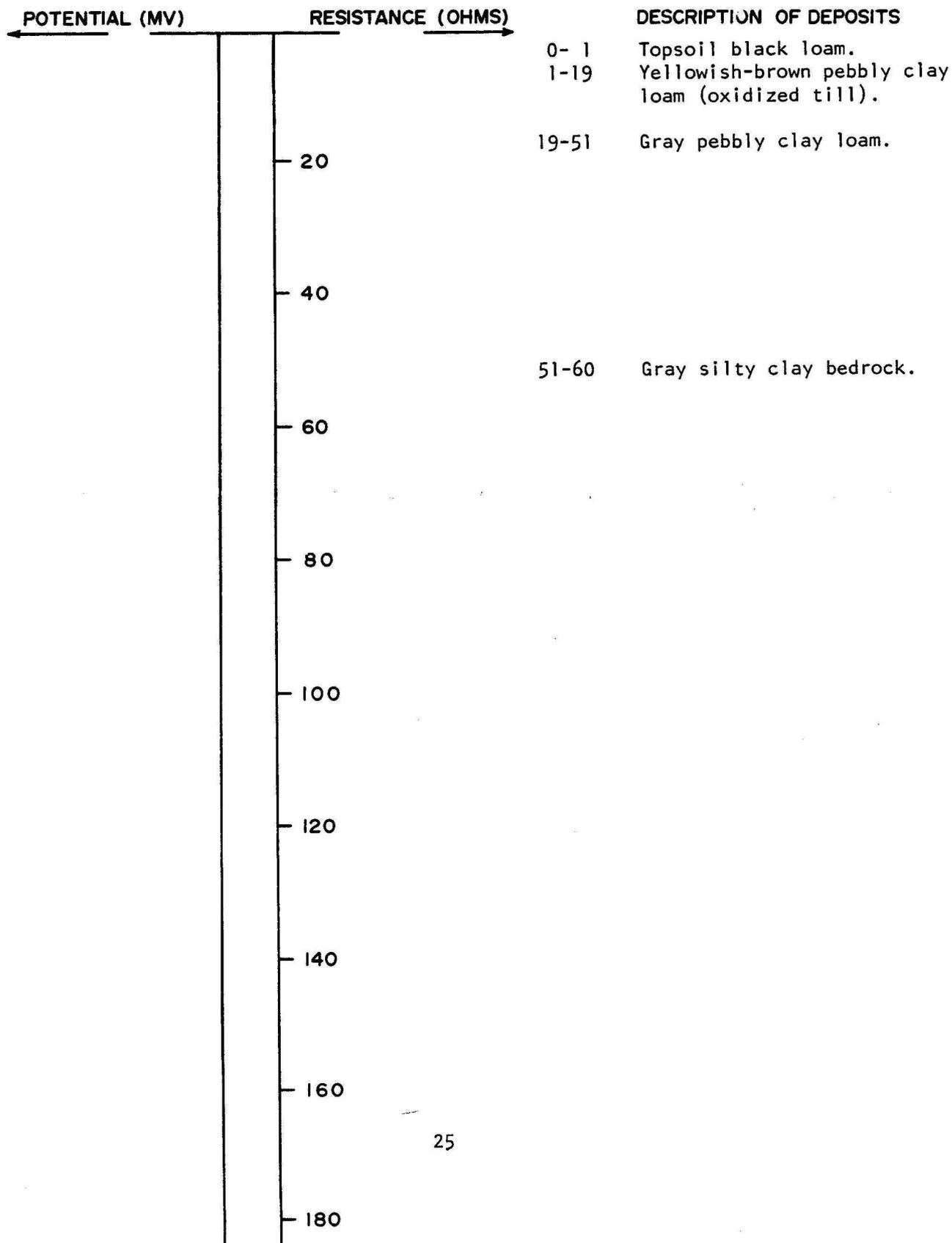
TEST HOLE 11768

LOCATION: 155-80-17BBBB

DATE DRILLED: 10/7/81

ELEVATION: 1547
(FT, MSL)

DEPTH: 60
(FT)



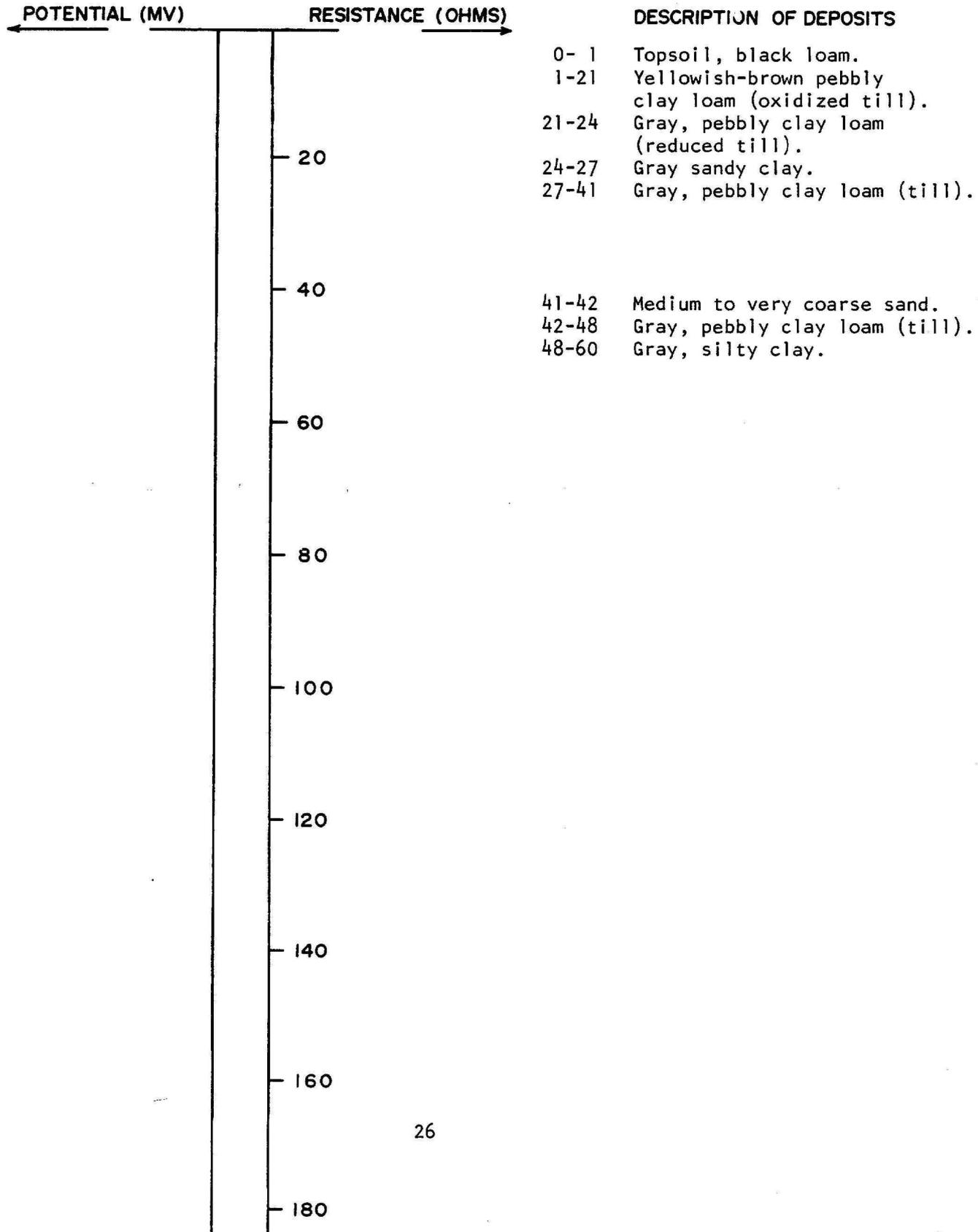
TEST HOLE 11772

LOCATION: 155-80-17BBCB

DATE DRILLED: 10/7/81

ELEVATION: 1545
(FT, MSL)

DEPTH: 60
(FT)



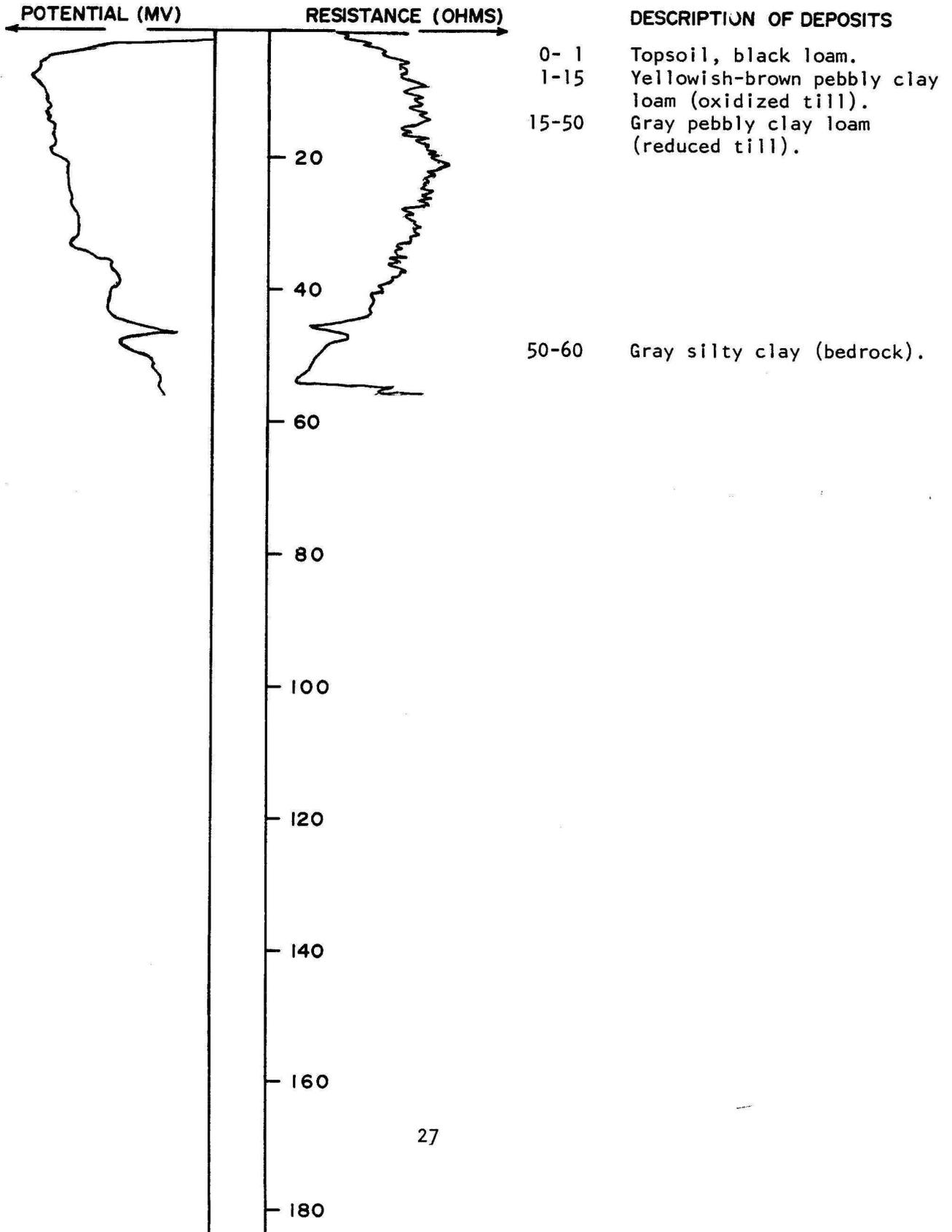
TEST HOLE 11766

LOCATION: 155-80-17BBCB

DATE DRILLED: 10/7/81

ELEVATION: 1548
(FT, MSL)

DEPTH: 60
(FT)



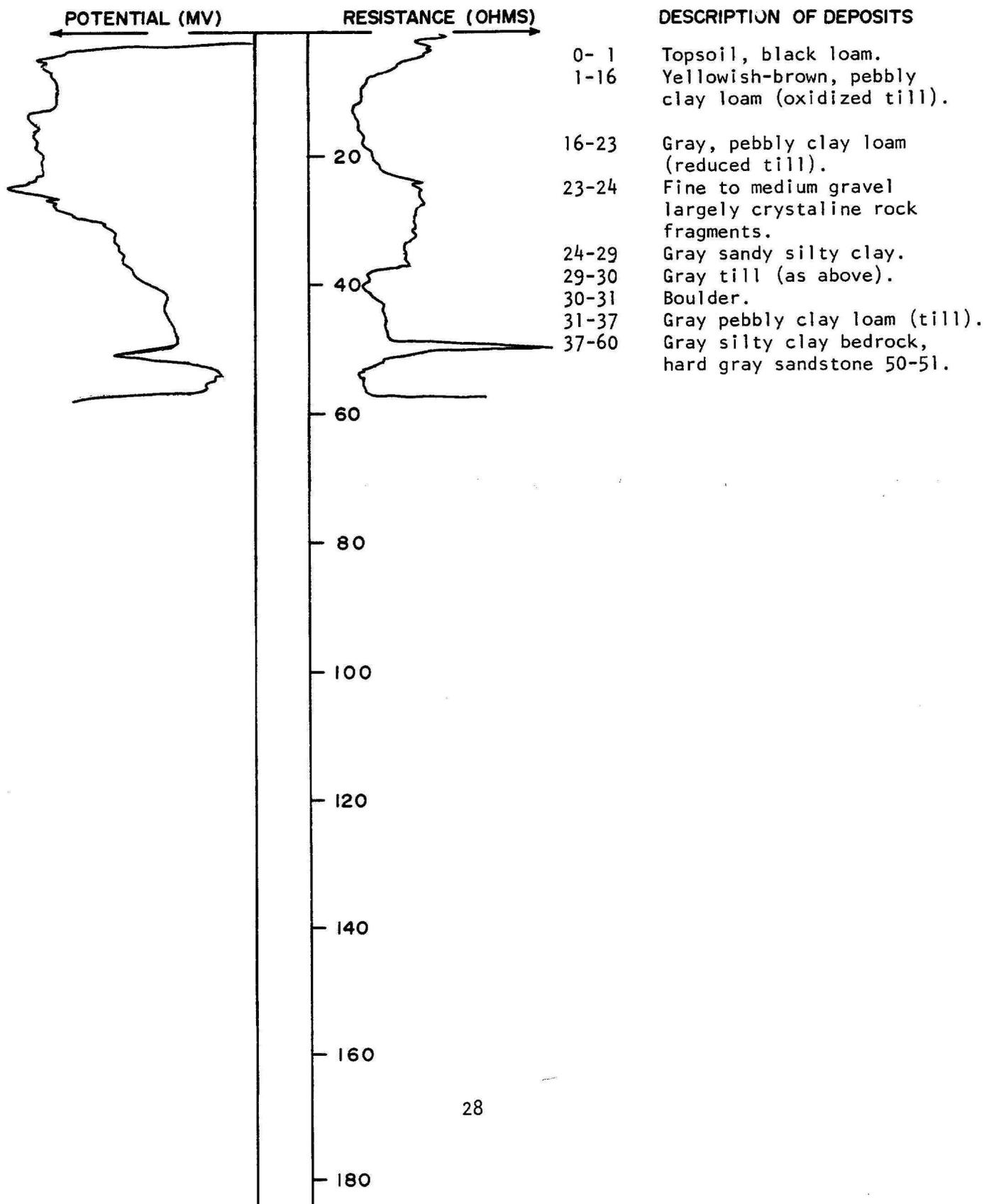
TEST HOLE 11767

LOCATION: 180-55-17BCBB

DATE DRILLED: 10/7/81

ELEVATION: 1535
(FT, MSL)

DEPTH: 60
(FT)



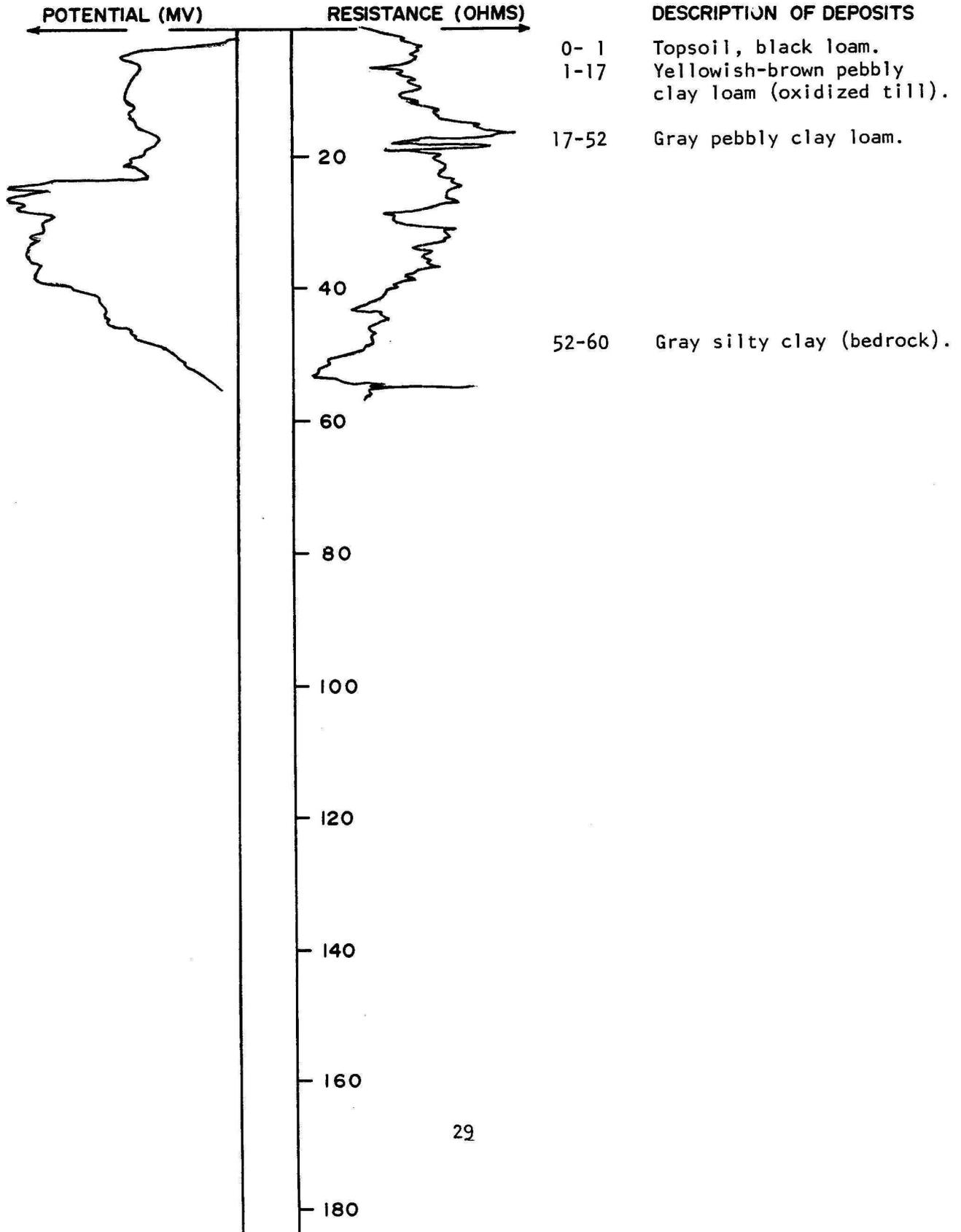
TEST HOLE 11765

LOCATION: 155-80-18AAA

DATE DRILLED: 10/7/81

ELEVATION: 1548
(FT, MSL)

DEPTH: 60
(FT)



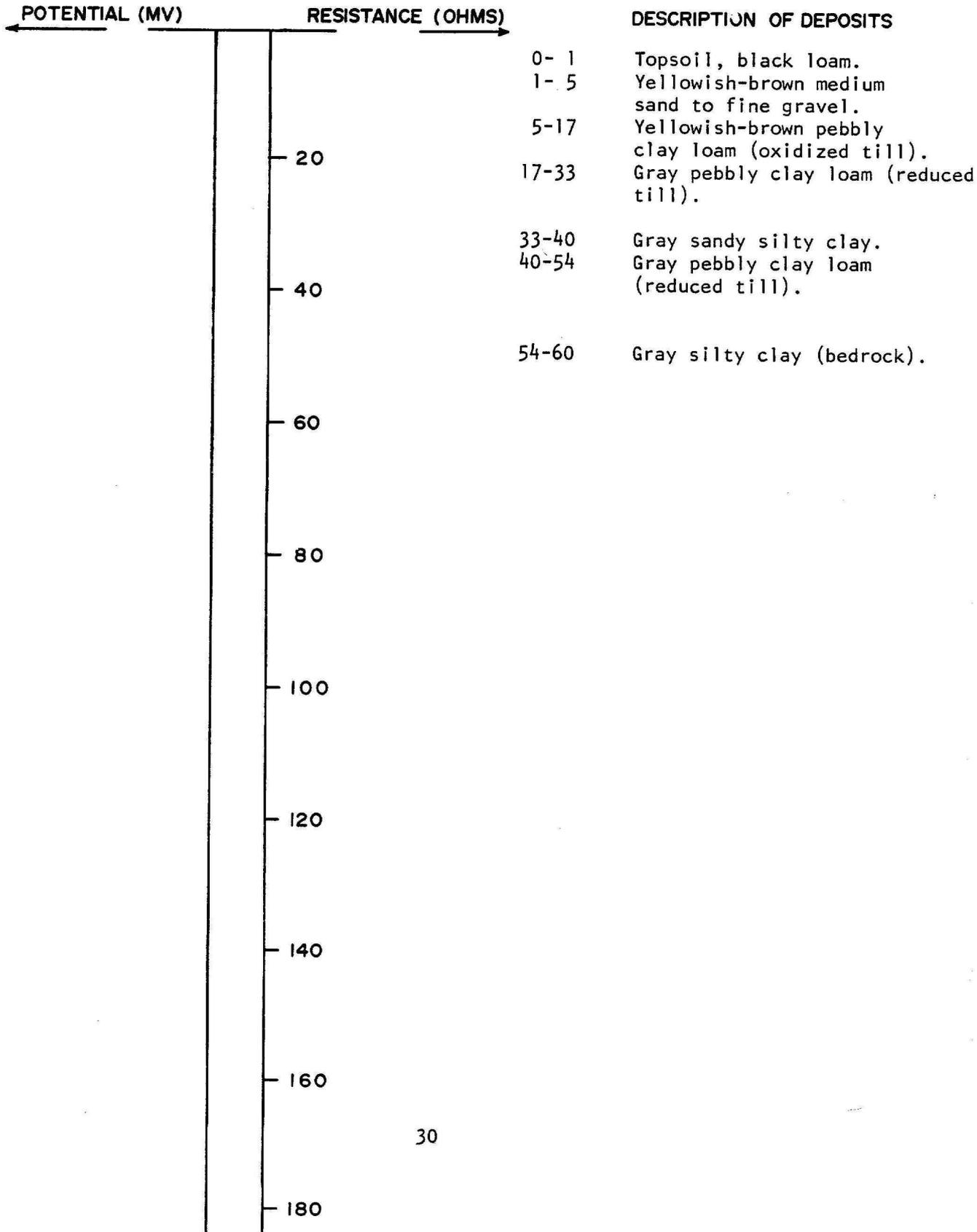
TEST HOLE 11771

LOCATION: 155-80-18AAAB

DATE DRILLED: 10/6/81

ELEVATION: 1550
(FT, MSL)

DEPTH: 60
(FT)



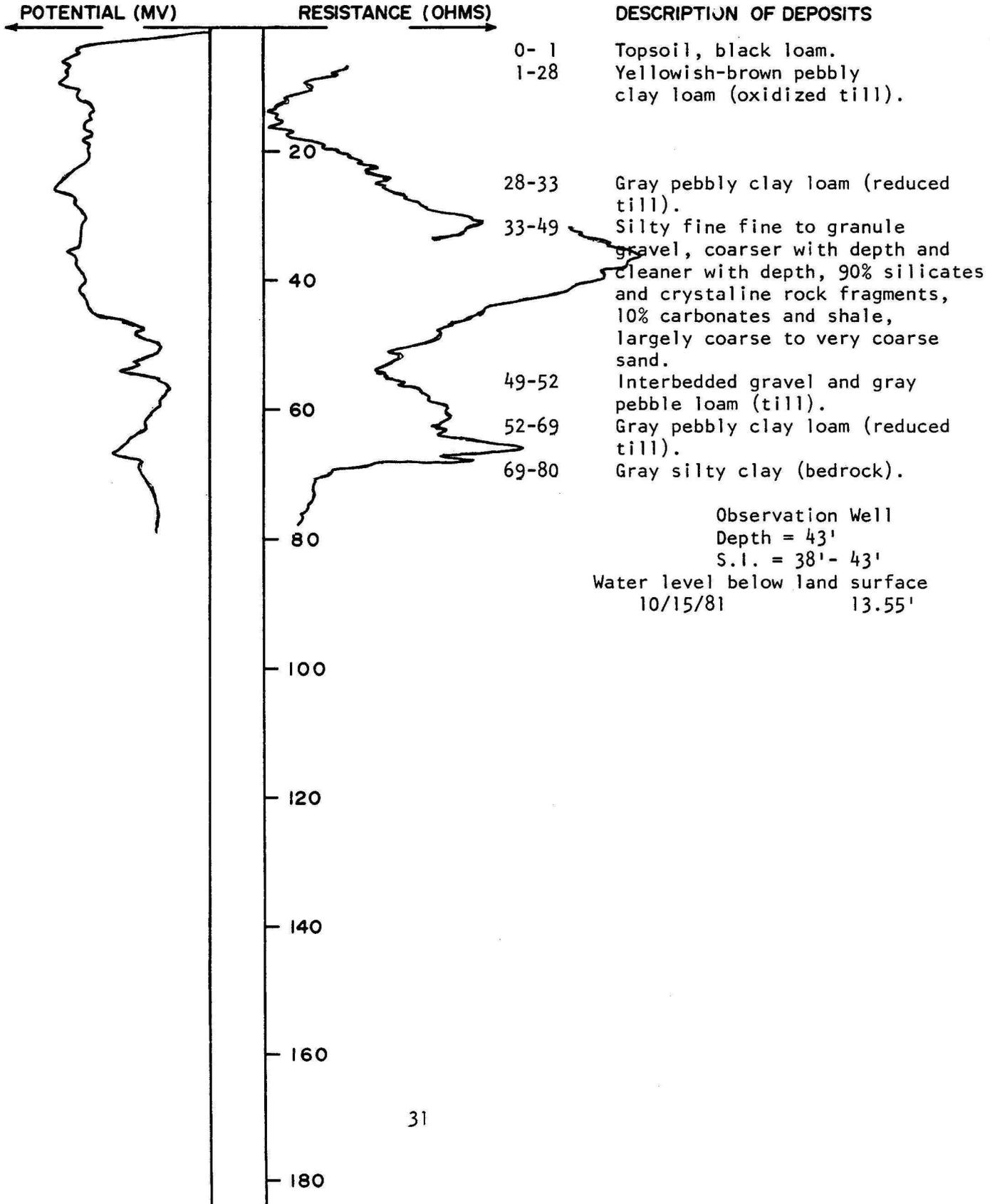
TEST HOLE 11769

LOCATION: 155-80-18AABA

DATE DRILLED: 10/7/81

ELEVATION: 1550
(FT, MSL)

DEPTH: 80
(FT)



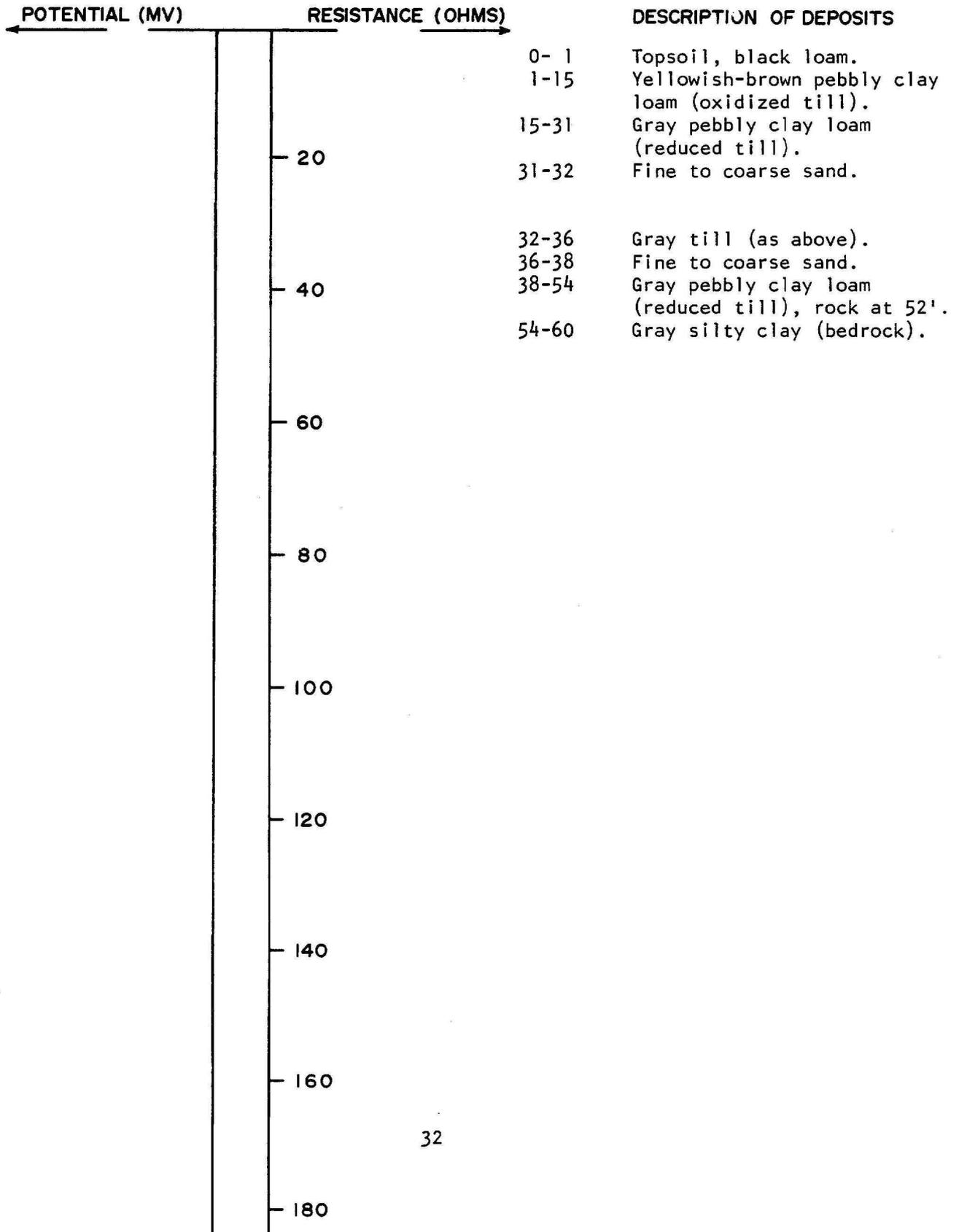
TEST HOLE 11770

LOCATION: 155-80-18AABB

DATE DRILLED: 10/7/81

ELEVATION: 1545
(FT, MSL)

DEPTH: 60
(FT)



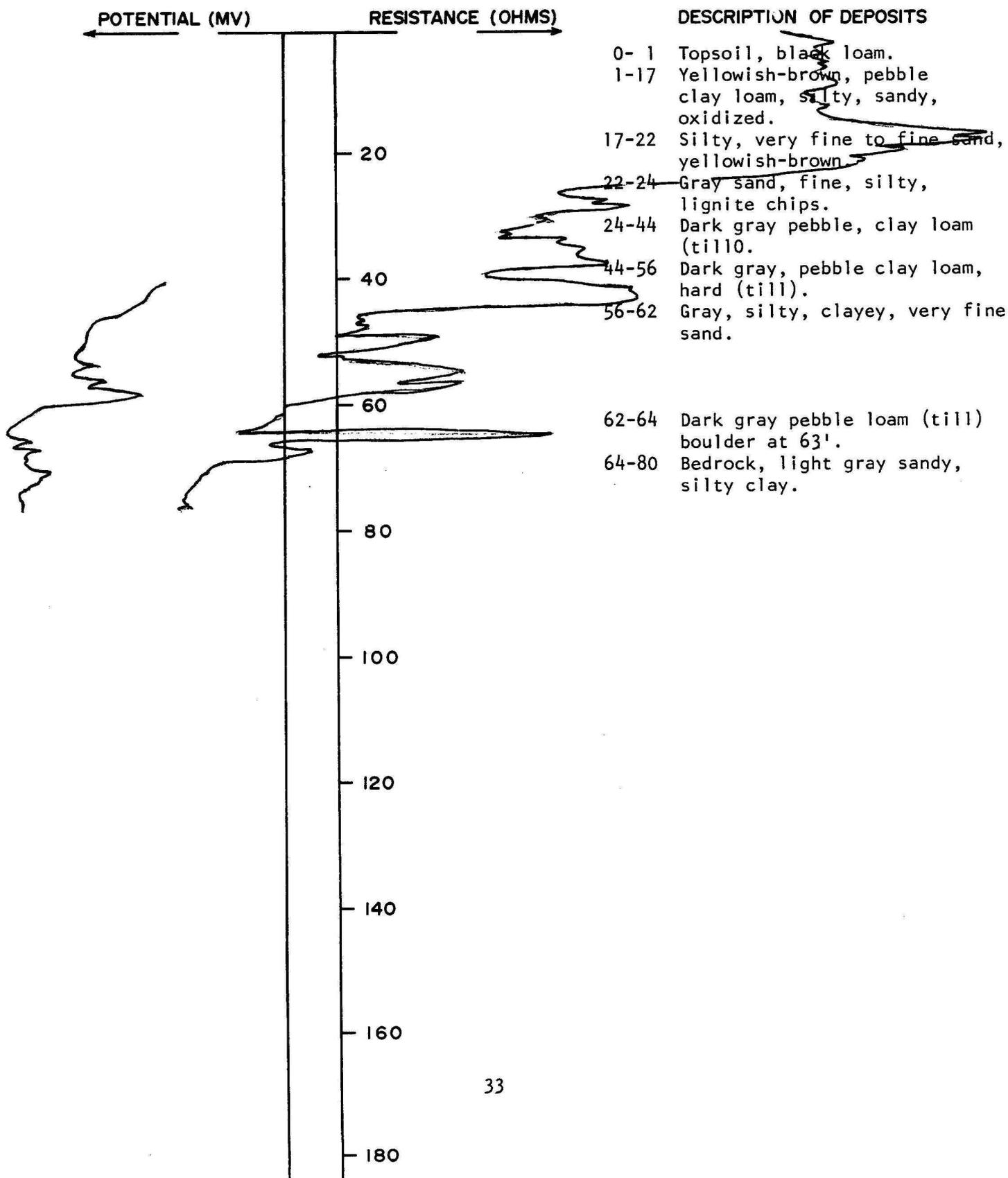
TEST HOLE 11758

LOCATION: 155-80-18ABB₂

DATE DRILLED: 10/6/81

ELEVATION: 1557
(FT, MSL)

DEPTH: 80
(FT)



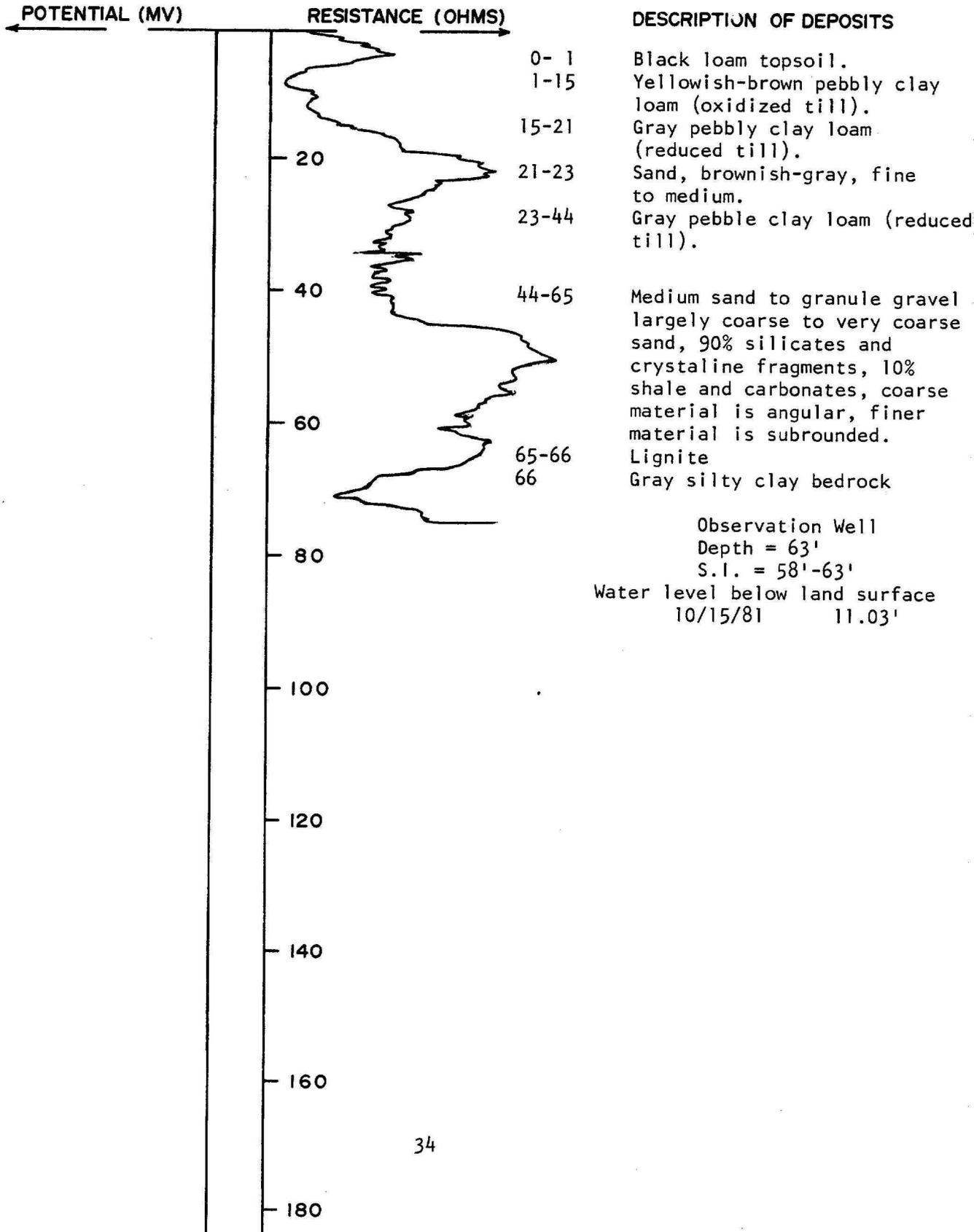
TEST HOLE 11764

LOCATION: 155-80-18ABAC

DATE DRILLED: 10/7/81

ELEVATION: 1550
(FT, MSL)

DEPTH: 80
(FT)



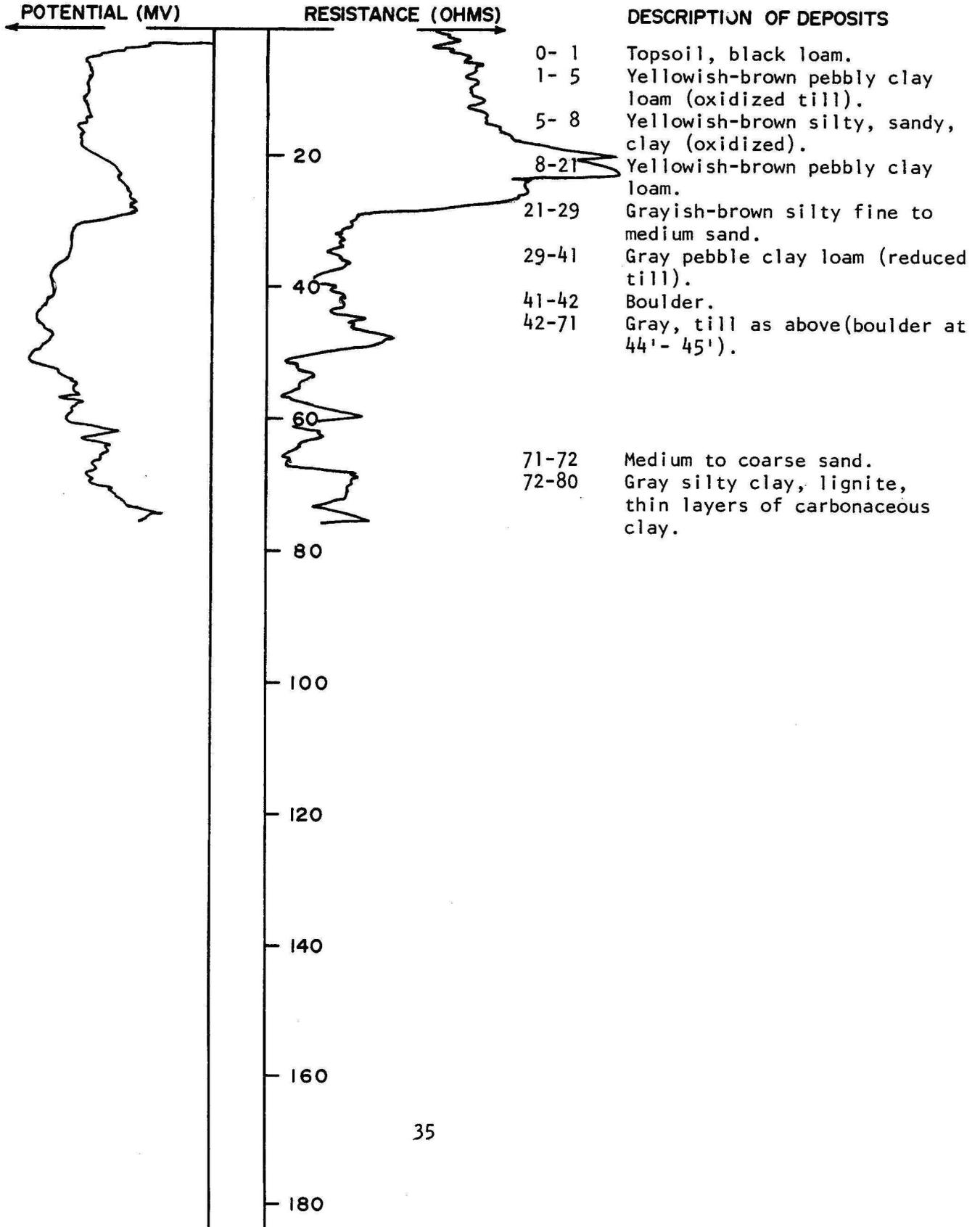
TEST HOLE 11763

LOCATION: 155-80-18ABBA

DATE DRILLED: 10/6/81

ELEVATION: 1550
(FT, MSL)

DEPTH: 80
(FT)



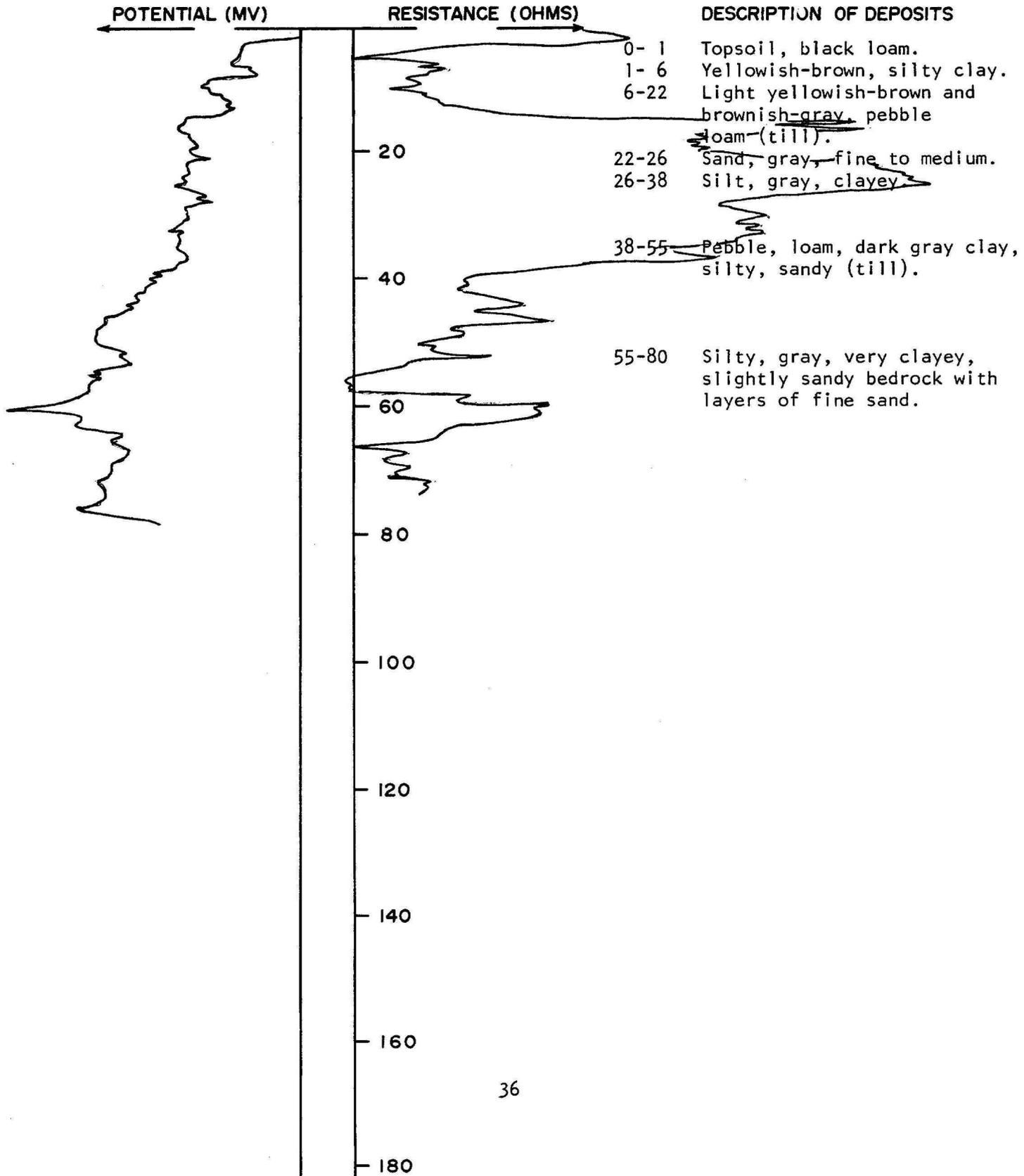
TEST HOLE 11757

LOCATION: 155-80-18ABB

DATE DRILLED: 10/6/81

ELEVATION: 1555
(FT, MSL)

DEPTH: 80
(FT)



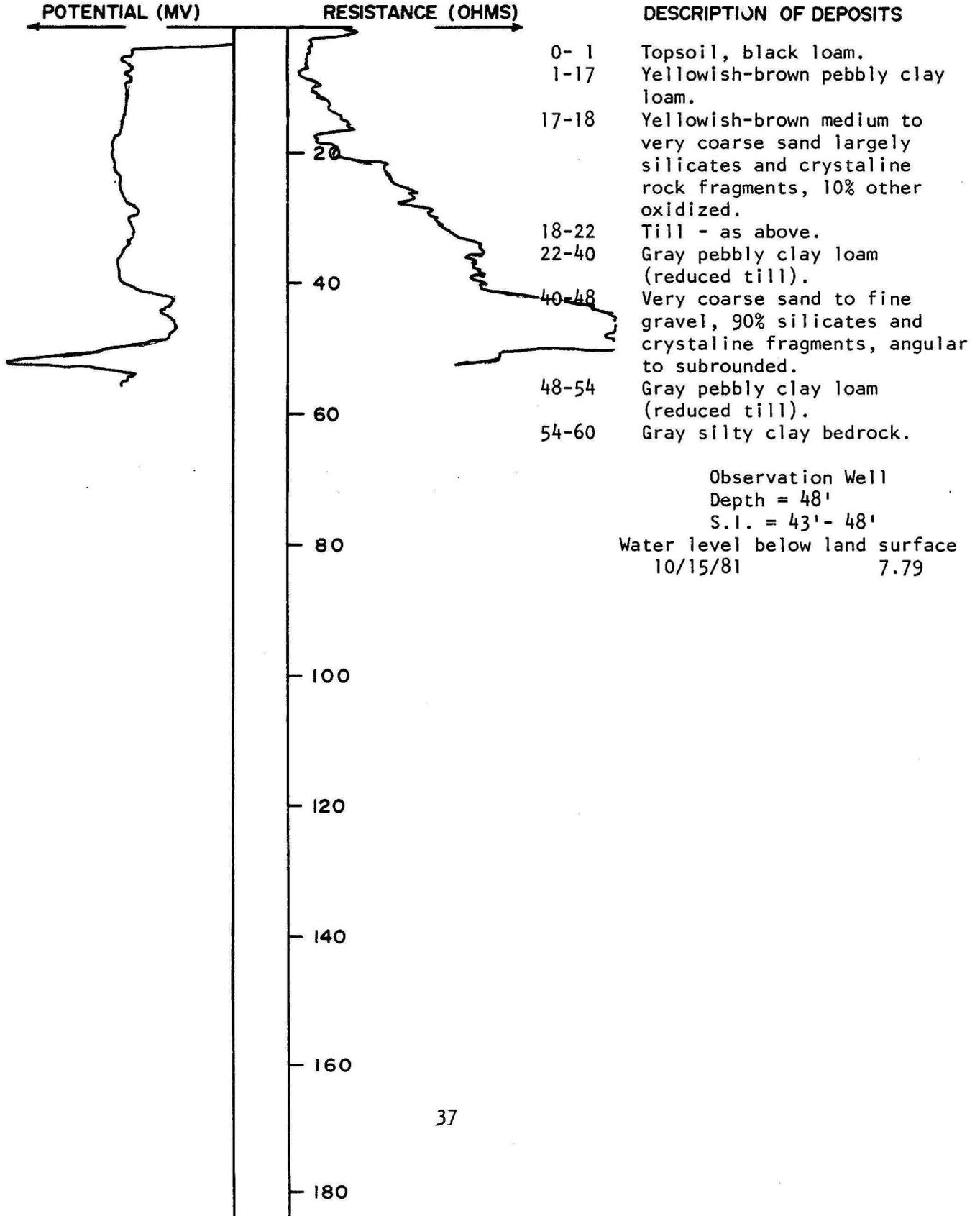
TEST HOLE 11762

LOCATION: 155-80-18ABCA

DATE DRILLED: 10/6/81

ELEVATION: 1550
(FT, MSL)

DEPTH: 60
(FT)



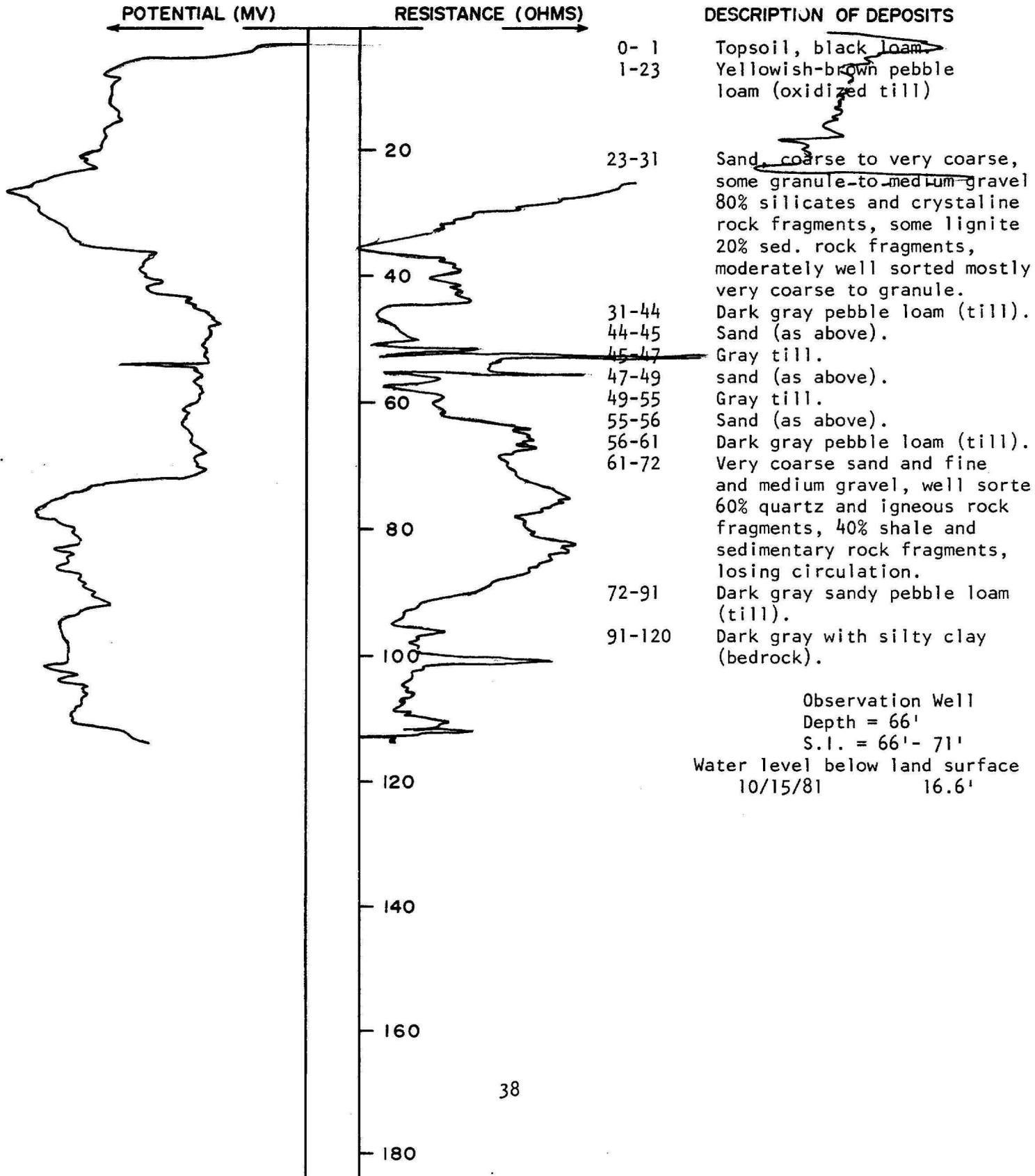
TEST HOLE 11759

LOCATION: 155-80-18ACB

DATE DRILLED: 10/6/81

ELEVATION: 1557
(FT, MSL)

DEPTH: 120'
(FT)



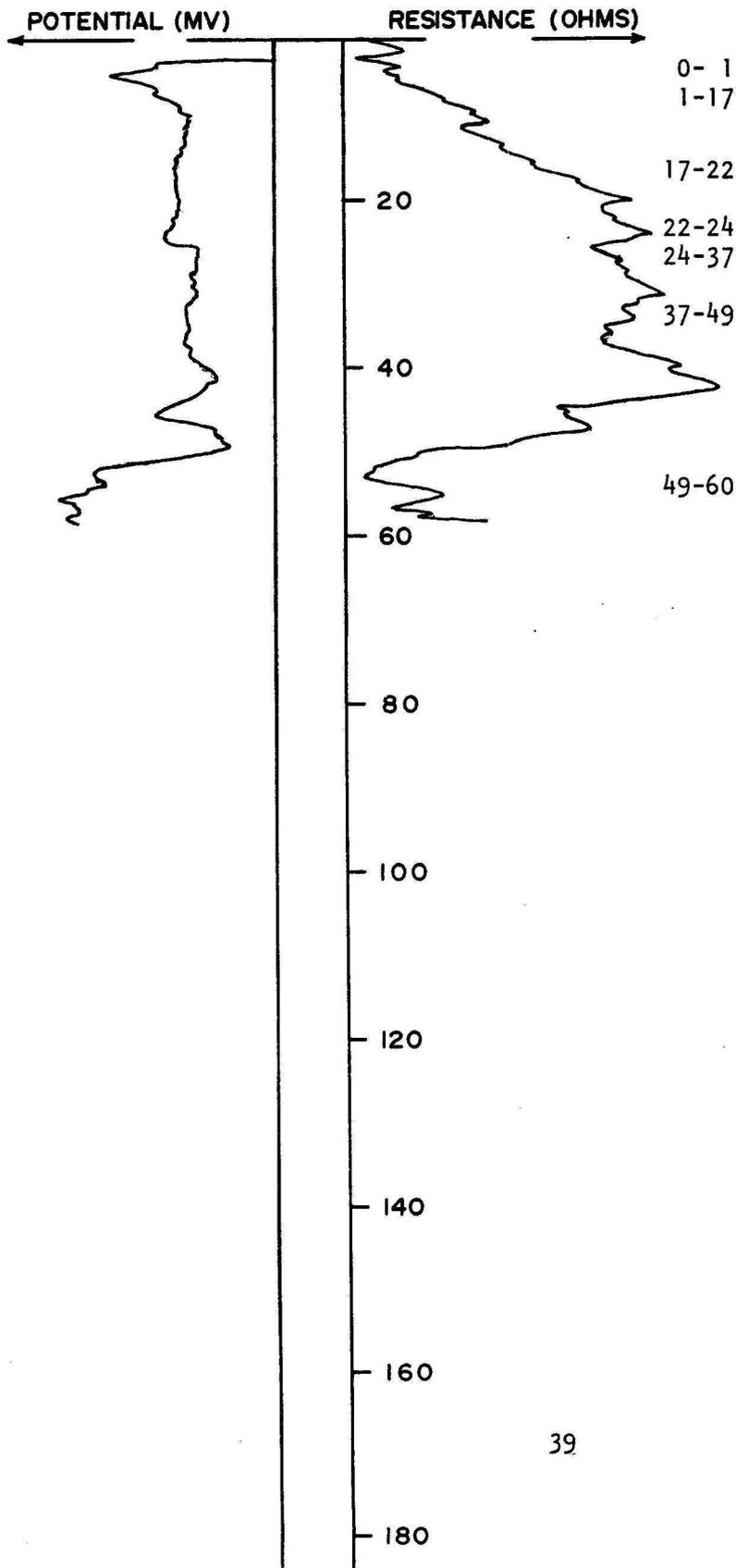
TEST HOLE 11760

LOCATION: 155-80-18ABCC

DATE DRILLED: 10/6/81

ELEVATION: 1550
(FT, MSL)

DEPTH: 60
(FT)



DESCRIPTION OF DEPOSITS

- 0- 1 Topsoil, black loam.
- 1-17 Yellowish-brown to grayish-brown clay loam (till) oxidized.
- 17-22 Gray pebble clay loam (till), reduced.
- 22-24 Gray clay, sandy, silty.
- 24-37 Gray pebble clay loam (till).
- 37-49 Very coarse sand to fine gravel, largely very coarse sand and granules, 90% silicates and crystalline rock fragments, 10% shale and sedimentary rock fragments.
- 49-60 Dark gray silty clay (bedrock).

Observation Well
 Depth = 48'
 S.I. = 43' - 48'
 Water level below land surface
 10/15/81 9.25'

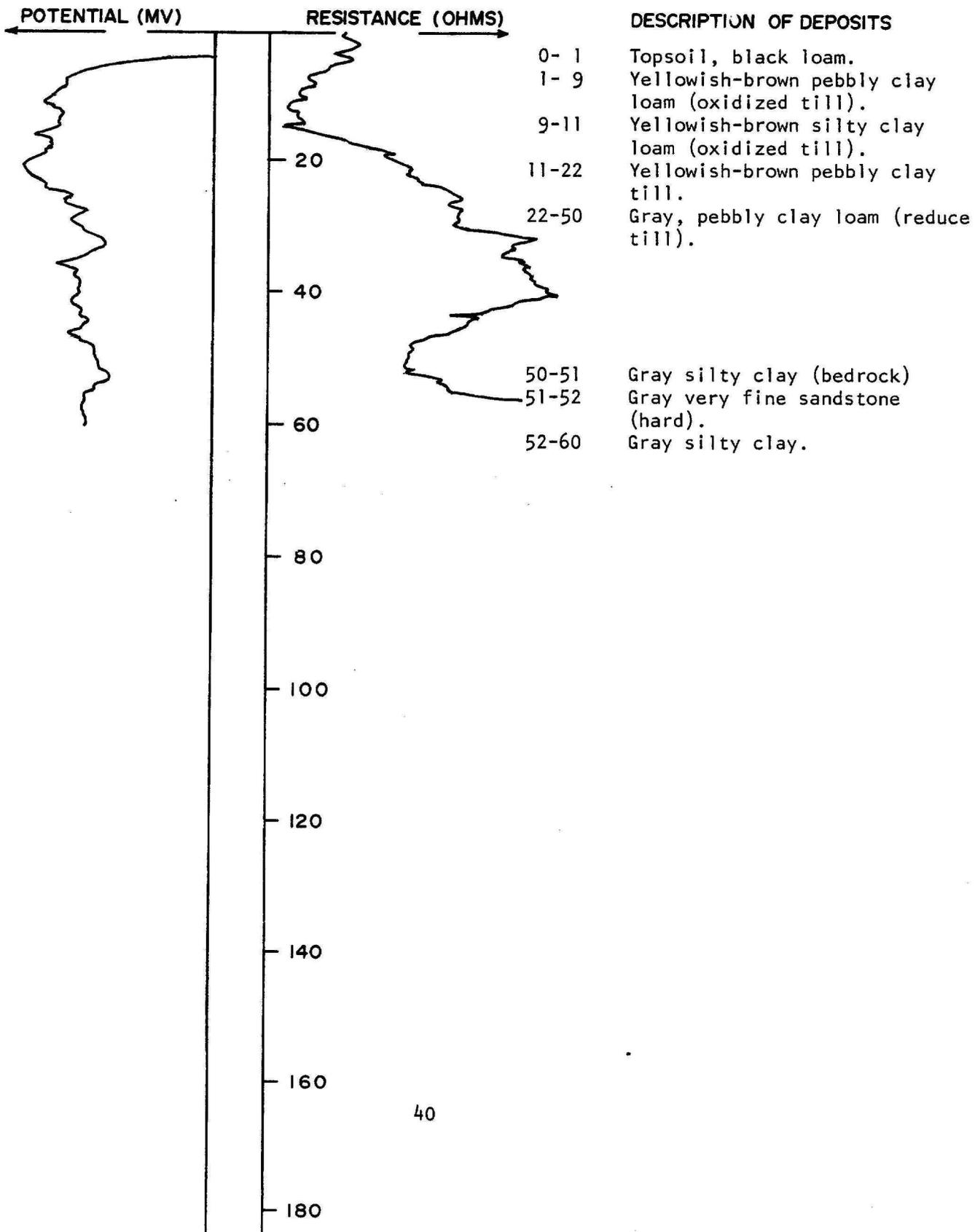
TEST HOLE 11761

LOCATION: 155-80-18ABCD

DATE DRILLED: 10/6/81

ELEVATION: 1548
(FT, MSL)

DEPTH: 60
(FT)



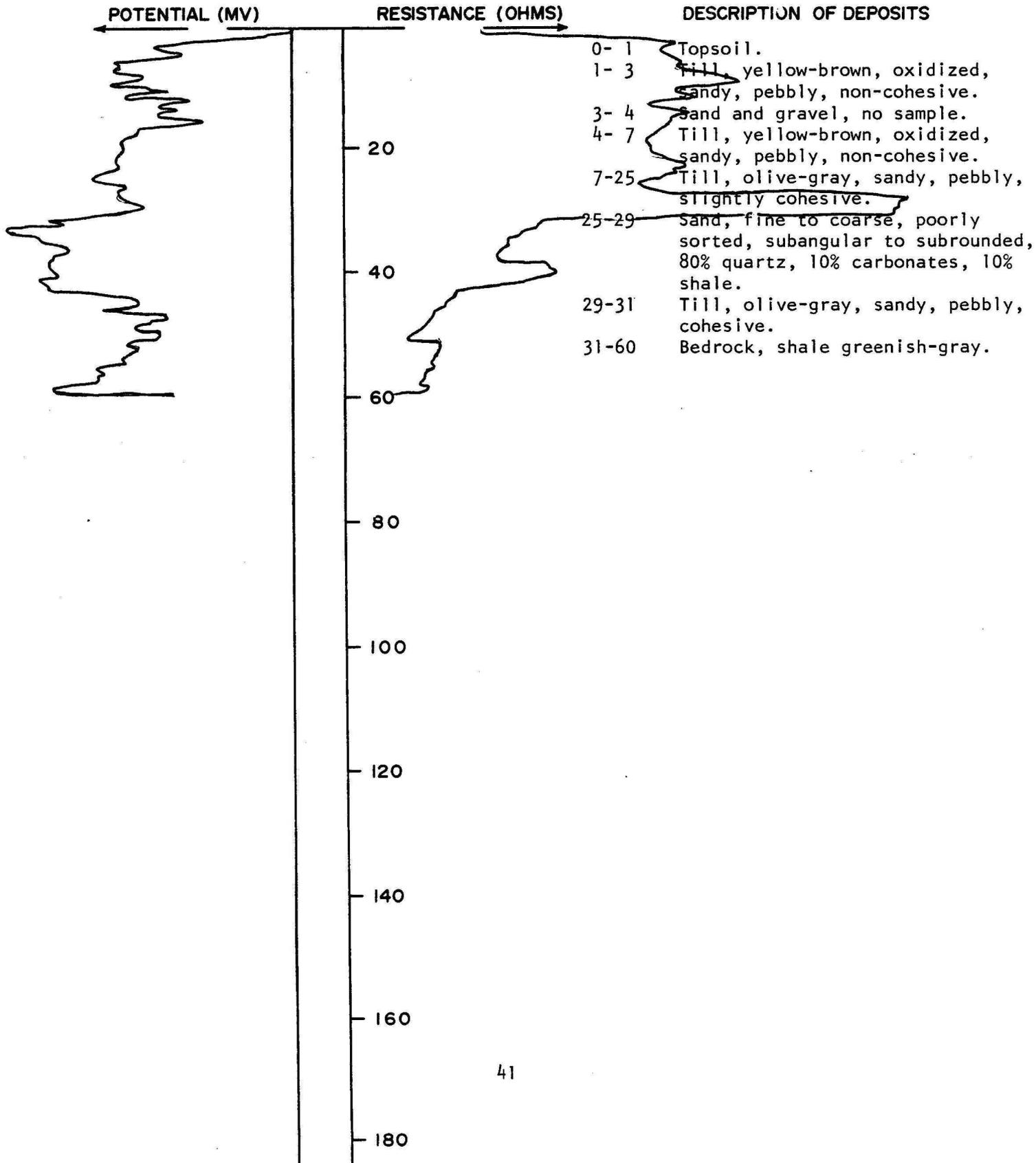
TEST HOLE 11083

LOCATION: 155-80-18BCC

DATE DRILLED: 9/19/79

ELEVATION: 1535
(FT, MSL)

DEPTH: 60
(FT)



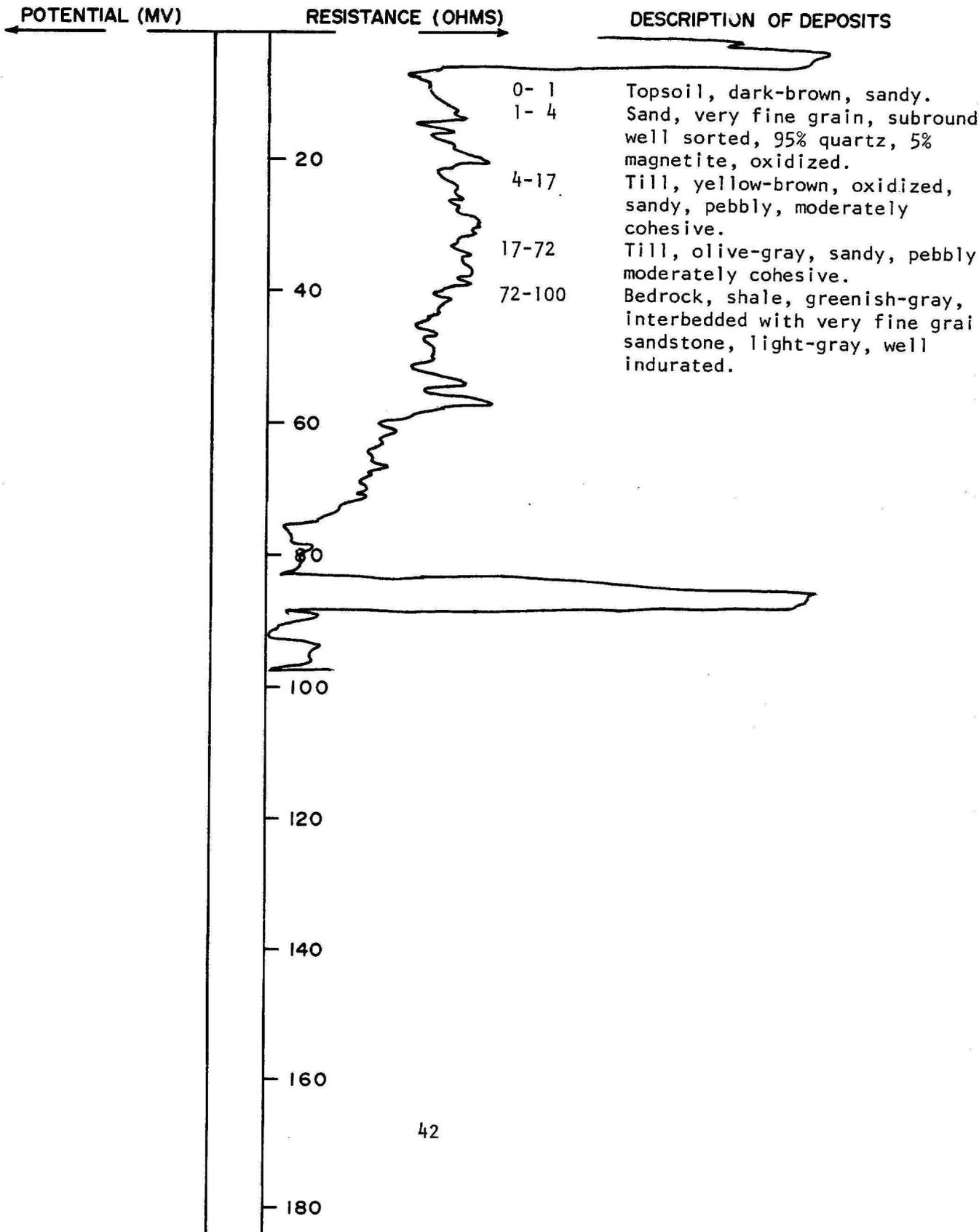
TEST HOLE 11086

LOCATION: 155-81-02DCC

DATE DRILLED: 9/19/79

ELEVATION: 1560
(FT, MSL)

DEPTH: 100
(FT)



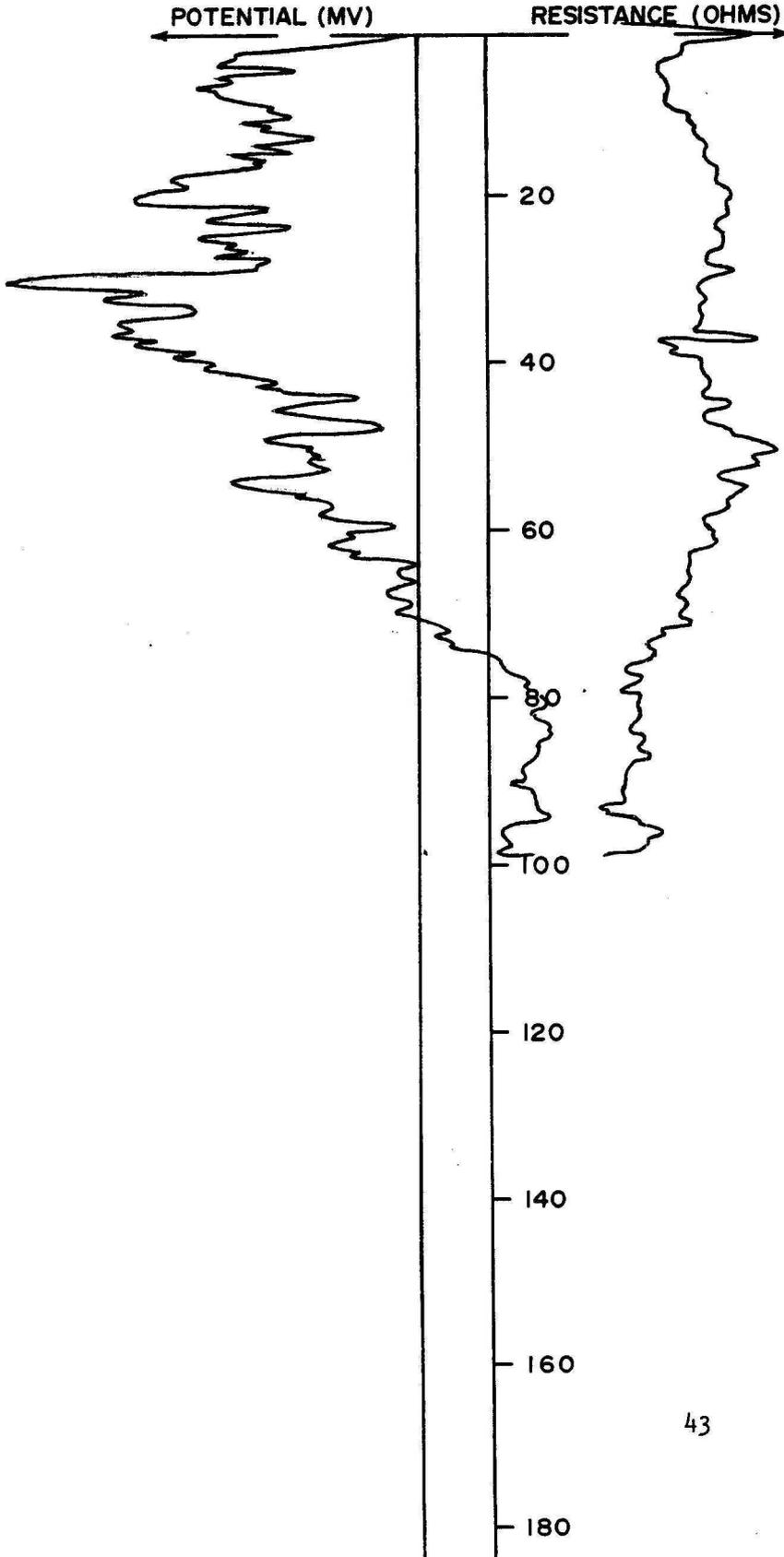
TEST HOLE 11087

LOCATION: 155-81-02DDC

DATE DRILLED: 9/19/79

ELEVATION: 1560
(FT, MSL)

DEPTH: 100
(FT)



DESCRIPTION OF DEPOSITS

- 0- 1 Topsoil.
- 1-17 Till, yellow-brown, oxidized, sandy, pebbly, moderately cohesive.
- 18-76 Till, olive-gray, sandy, pebbly, moderately cohesive, with sand lenses.
- 76-100 Bedrock, shale, greenish-gray.

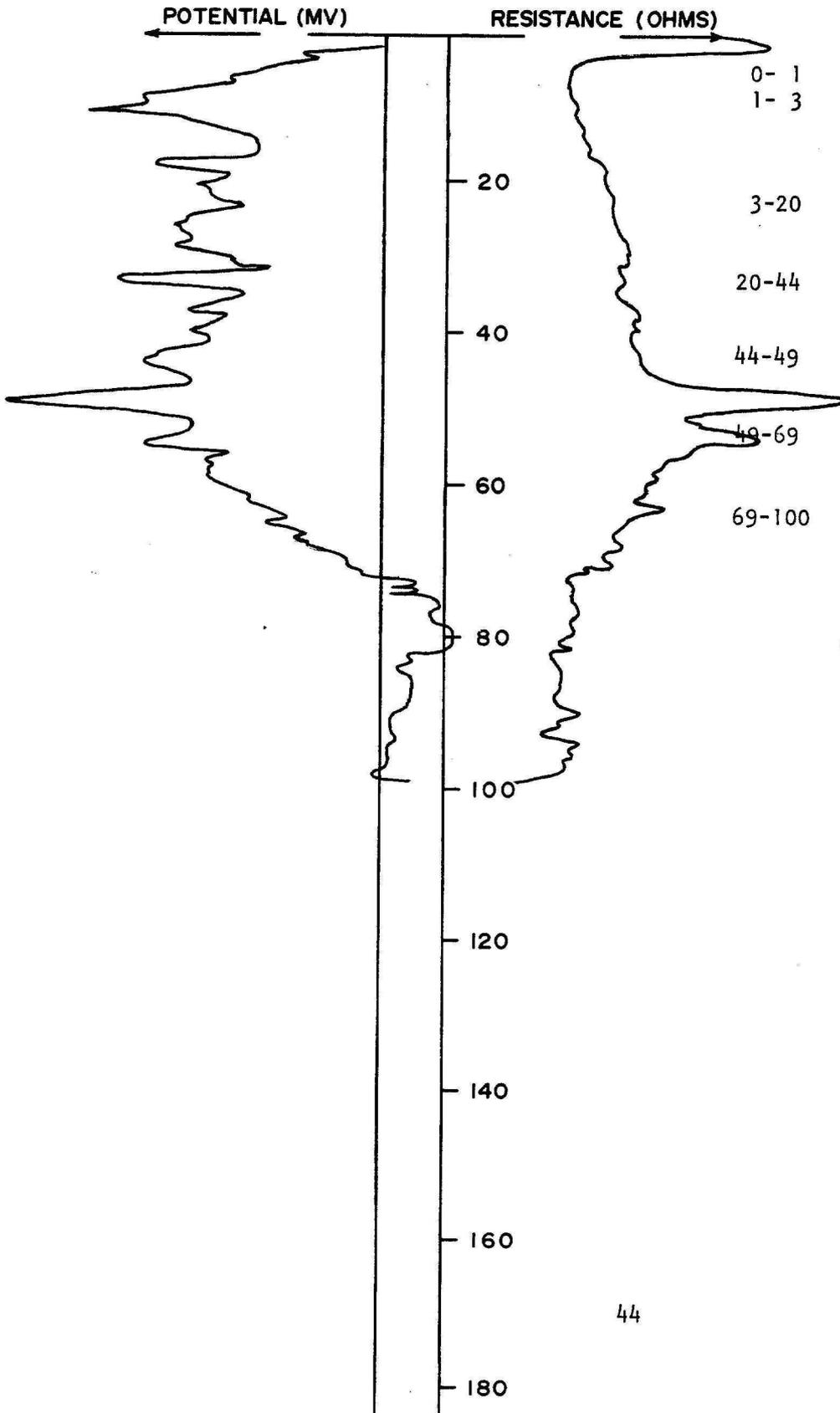
TEST HOLE 11075

LOCATION: 155-81- 2DDD

DATE DRILLED: 9/18/79

ELEVATION: 1562.7
(FT, MSL)

DEPTH: 100'
(FT)



DESCRIPTION OF DEPOSITS

- 0- 1 Topsoil.
- 1- 3 Sand and gravel, coarse sand to gravel, subrounded, 80% quartz, 10% shale, 10% carbonates.
- 3-20 Till, yellow-brown, sandy, pebbly, moderately cohesive, oxidized.
- 20-44 Till, olive-gray, sandy, pebbly, moderately cohesive.
- 44-49 Sand, fine to very fine grain, rounded to subrounded, well sorted, 90% quartz, 10% igneous.
- 49-69 Till, olive-gray, sandy, pebbly, cohesive.
- 69-100 Bedrock, shale, greenish-gray.

Observation Well
 Depth = 49'
 S.I. = 46' to 49'
 Water level below land surface
 1/16/80 8.76'

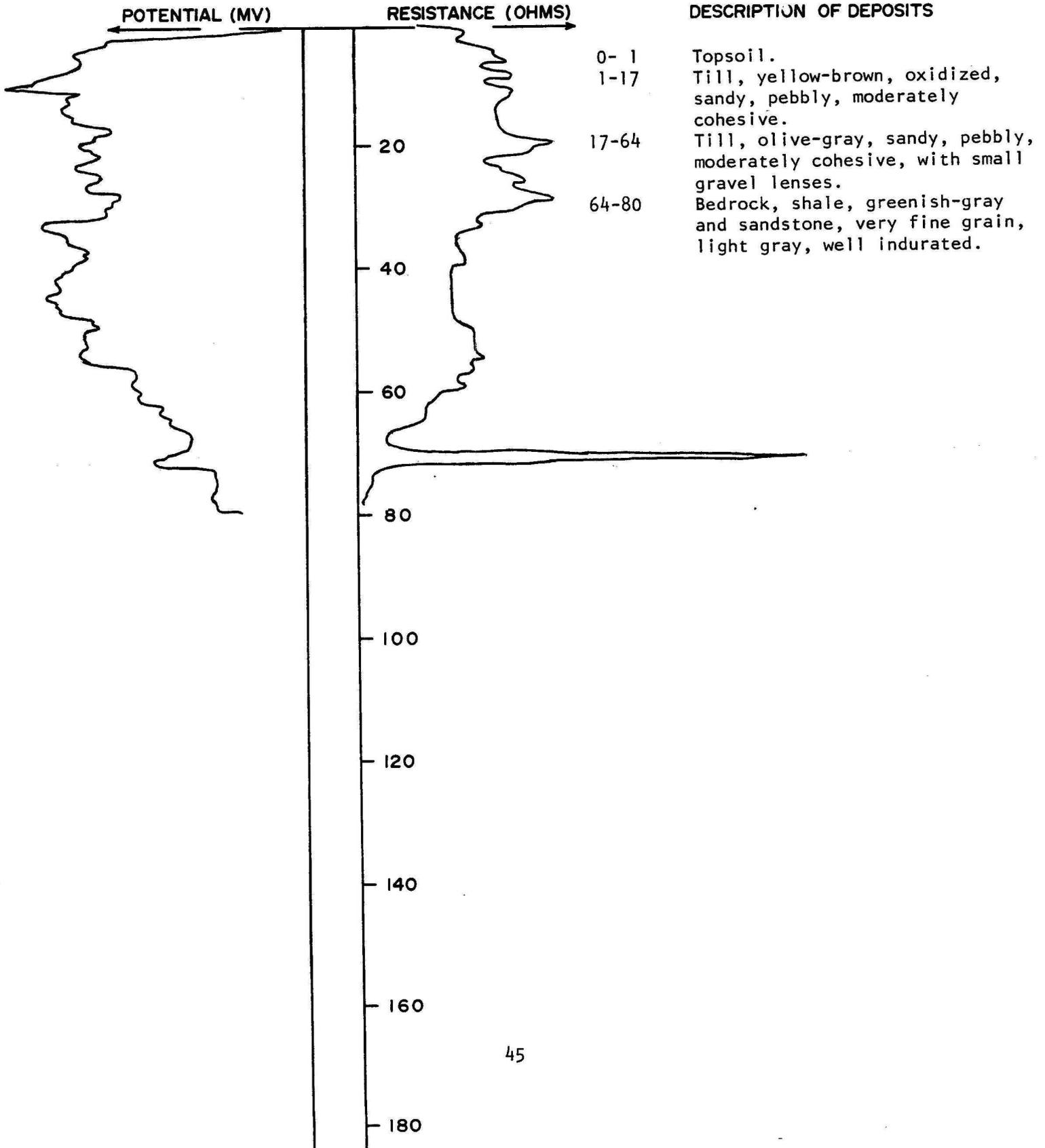
TEST HOLE 11102

LOCATION: 155-81-04DCC

DATE DRILLED: 9/25/79

ELEVATION: 1581
(FT, MSL)

DEPTH: 80
(FT)



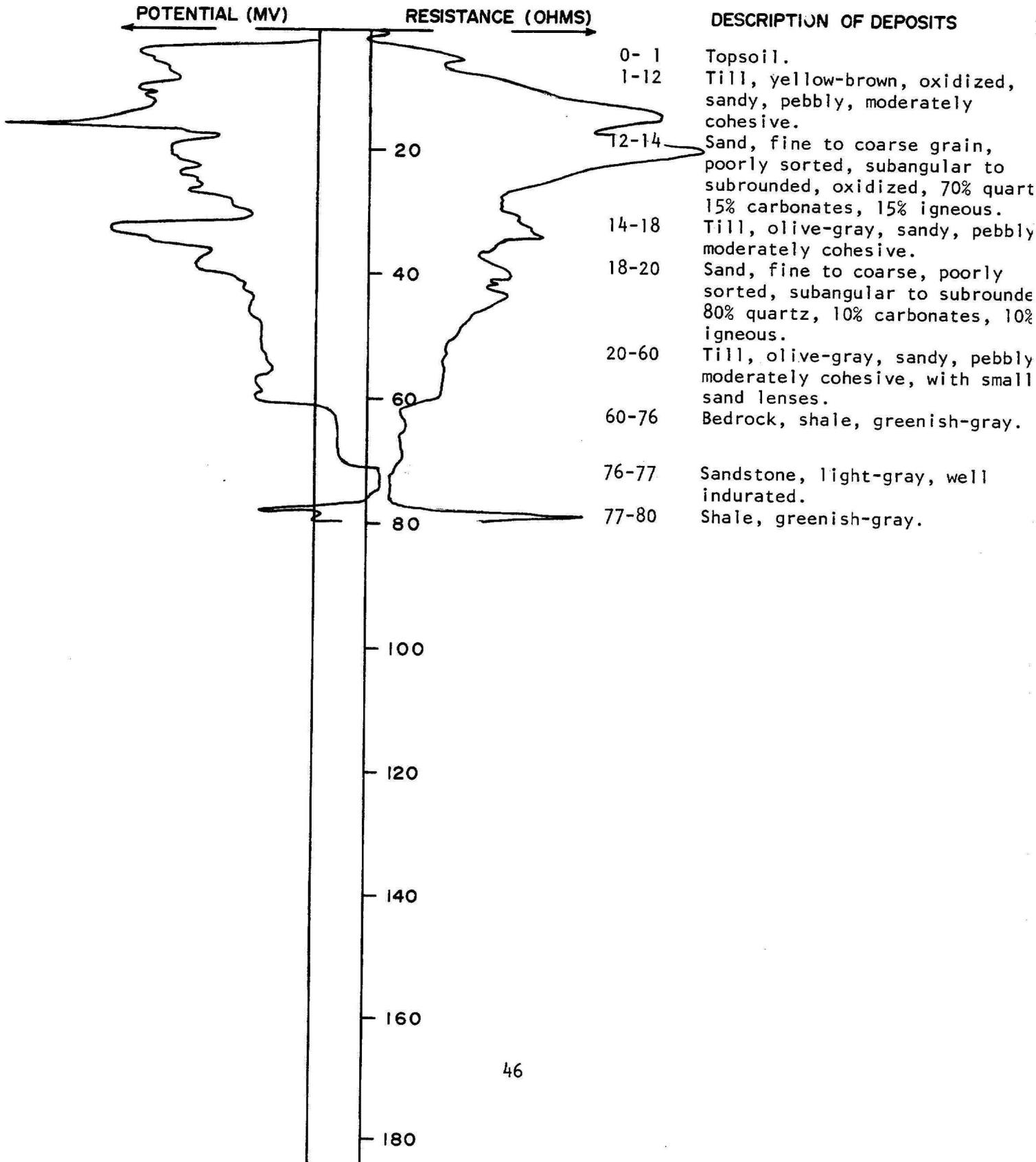
TEST HOLE 11115

LOCATION: 155-81-08AAD

DATE DRILLED: 9/25/79

ELEVATION: 1560
(FT, MSL)

DEPTH: 80
(FT)



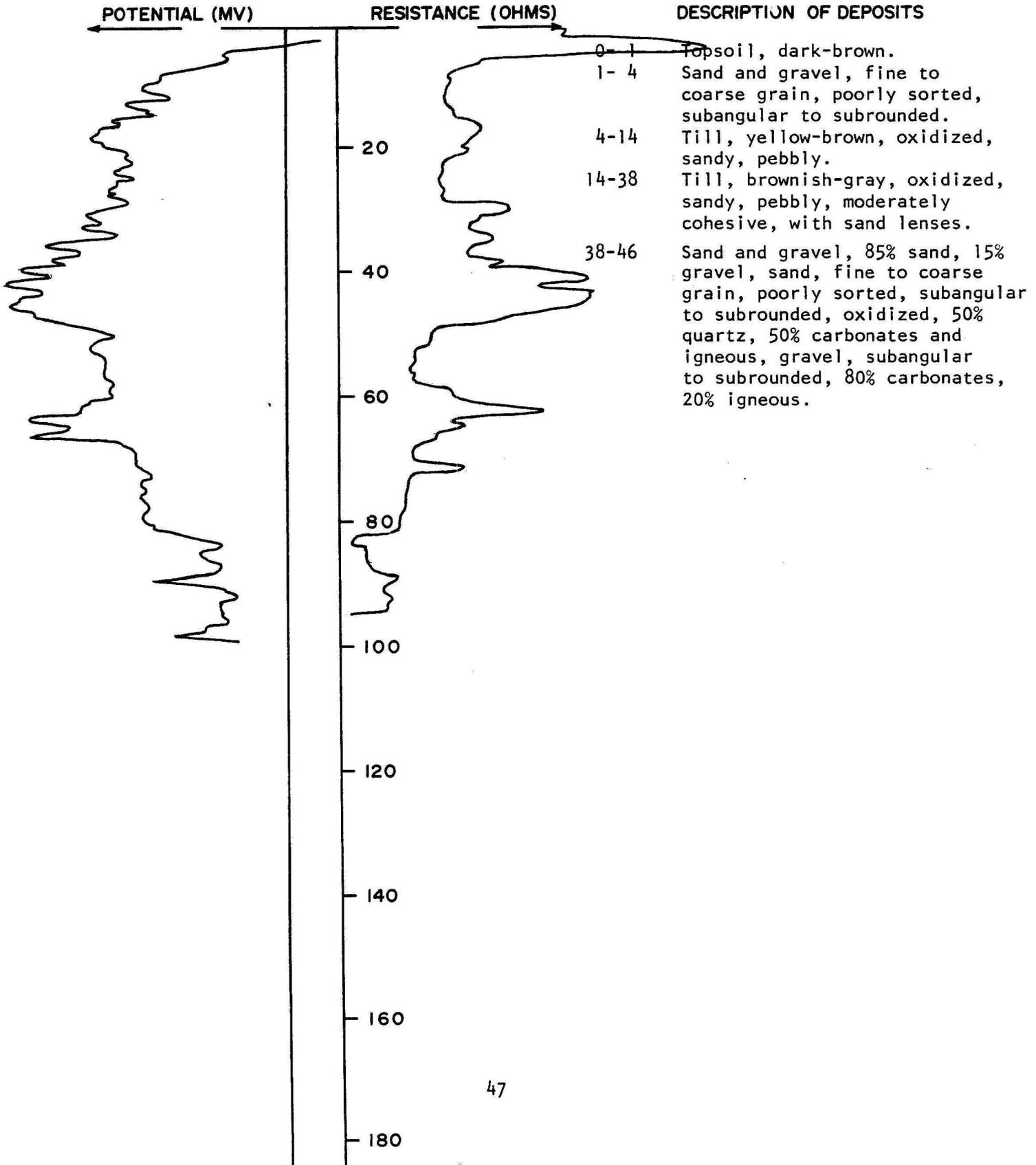
TEST HOLE 11114

LOCATION: 155-81-08ADA

DATE DRILLED: 9/27/79

ELEVATION: 1590
(FT, MSL)

DEPTH: 100
(FT)



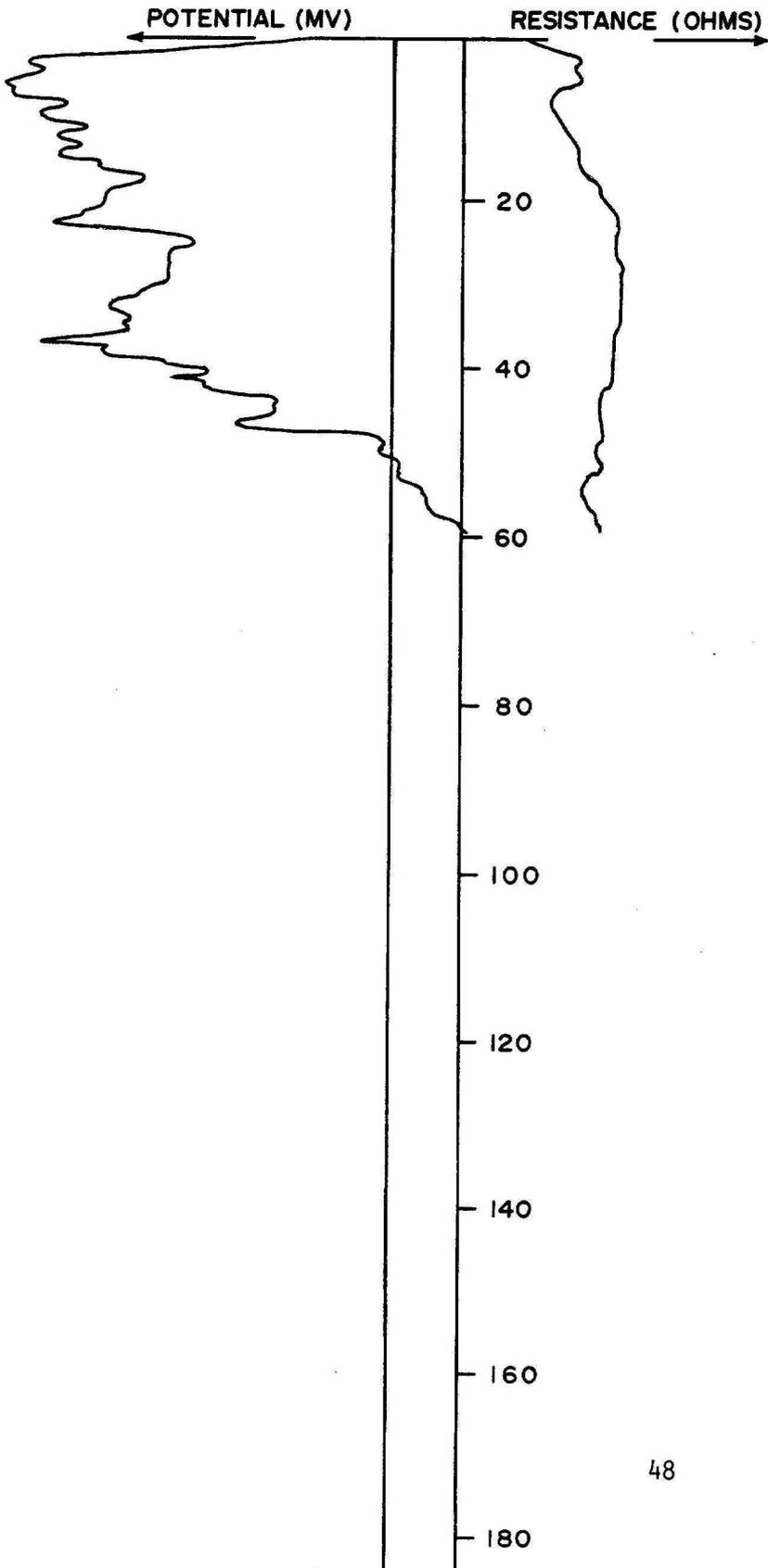
TEST HOLE 11101

LOCATION: 155-81-08ADD

DATE DRILLED: 9/25/79

ELEVATION: 1559
(FT, MSL)

DEPTH: 60
(FT)



DESCRIPTION OF DEPOSITS

- 0- 1 Topsoil, dark-brown.
- 1-10 Till, yellow-brown, oxidized, very sandy, pebbly, moderately cohesive.
- 10-40 Till, olive-gray, very sandy, pebbly, moderately cohesive.
- 40-60 Bedrock, shale, greenish-gray.

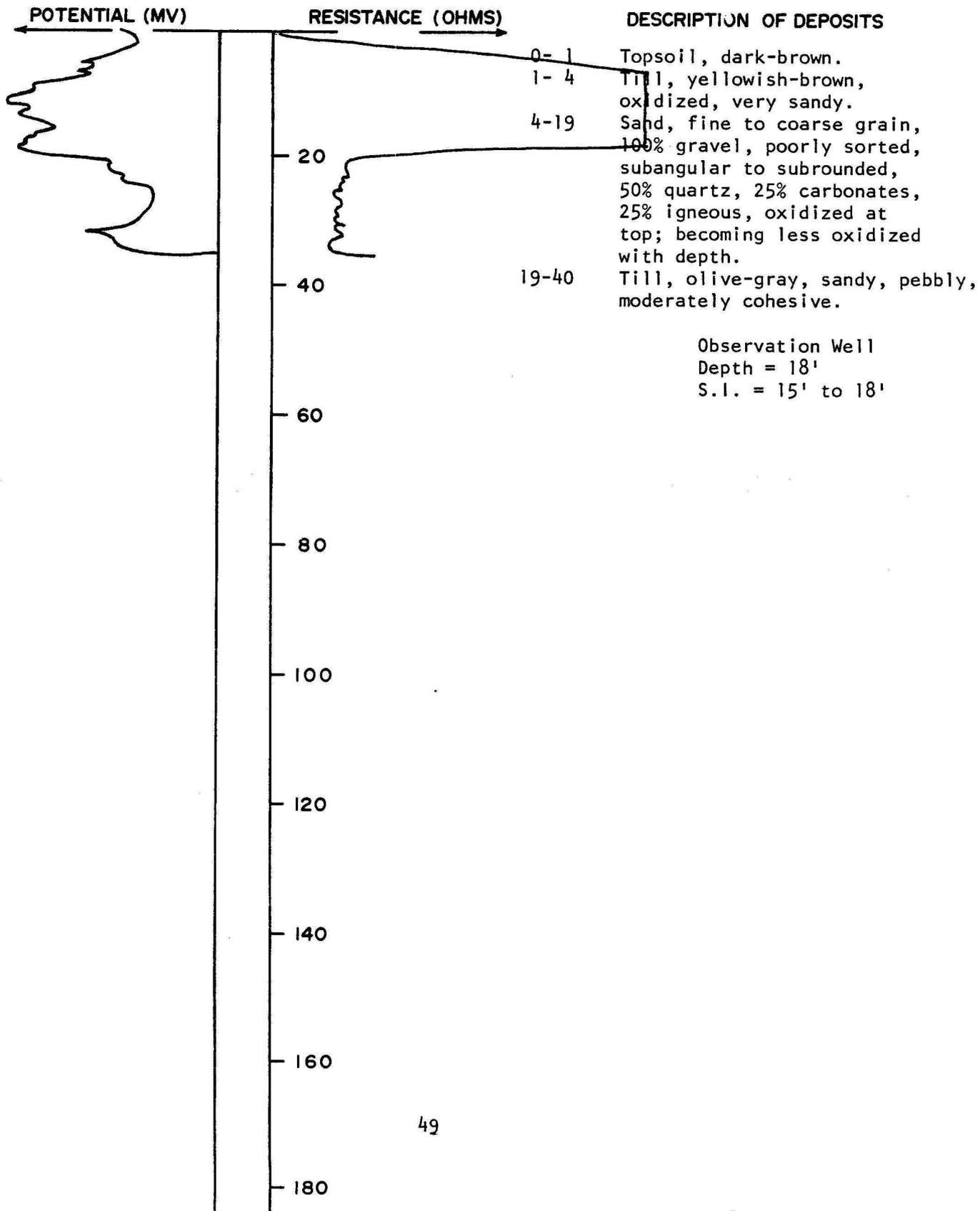
TEST HOLE 11113

LOCATION: 155-81- 8CCC

DATE DRILLED: 9/27/79

ELEVATION: 1580
(FT, MSL)

DEPTH: 40
(FT)



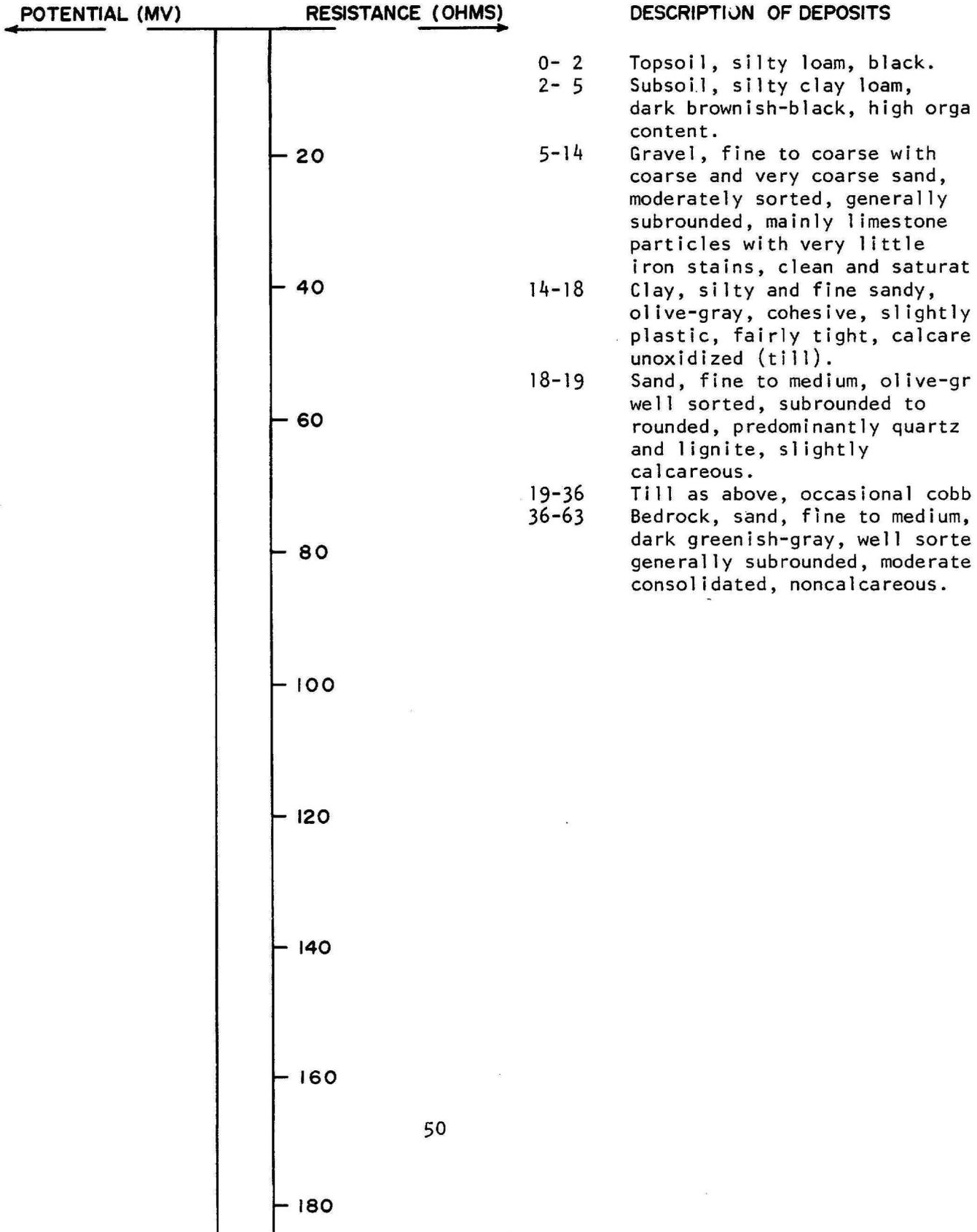
TEST HOLE 11-992

LOCATION: 155-81-8ddd

DATE DRILLED: 4/17/63

ELEVATION: 1563
(FT, MSL)

DEPTH: 63
(FT)



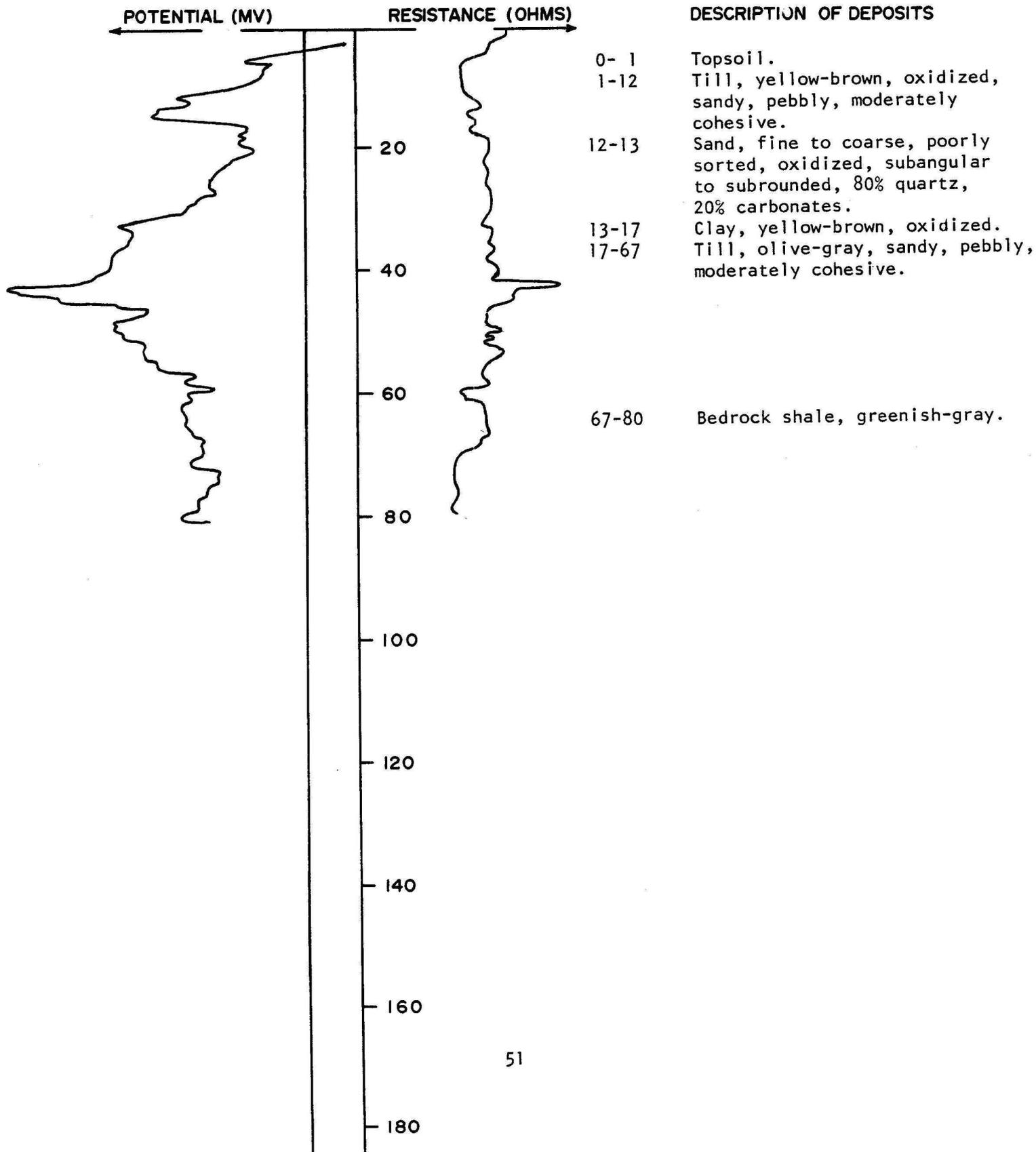
TEST HOLE 11103

LOCATION: 155-81-09AAB

DATE DRILLED: 9/25/79

ELEVATION: 1575
(FT, MSL)

DEPTH: 80
(FT)



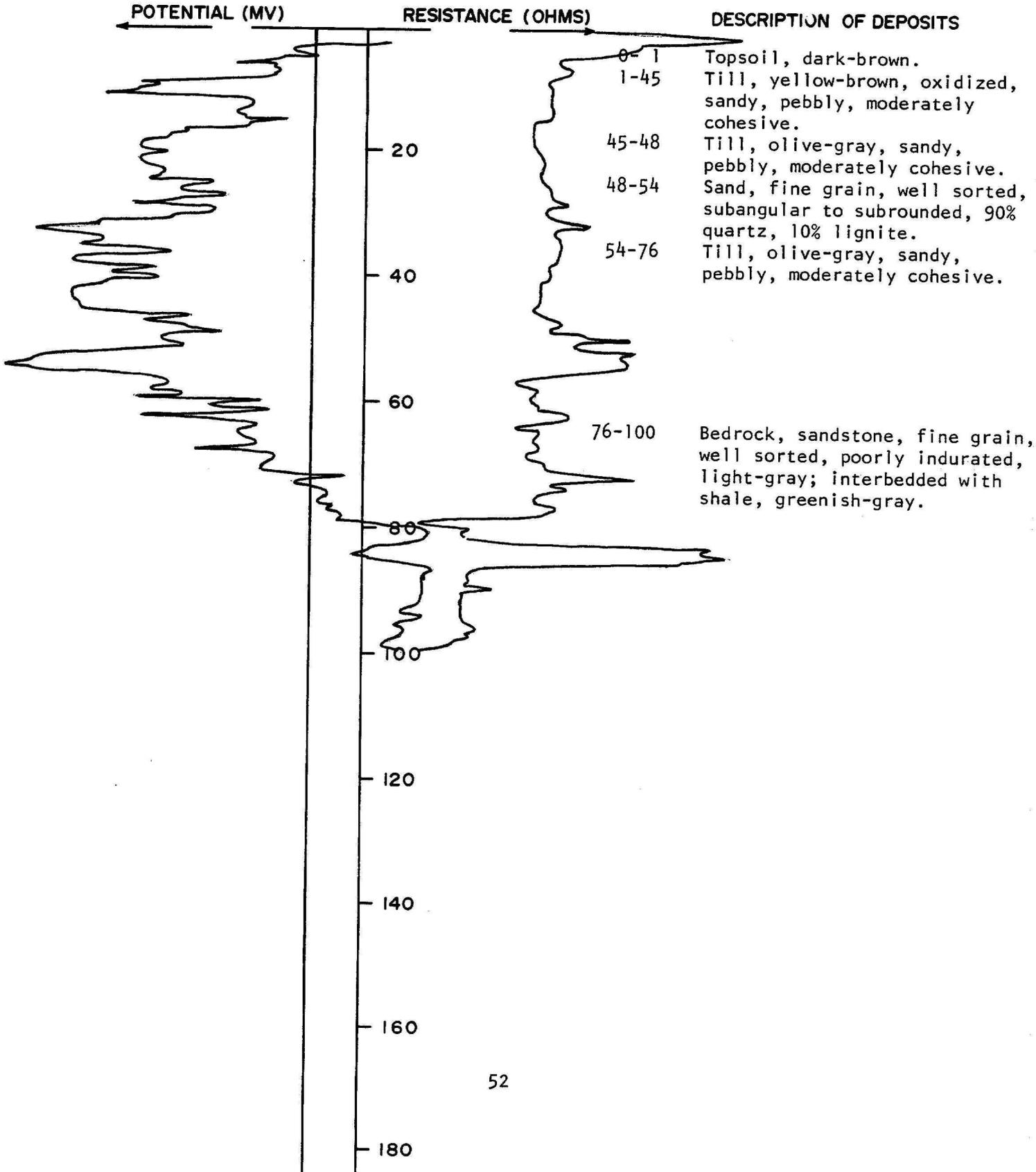
TEST HOLE 11111

LOCATION: 155-81-09CBC

DATE DRILLED: 9/26/79

ELEVATION: 1590
(FT, MSL)

DEPTH: 100
(FT)



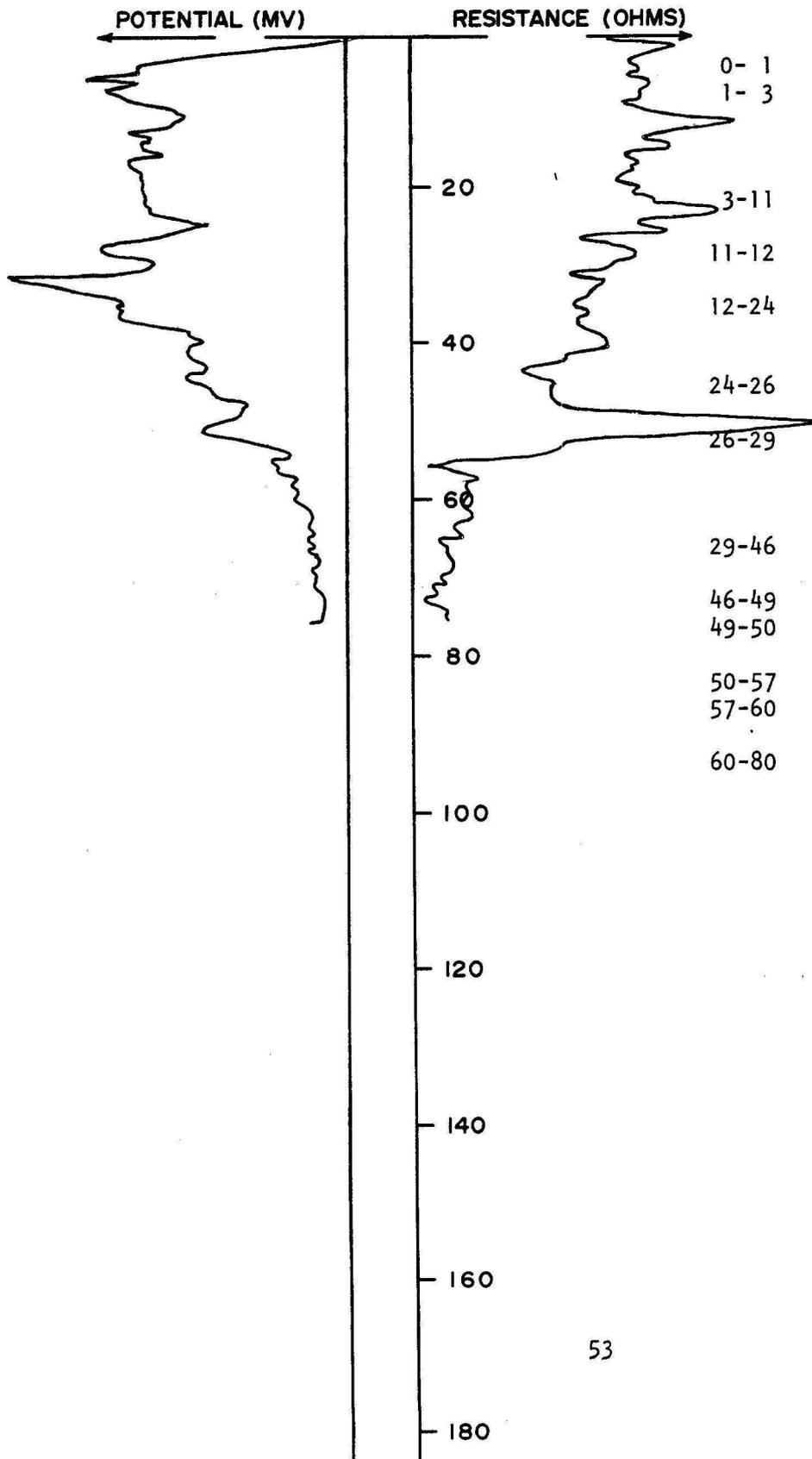
TEST HOLE 11100

LOCATION: 155-81-10BBC

DATE DRILLED: 9/25/79

ELEVATION: 1556.5
(FT, MSL)

DEPTH: 80
(FT)



DESCRIPTION OF DEPOSITS

- 0-1 Topsoil.
- 1-3 Sand, fine to coarse grain, poorly sorted, subangular to subrounded, oxidized, 80% quartz, 20% carbonates.
- 3-11 Till, yellow-brown, oxidized, sandy, pebbly, not cohesive.
- 11-12 Till, olive-gray, sandy, pebbly, very cohesive.
- 12-24 Sand, fine grain, well sorted, subangular to subrounded, 80% quartz, 10% shale, 10% carbonates.
- 24-26 Till, olive-gray, sandy, pebbly, very cohesive.
- 26-29 Sand, fine to coarse grain, well sorted (very little coarse grain) subangular to subrounded, 80% quartz, 10% shale, 10% carbonates.
- 29-46 Till, olive-gray, sandy, pebbly, cohesive.
- 46-49 Sand, no sample.
- 49-50 Till, olive-gray, sandy, pebbly, cohesive.
- 50-57 Sand, no sample.
- 57-60 Till, olive-gray, sandy, pebbly, cohesive.
- 60-80 Bedrock, shale, greenish-gray, sandy.

Observation Well
 Depth = 23'
 S.I. = 20' to 23'
 Water level below land surface
 1/16/80 5.95'

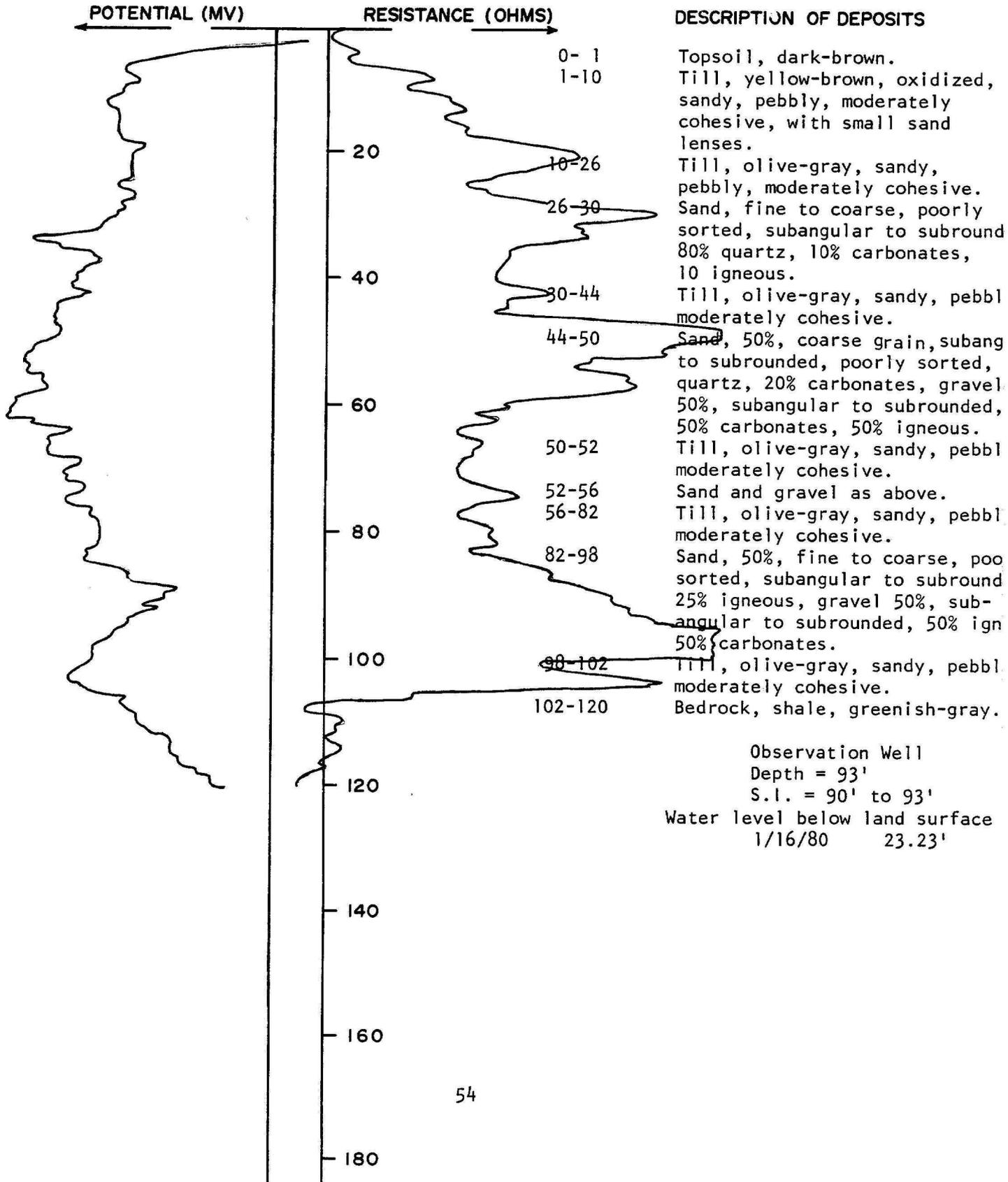
TEST HOLE 11099

LOCATION: 155-81-10CBB

DATE DRILLED: 9/24/79

ELEVATION: 1559.3
(FT, MSL)

DEPTH: 120
(FT)



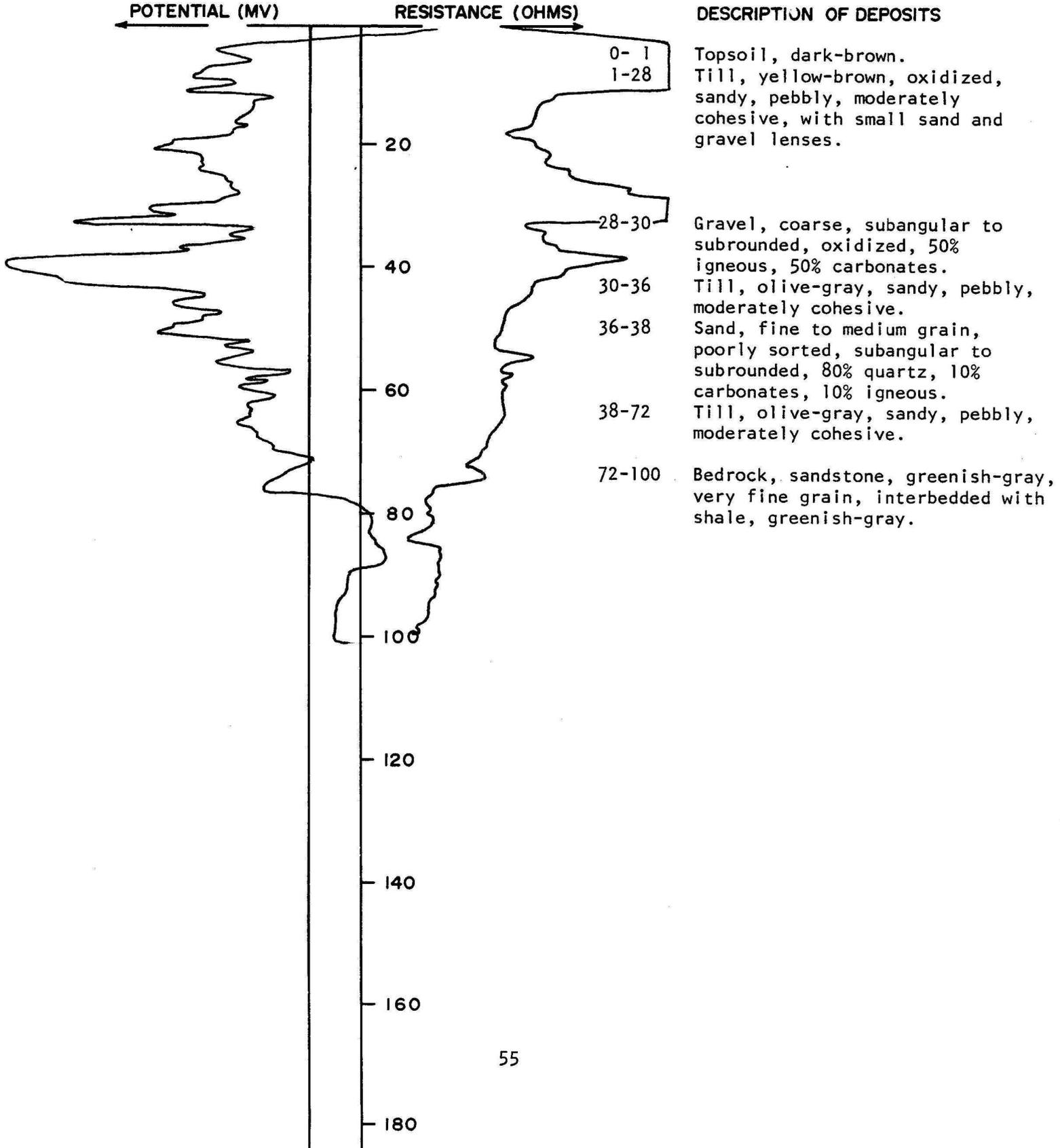
TEST HOLE 11098

LOCATION: 155-81-10CBC

DATE DRILLED: 9/24/79

ELEVATION: 1580
(FT, MSL)

DEPTH: 100
(FT)



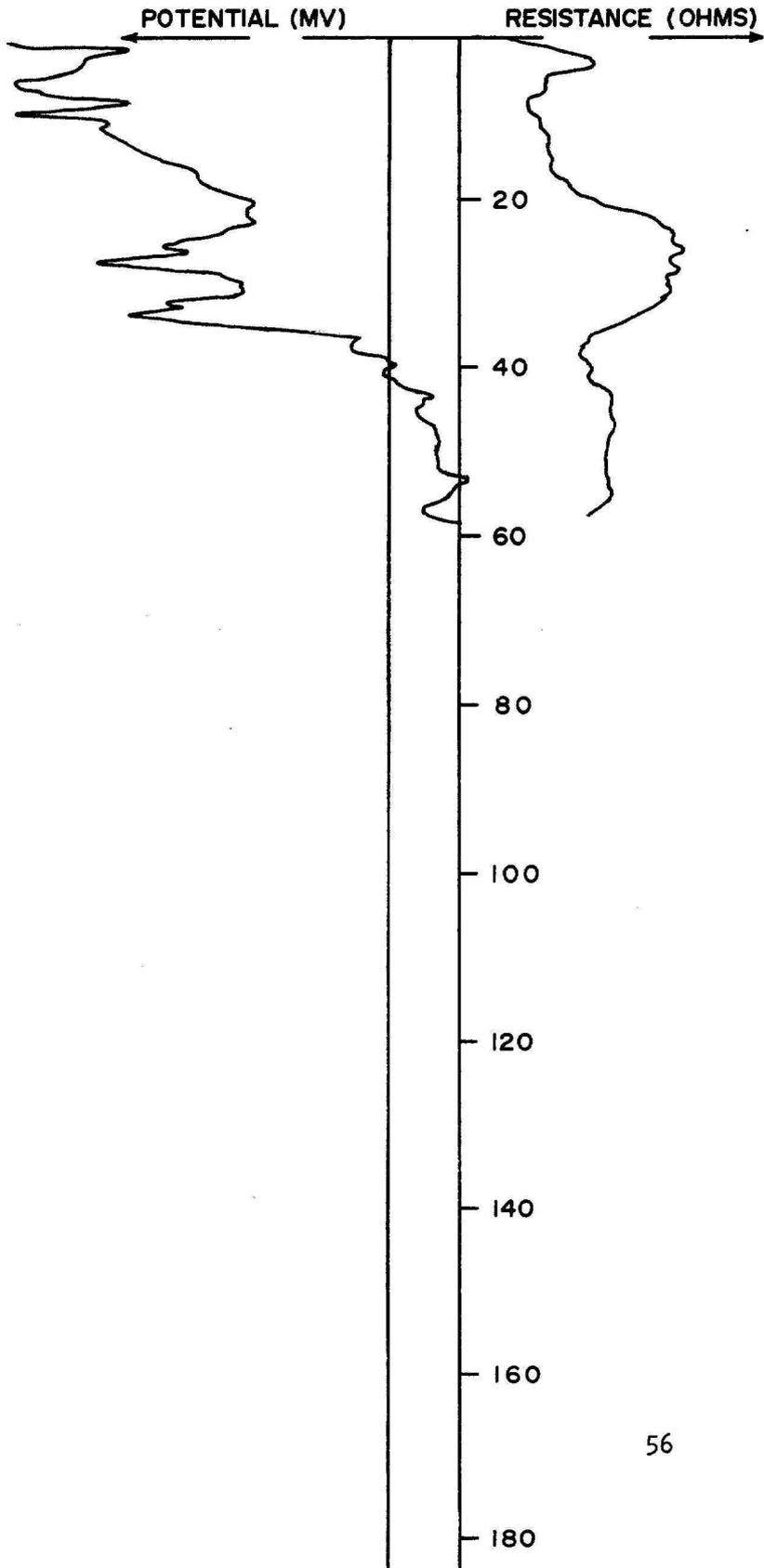
TEST HOLE 11092

LOCATION: 155-81-10DCD

DATE DRILLED: 9/20/79

ELEVATION: 1545
(FT, MSL)

DEPTH: 60
(FT)



DESCRIPTION OF DEPOSITS

0-1 Topsoil
1-9 Till, yellow-brown, oxidized, sandy, pebbly, cohesive.
9-36 Till, olive-gray, sandy, pebbly, moderately cohesive with small sand lenses.
36-60 Bedrock, shale, greenish-gray, sandy, carbonaceous.

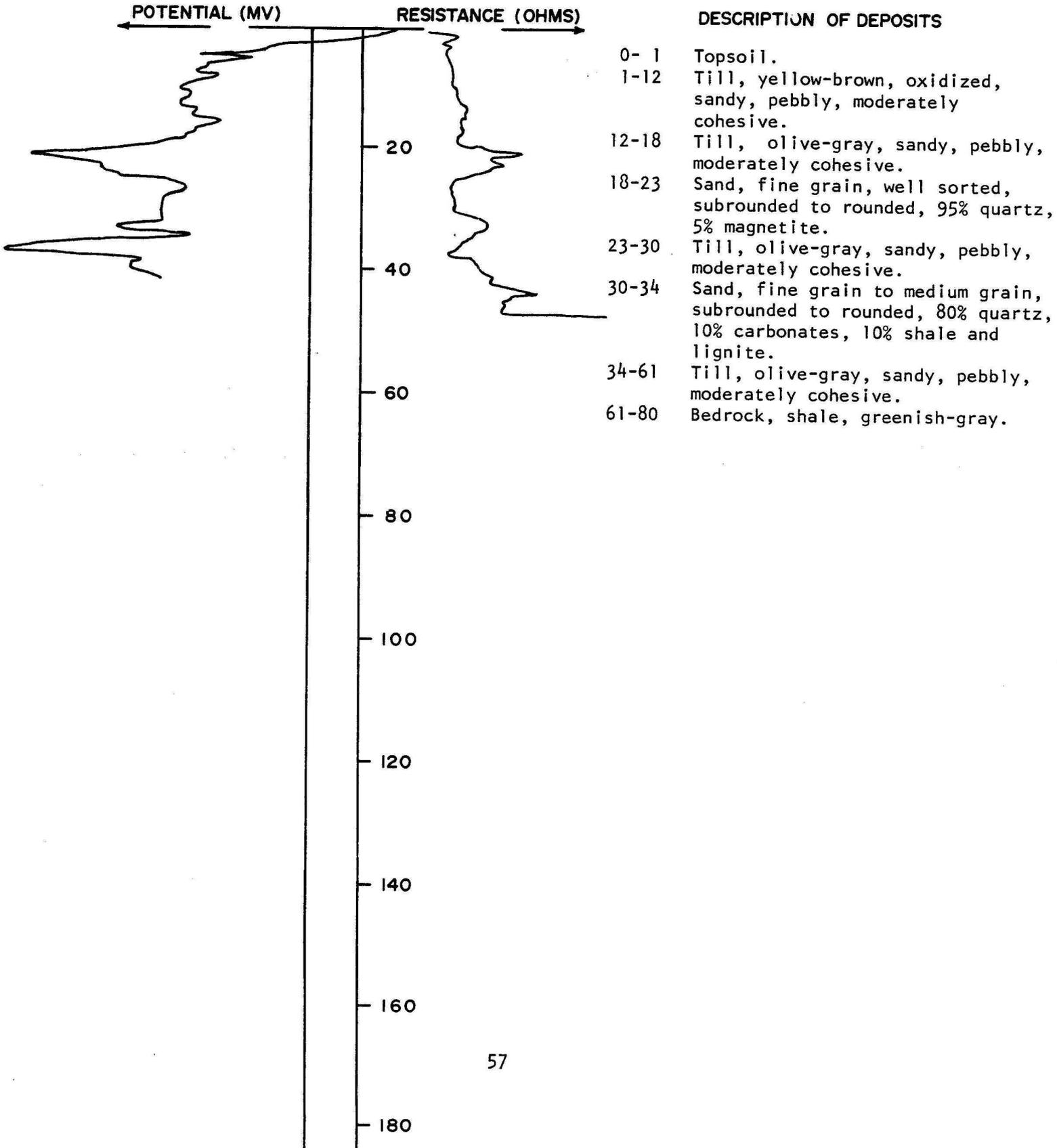
TEST HOLE 11088

LOCATION: 155-81-11ADA

DATE DRILLED: 9/19/79

ELEVATION: 1560
(FT, MSL)

DEPTH: 80
(FT)



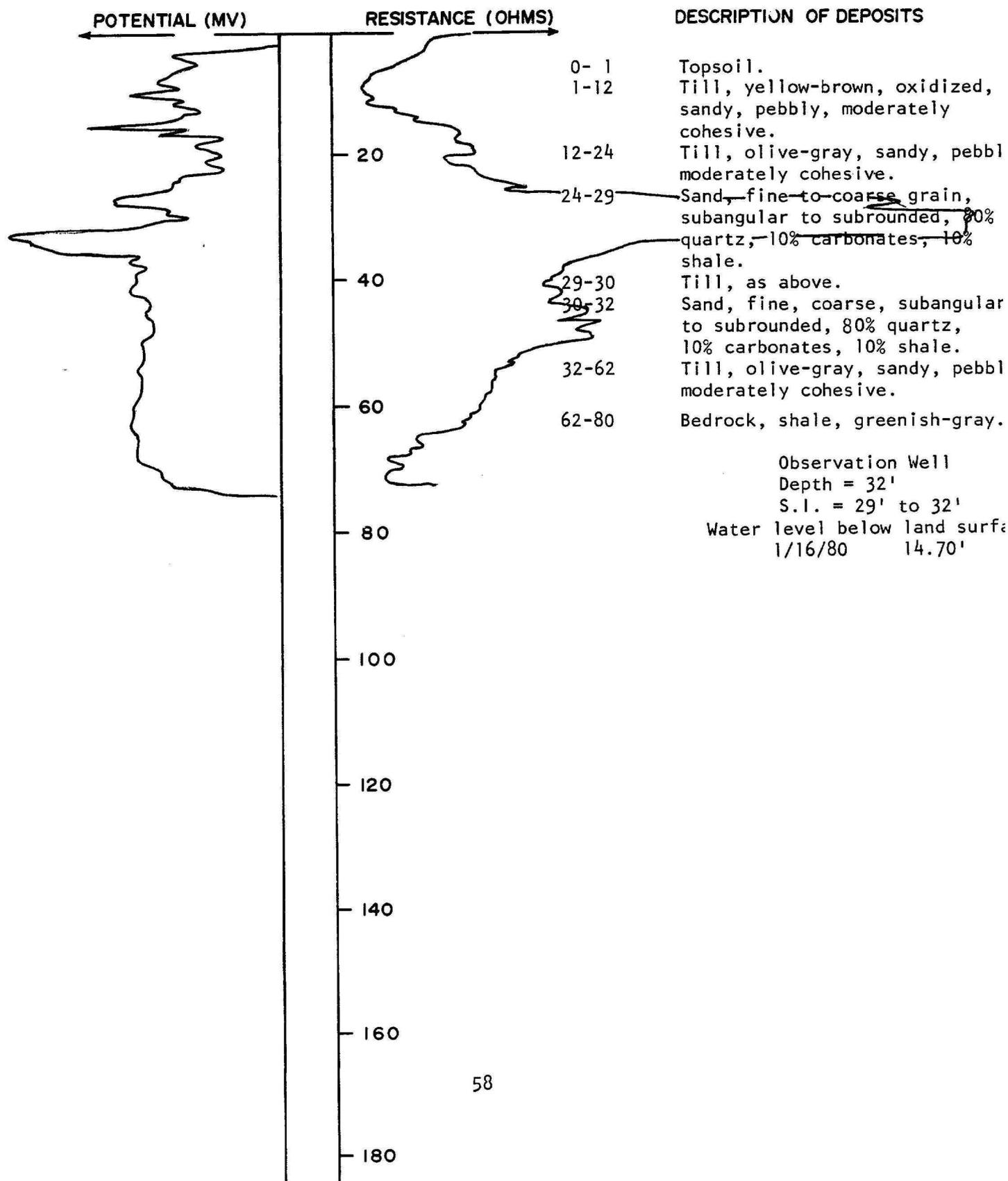
TEST HOLE 11074

LOCATION: 155-81-11ADD

DATE DRILLED: 9/18/79

ELEVATION: 1558.8
(FT, MSL)

DEPTH: 80
(FT)



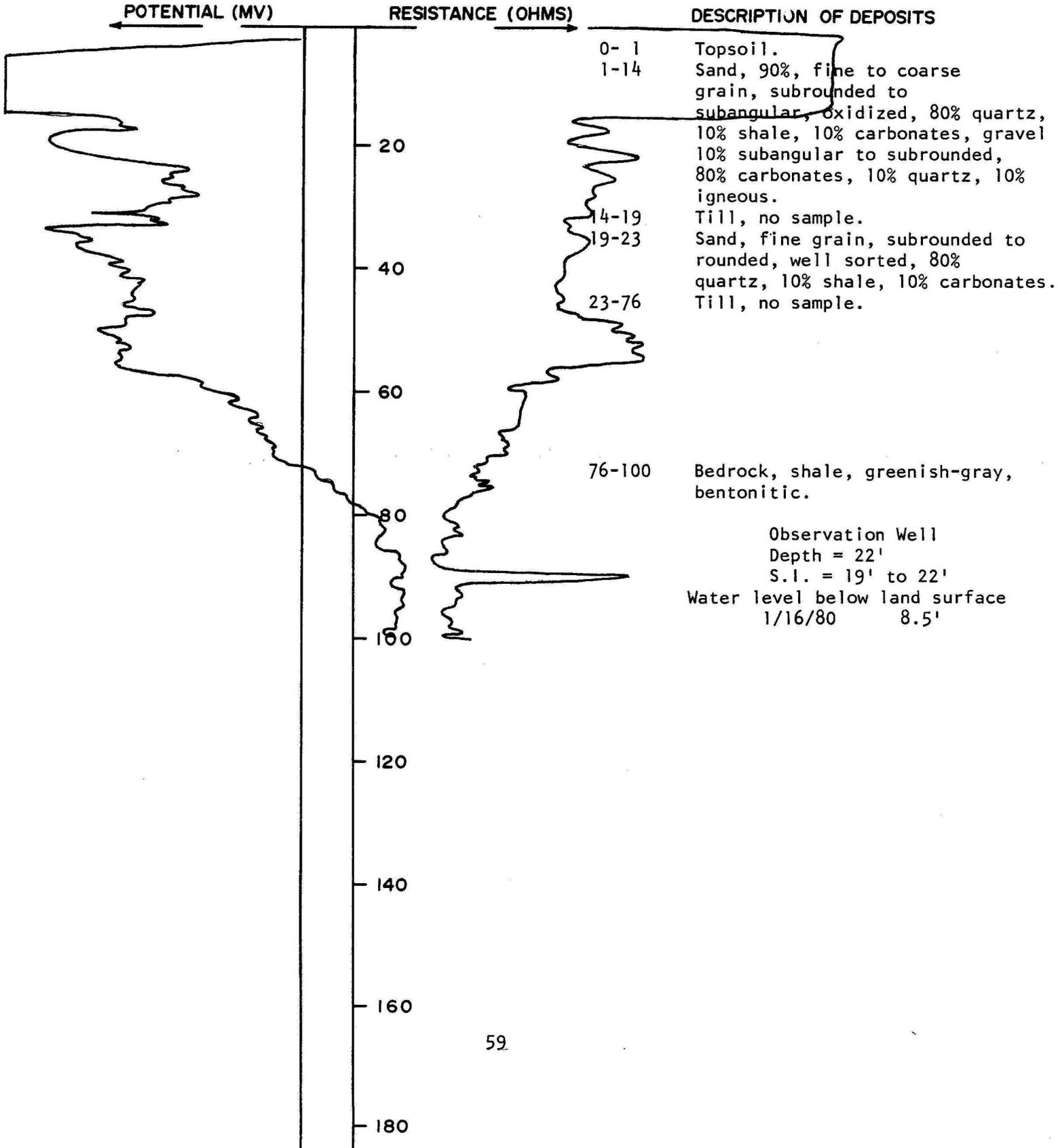
TEST HOLE 11077

LOCATION: 155-81-11BBB

DATE DRILLED: 9/18/79

ELEVATION: 1561.1
(FT, MSL)

DEPTH: 100
(FT)



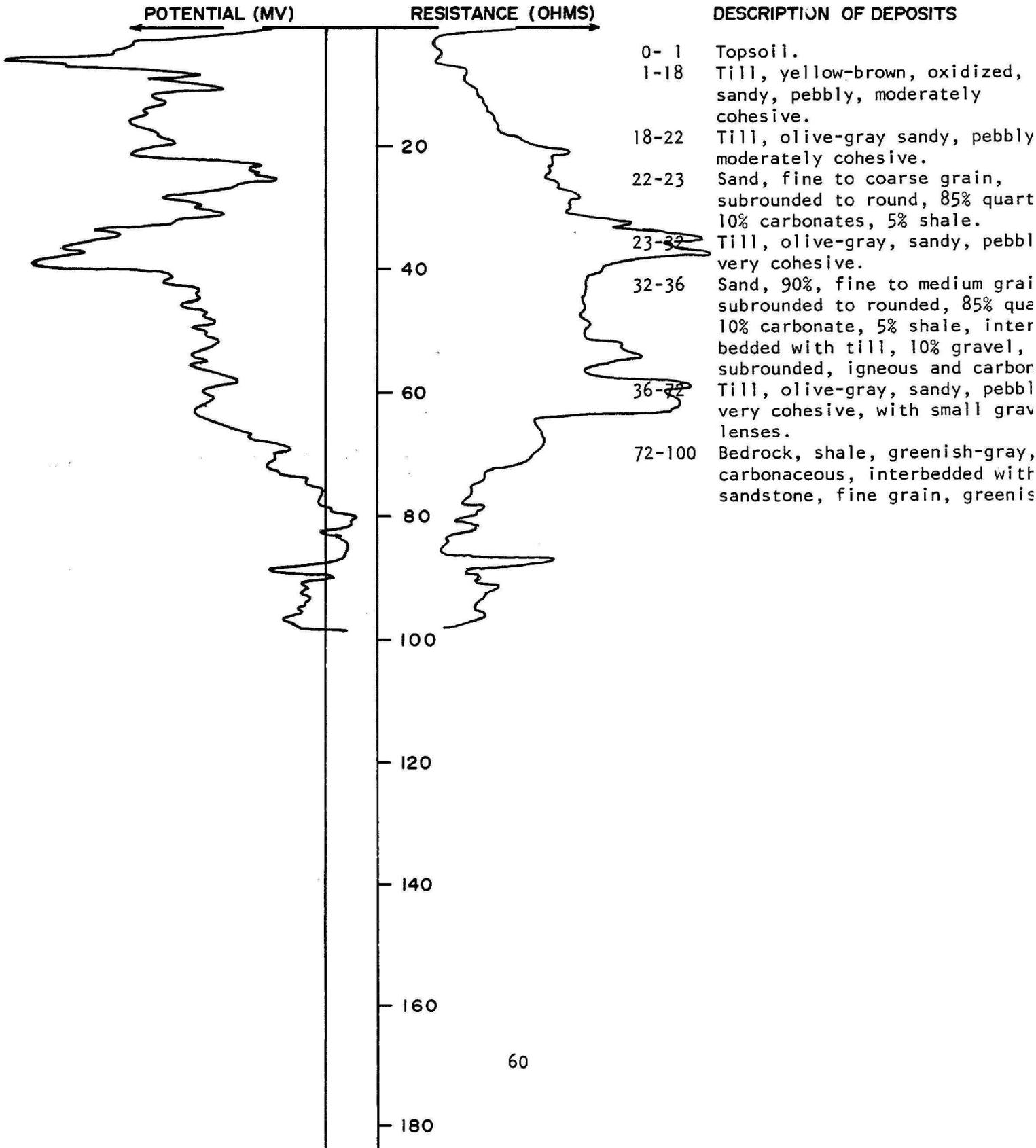
TEST HOLE 11076

LOCATION: 155-81-11CBB

DATE DRILLED: 9/18/79

ELEVATION: 1570
(FT, MSL)

DEPTH: 100
(FT)



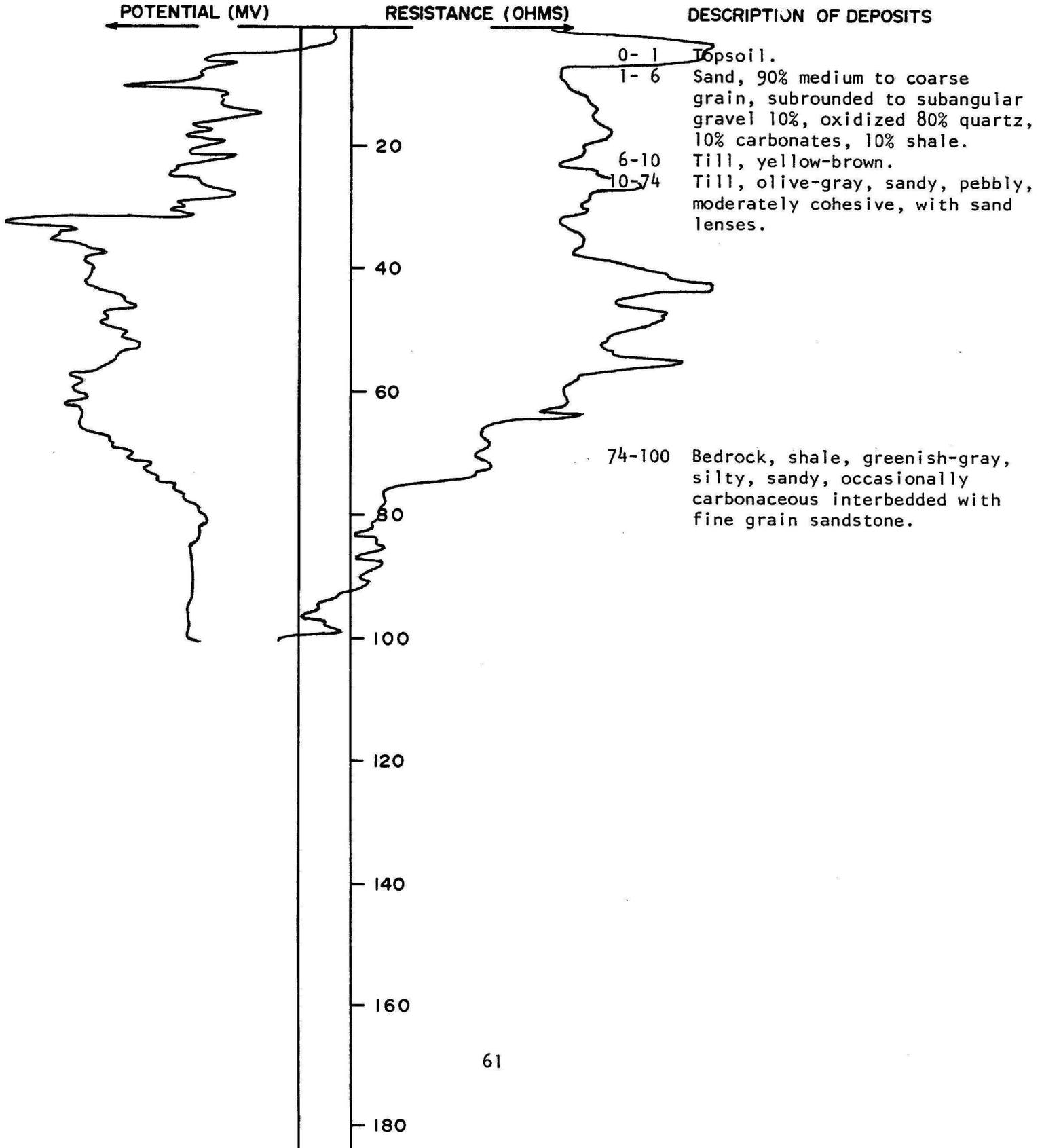
TEST HOLE 11072

LOCATION: 155-81-11CCB

DATE DRILLED: 9/17/79

ELEVATION: 1550
(FT, MSL)

DEPTH: 100
(FT)



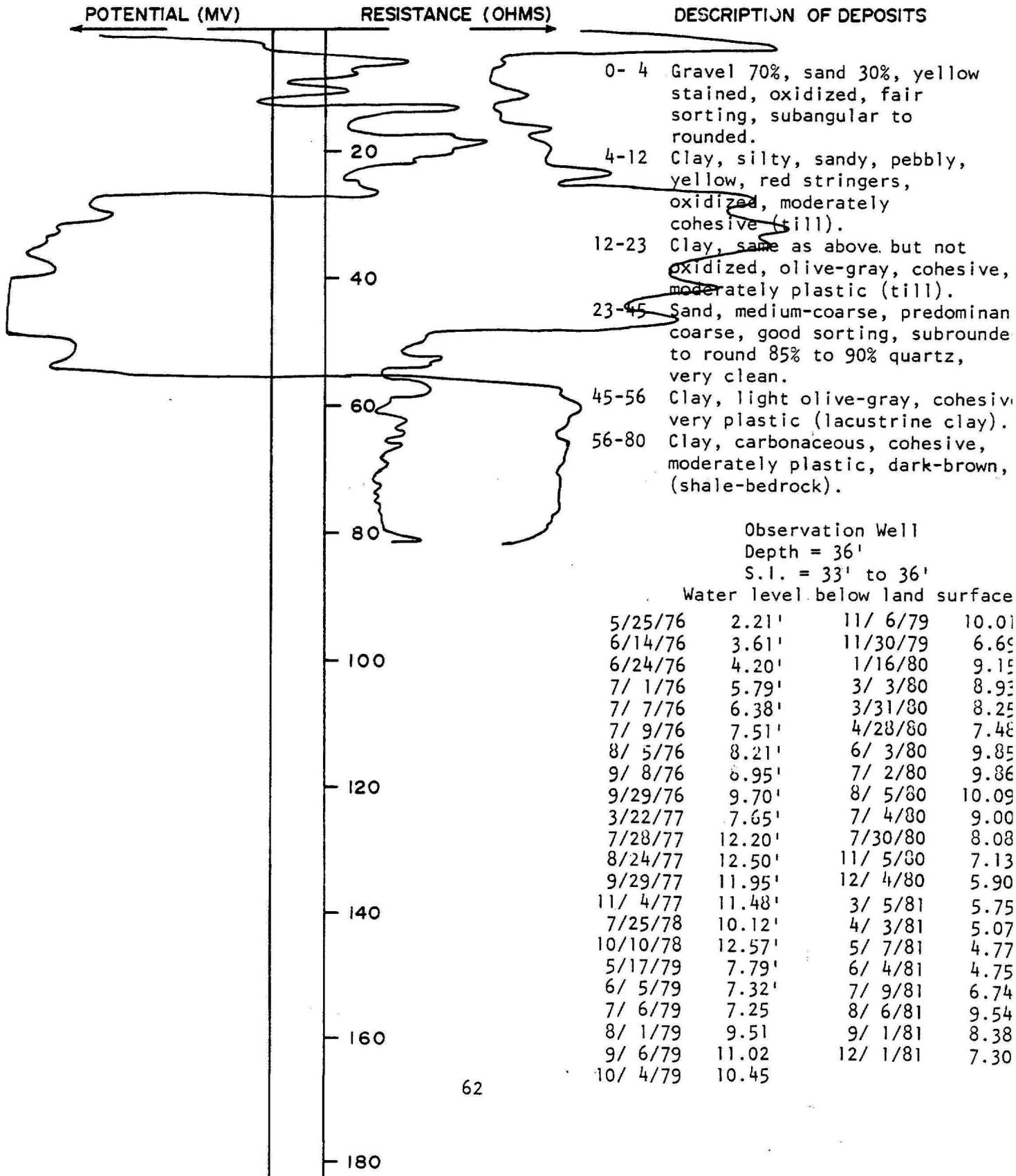
TEST HOLE 9559

LOCATION: 155-81-11CCC

DATE DRILLED: 5/20/76

ELEVATION: 1545.3
(FT, MSL)

DEPTH: 80
(FT)



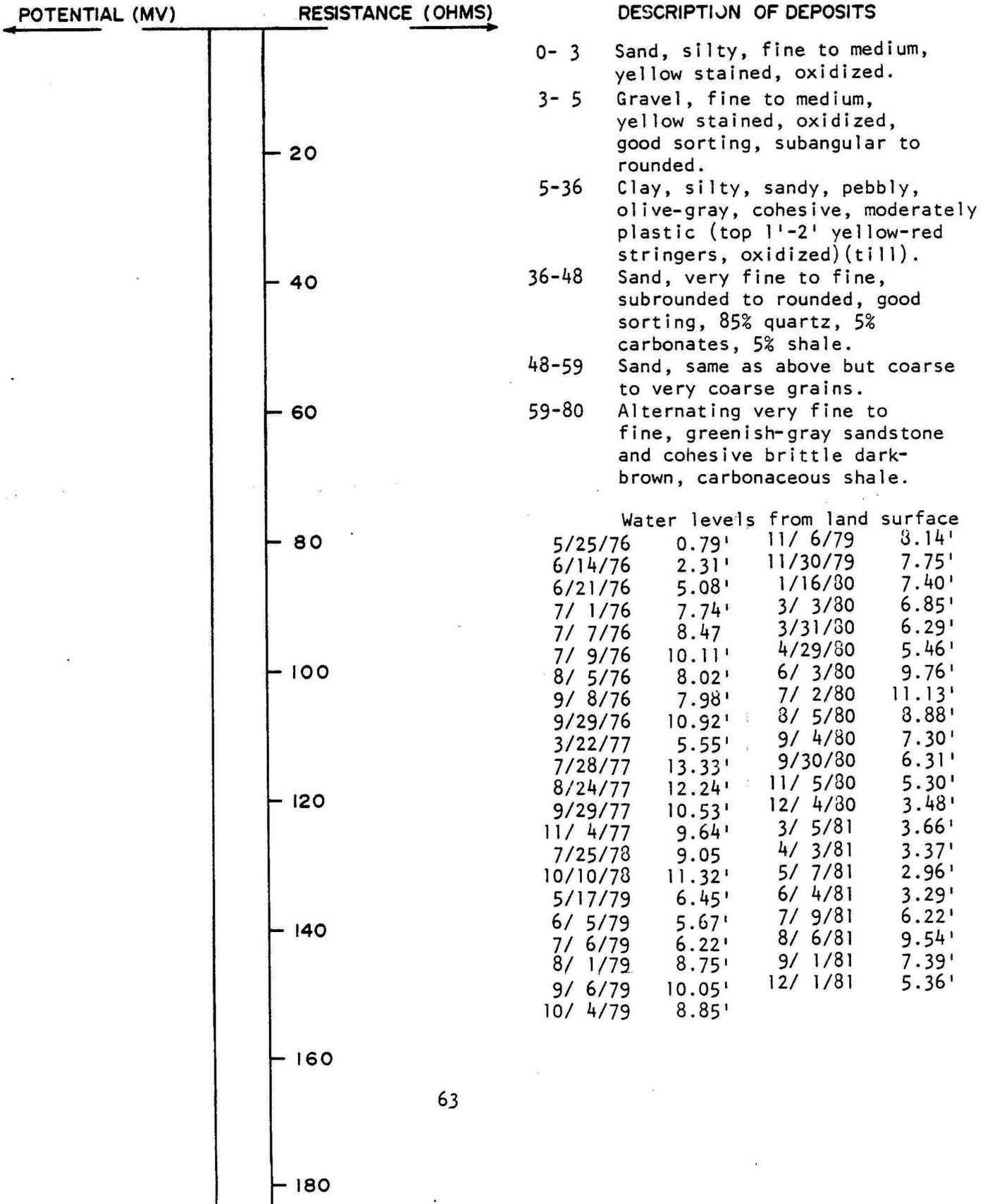
TEST HOLE 9560

LOCATION: 155-81-11CCD

DATE DRILLED: 5/20/76

ELEVATION: 1542.8
(FT, MSL)

DEPTH: 80
(FT)



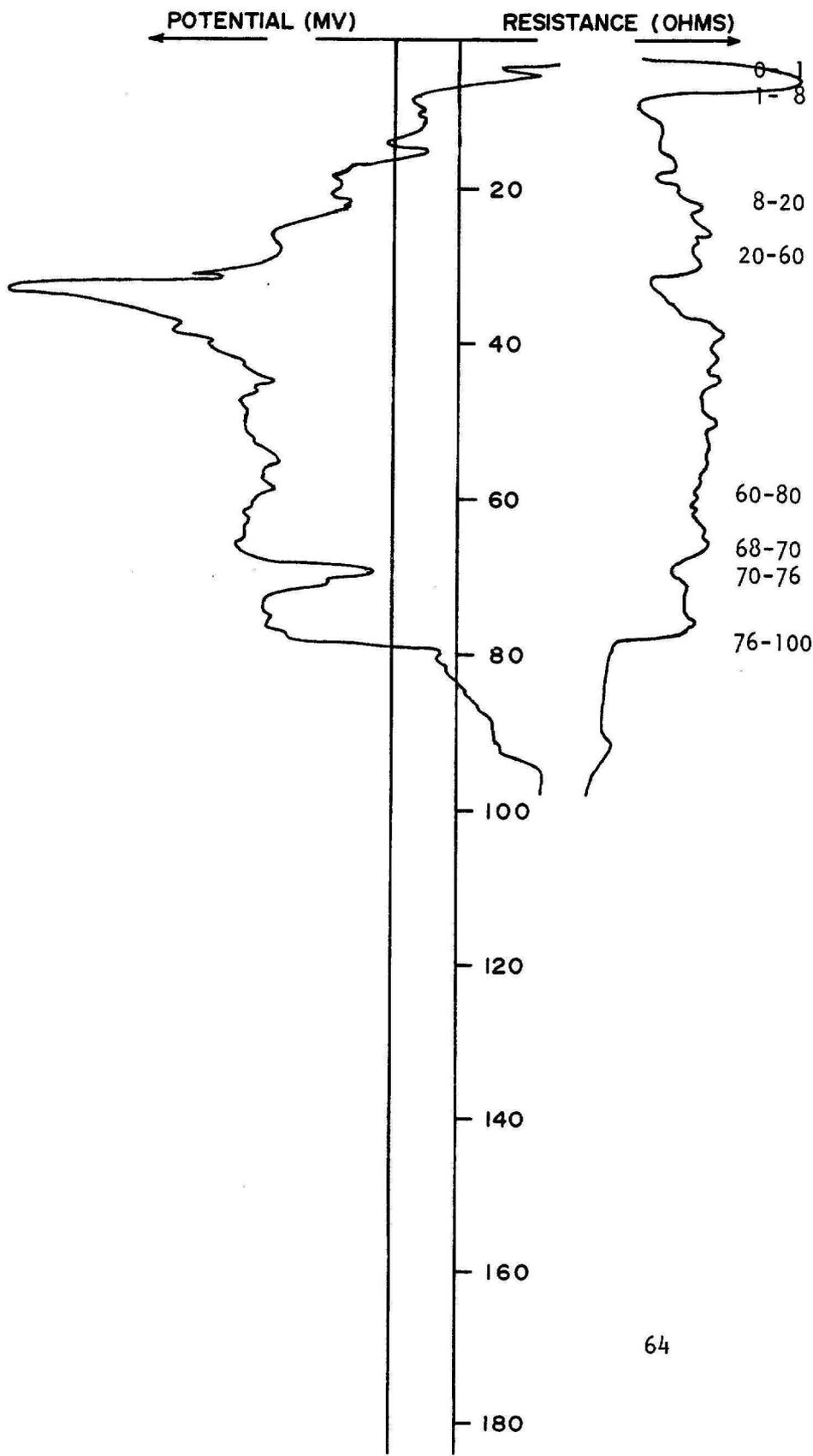
TEST HOLE 11091

LOCATION: 155-81-11CDD

DATE DRILLED: 9/20/79

ELEVATION: 1543.0
(FT, MSL)

DEPTH: 100
(FT)



DESCRIPTION OF DEPOSITS

0-1 Topsoil
 1-8 Gravel, coarse sand and gravel, oxidized, subangular to subrounded, 50% quartz, 25% carbonates, 25% igneous.
 8-20 Till, olive-gray, sandy, pebbly very cohesive.
 20-60 Sand, very fine grain, very well sorted, subangular to subrounded, 85% quartz, 15% shale and magnetite.
 60-80 Till, olive-gray, sandy, pebbly cohesive.
 68-70 Sand, no sample.
 70-76 Till, olive-gray, sandy, pebbly cohesive.
 76-100 Bedrock, shale, greenish-gray, arenaceous.

Observation Well
 Depth = 53'
 S.I. = 50' to 53'
 Water level from land surface
 1/16/80 7.66'

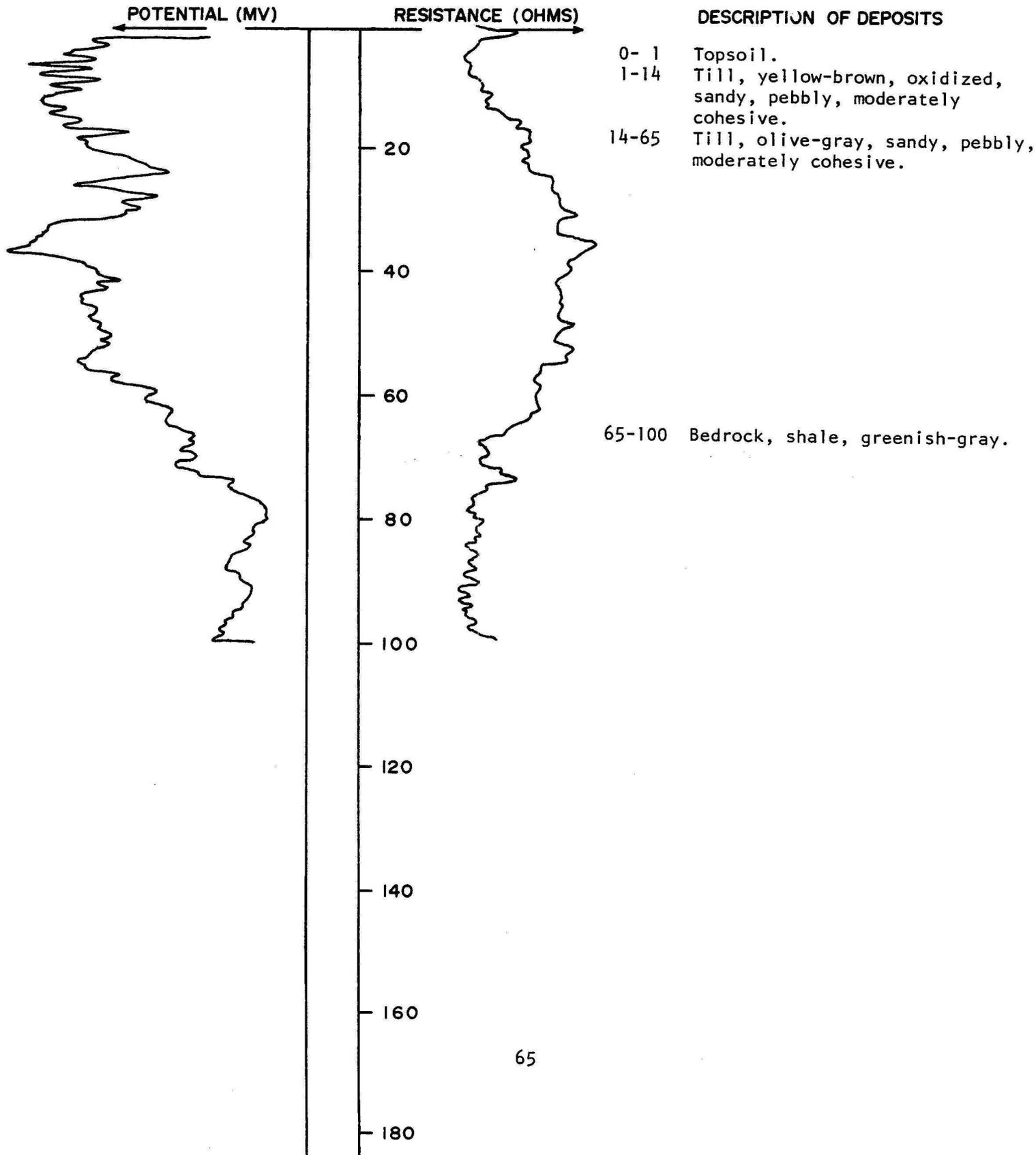
TEST HOLE 11089

LOCATION: 155-81-11DAD North

DATE DRILLED: 9/20/79

ELEVATION: 1560
(FT, MSL)

DEPTH: 100
(FT)



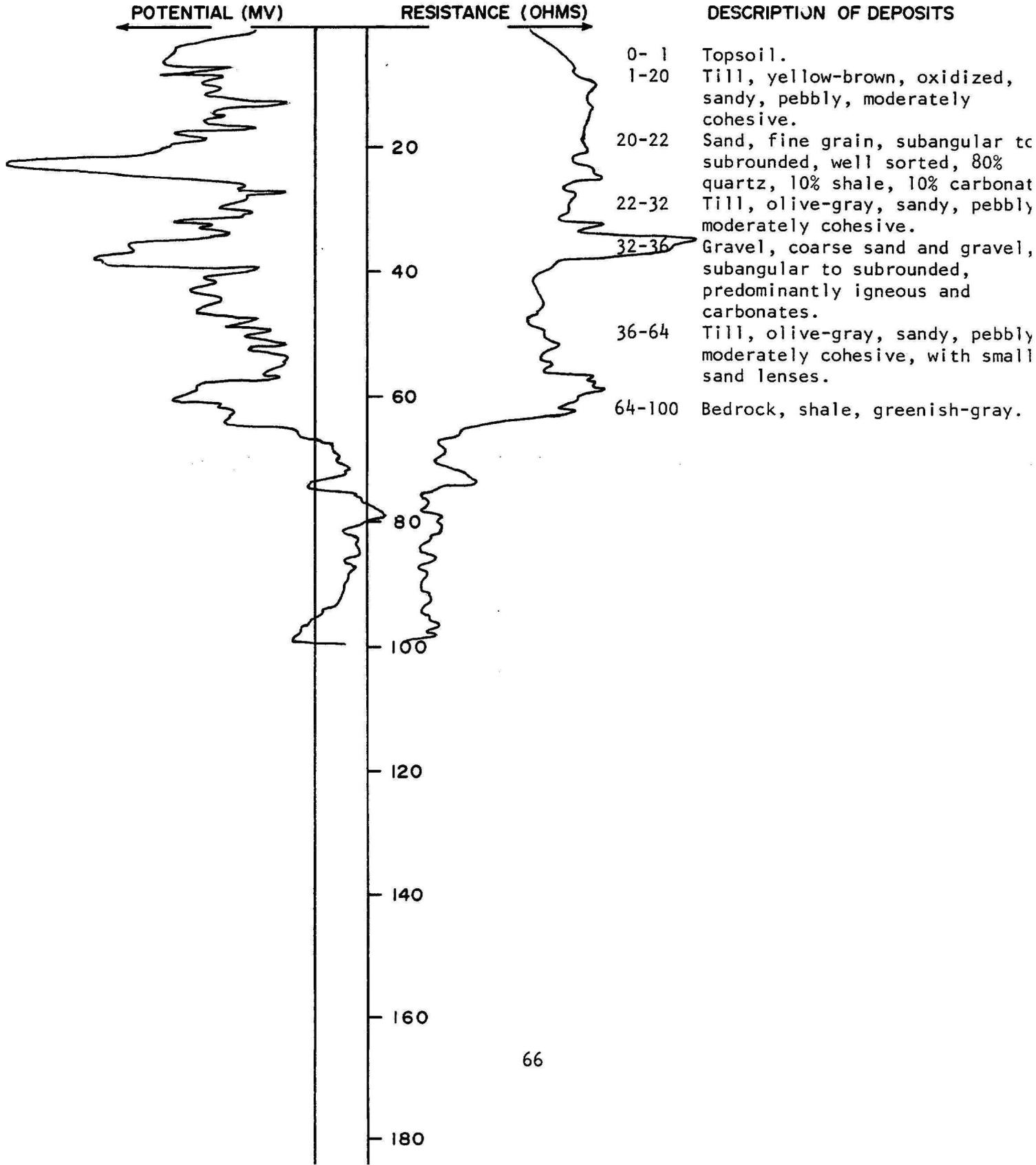
TEST HOLE 11085

LOCATION: 155-81-11DAD South

DATE DRILLED: 9/19/79

ELEVATION: 1560
(FT, MSL)

DEPTH: 100
(FT)



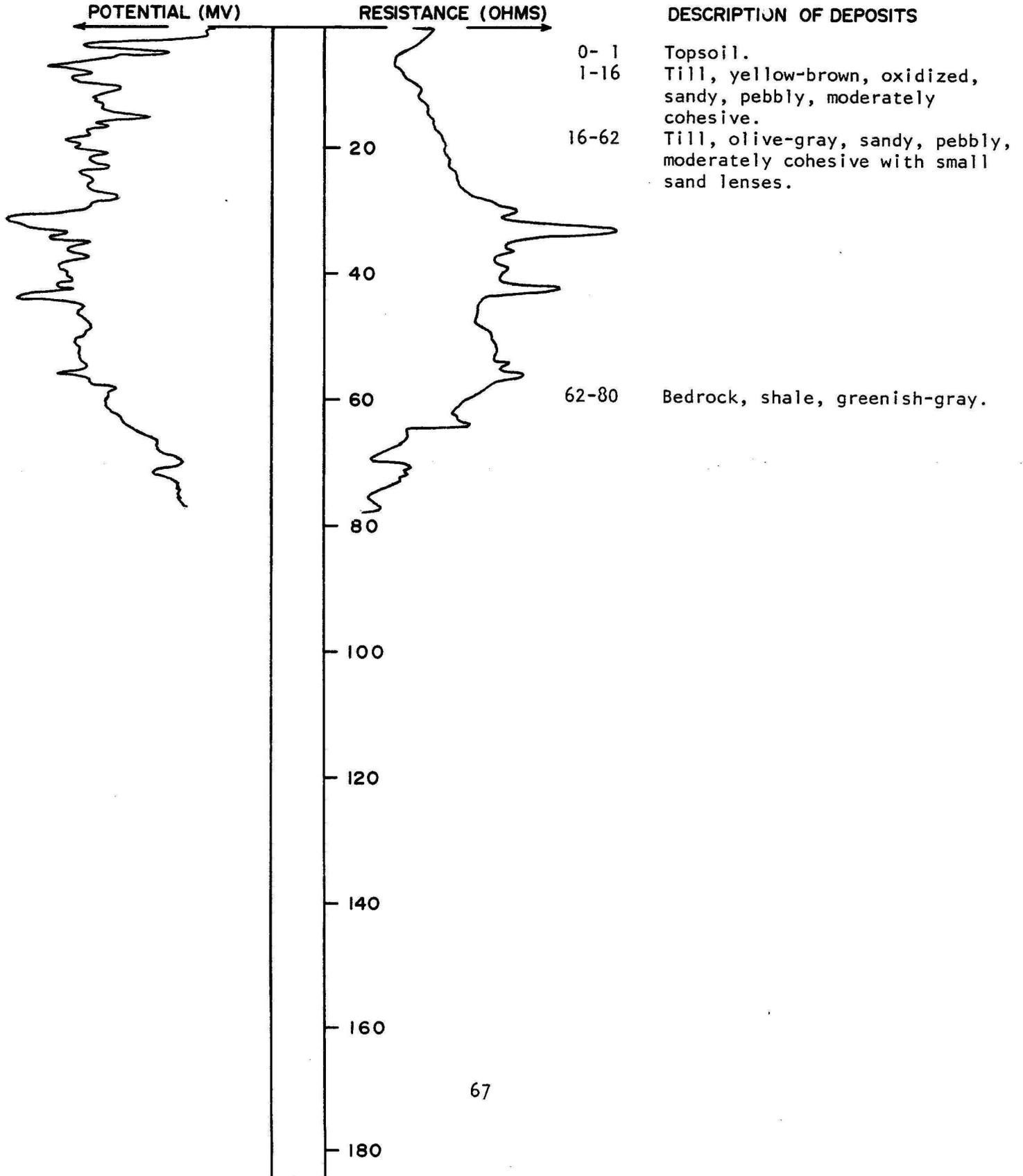
TEST HOLE 11090

LOCATION: 155-81-11DDA

DATE DRILLED: 9/20/79

ELEVATION: 1555
(FT, MSL)

DEPTH: 80
(FT)



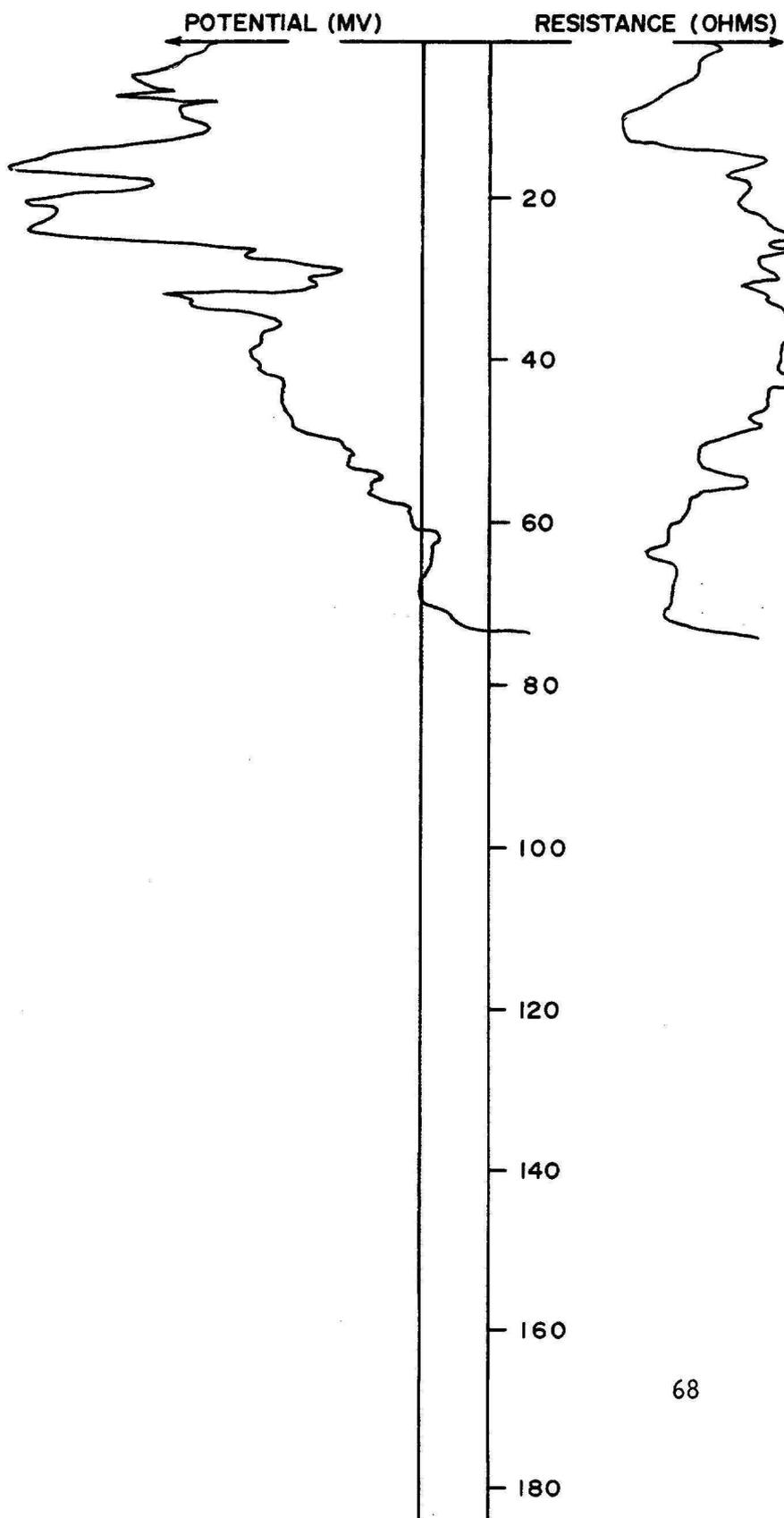
TEST HOLE 11081

LOCATION: 155-81-12DDA

DATE DRILLED: 9/19/79

ELEVATION: 1550
(FT, MSL)

DEPTH: 80
(FT)



DESCRIPTION OF DEPOSITS

- 0- 1 Topsoil, dark-brown, sandy.
- 1- 2 Sand, medium grain, well sorte subangular to subrounded, 80% quartz, 10% carbonates, 10% shale.
- 2-14 Till, yellow-brown, oxidized, sandy, pebbly, moderately cohesive.
- 14-16 Sand and gravel, fine sand to gravel, poorly sorted, subangu to subrounded, oxidized.
- 16-18 Till, olive-gray, sandy, pebbli moderately cohesive.
- 18-24 Sand, 90% fine grain to coarse predominantly fine subangular subrounded, 80% quartz, 10% carbonates, 10% shale, gravel 10%, subrounded, 80% carbonate 20% igneous, interbedded with till.
- 24-59 Till, olive-gray, sandy, pebbli moderately cohesive, lignite from 41' to 42'.
- 59-80 Bedrock, shale, greenish-gray.

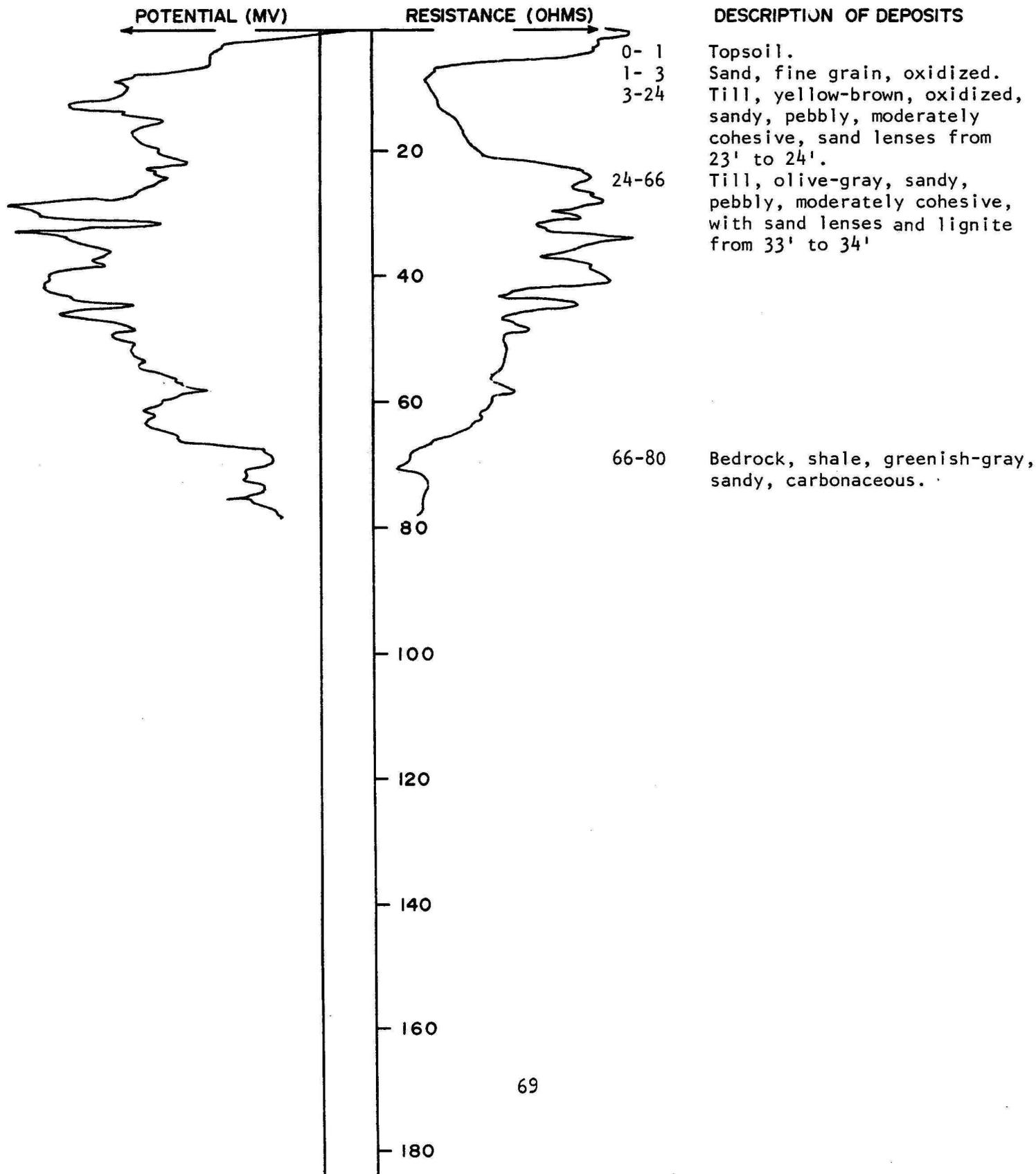
TEST HOLE 11093

LOCATION: 155-81-12DDD North

DATE DRILLED: 9/20/79

ELEVATION: 1550
(FT, MSL)

DEPTH: 80
(FT)



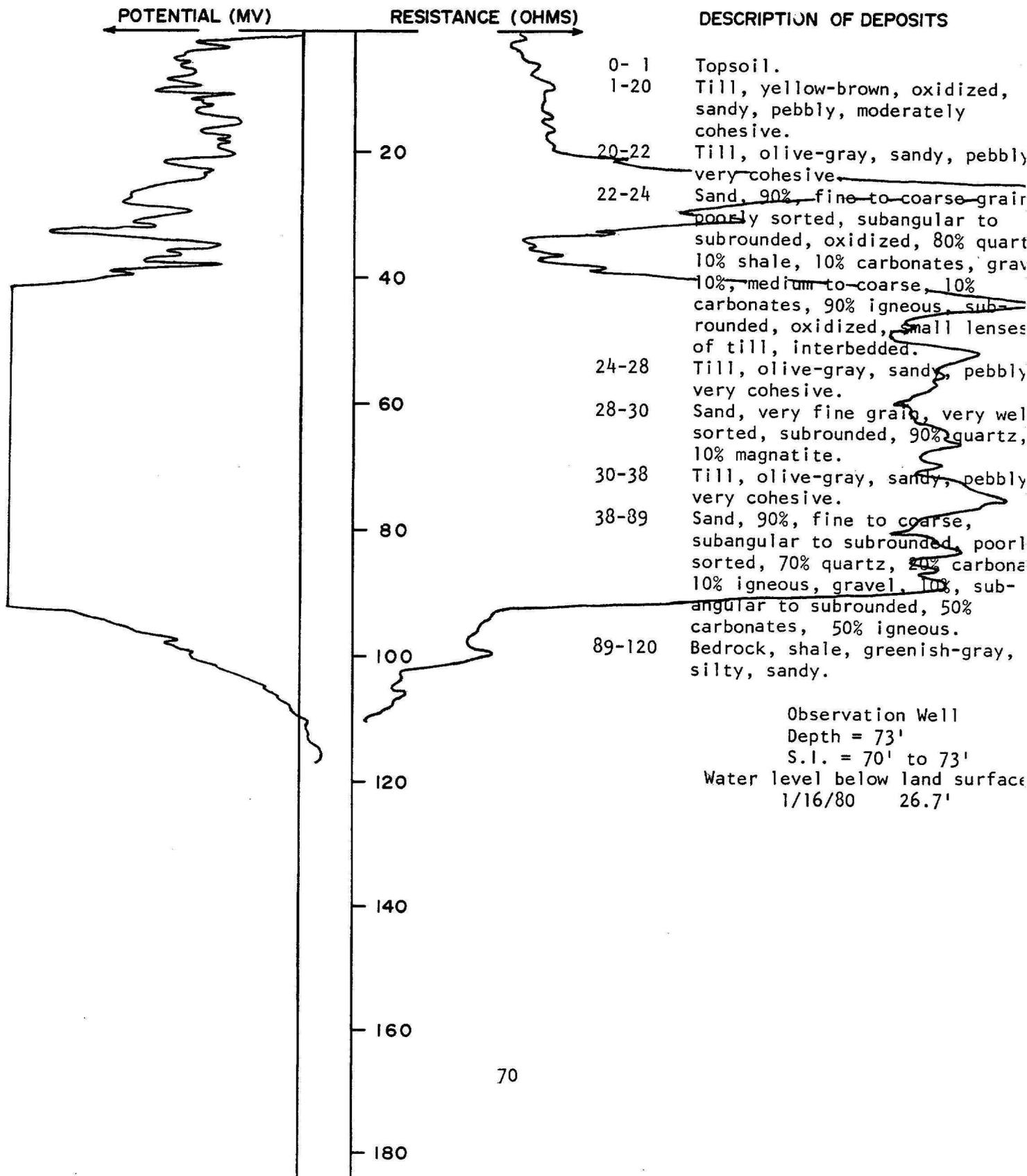
TEST HOLE 11080

LOCATION: 155-81-13AAA 1

DATE DRILLED: 9/18/79

ELEVATION: 1565.3
(FT, MSL)

DEPTH: 120
(FT)



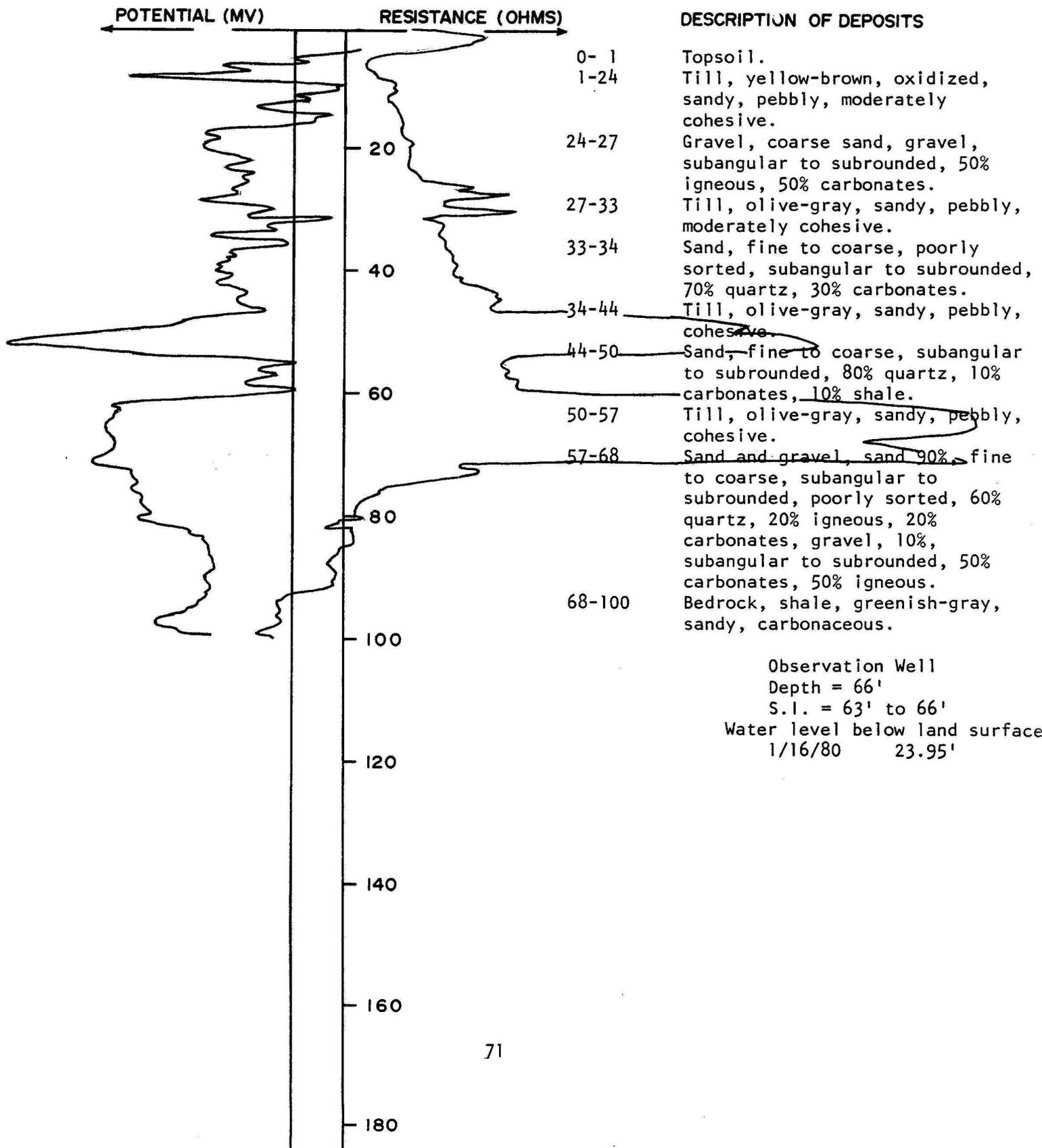
TEST HOLE 11094

LOCATION: 155-81-13AAA 2

DATE DRILLED: 9/20/79

ELEVATION: 1563.4
(FT, MSL)

DEPTH: 100
(FT)



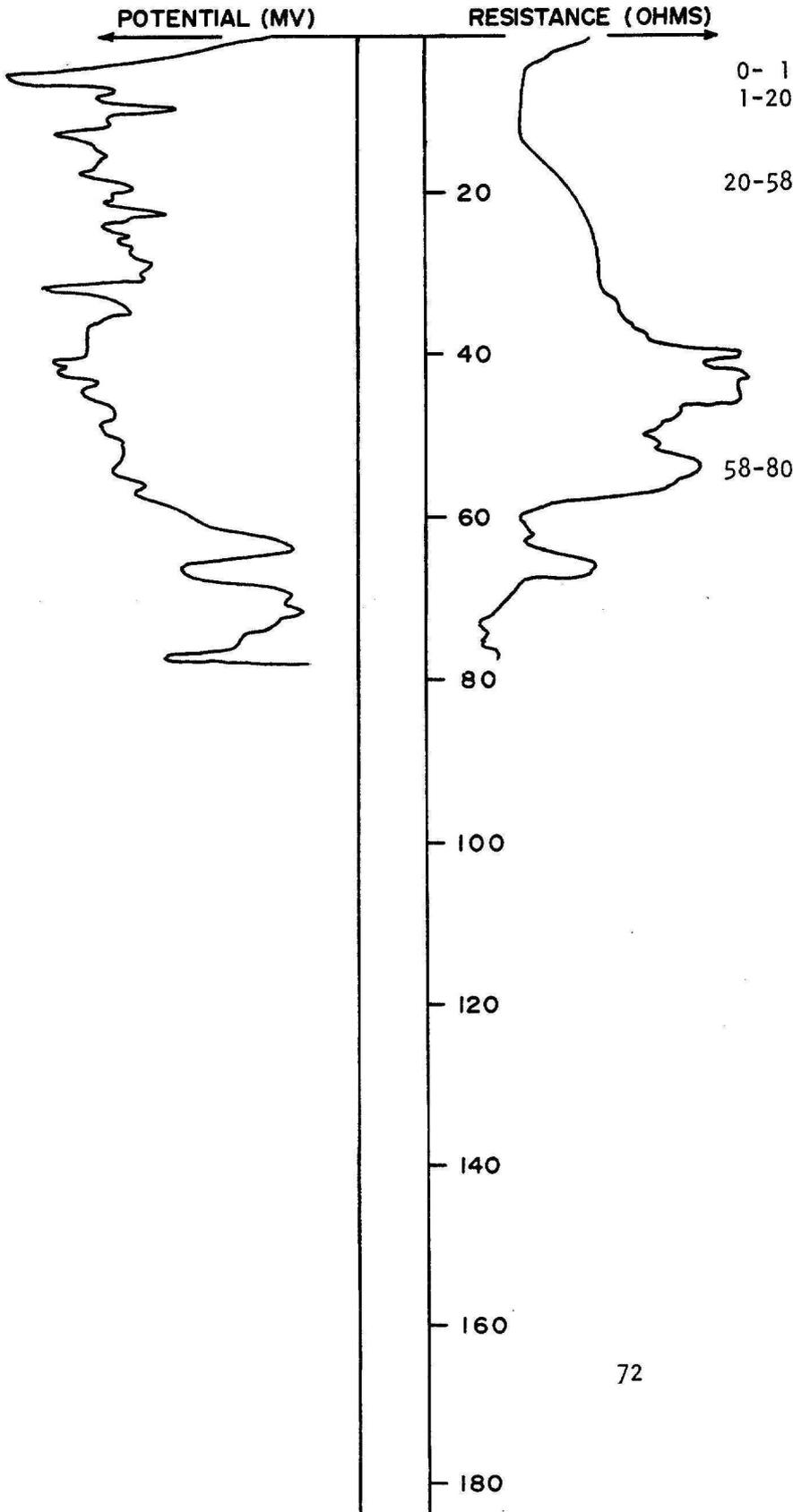
TEST HOLE 11082

LOCATION: 155-81-13AAD

DATE DRILLED: 9/19/79

ELEVATION: 1550
(FT, MSL)

DEPTH: 80
(FT)



DESCRIPTION OF DEPOSITS

0- 1 Topsoil.
1-20 Till, yellow-brown, oxidized, sandy, pebbly, moderately cohesive.
20-58 Till, olive-gray, sandy, pebbly, moderately cohesive.
58-80 Bedrock, shale, greenish-gray.

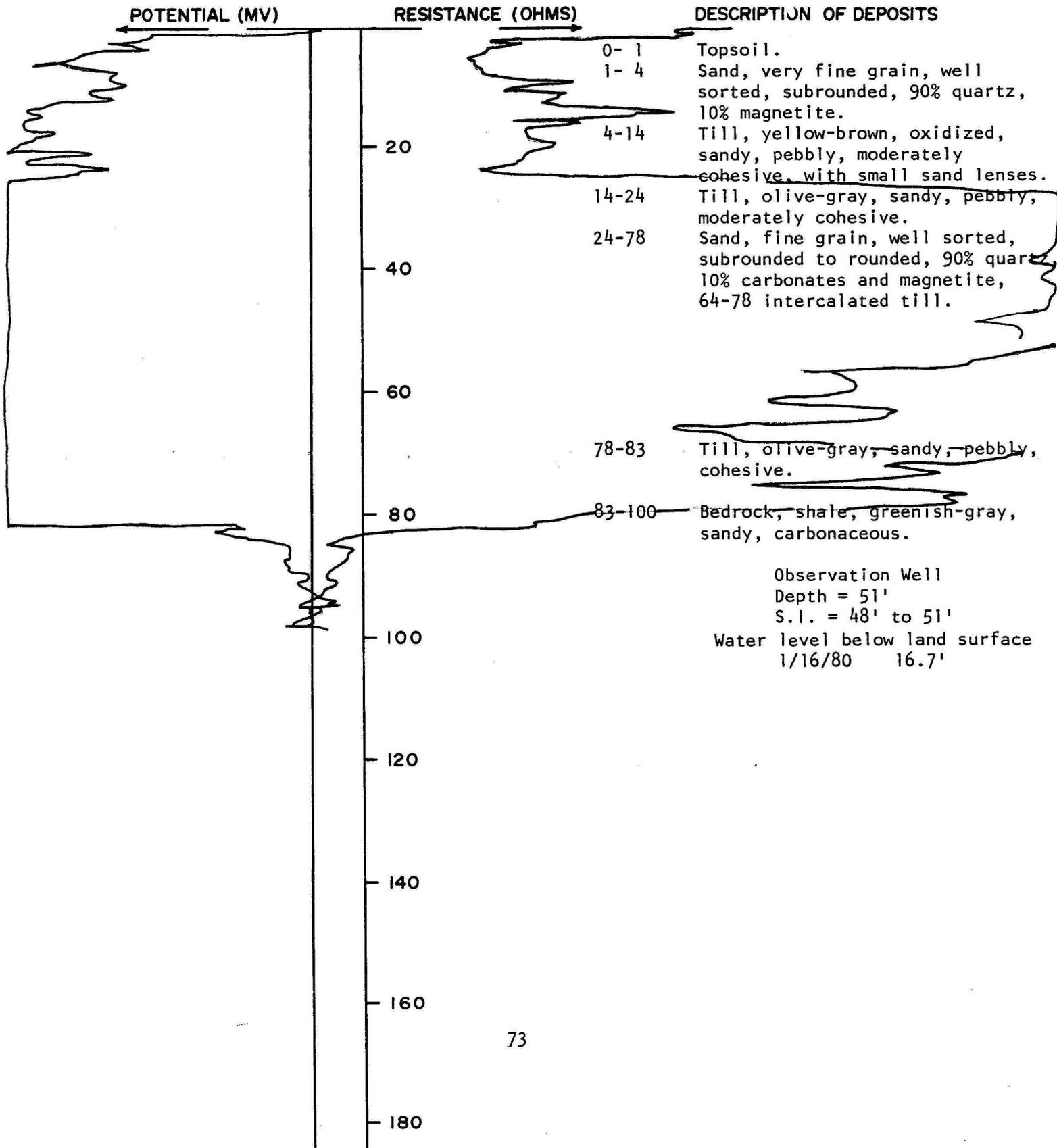
TEST HOLE 11095

LOCATION: 155-81-13ABA

DATE DRILLED: 9/20/79

ELEVATION: 1554.6
(FT, MSL)

DEPTH: 100
(FT)



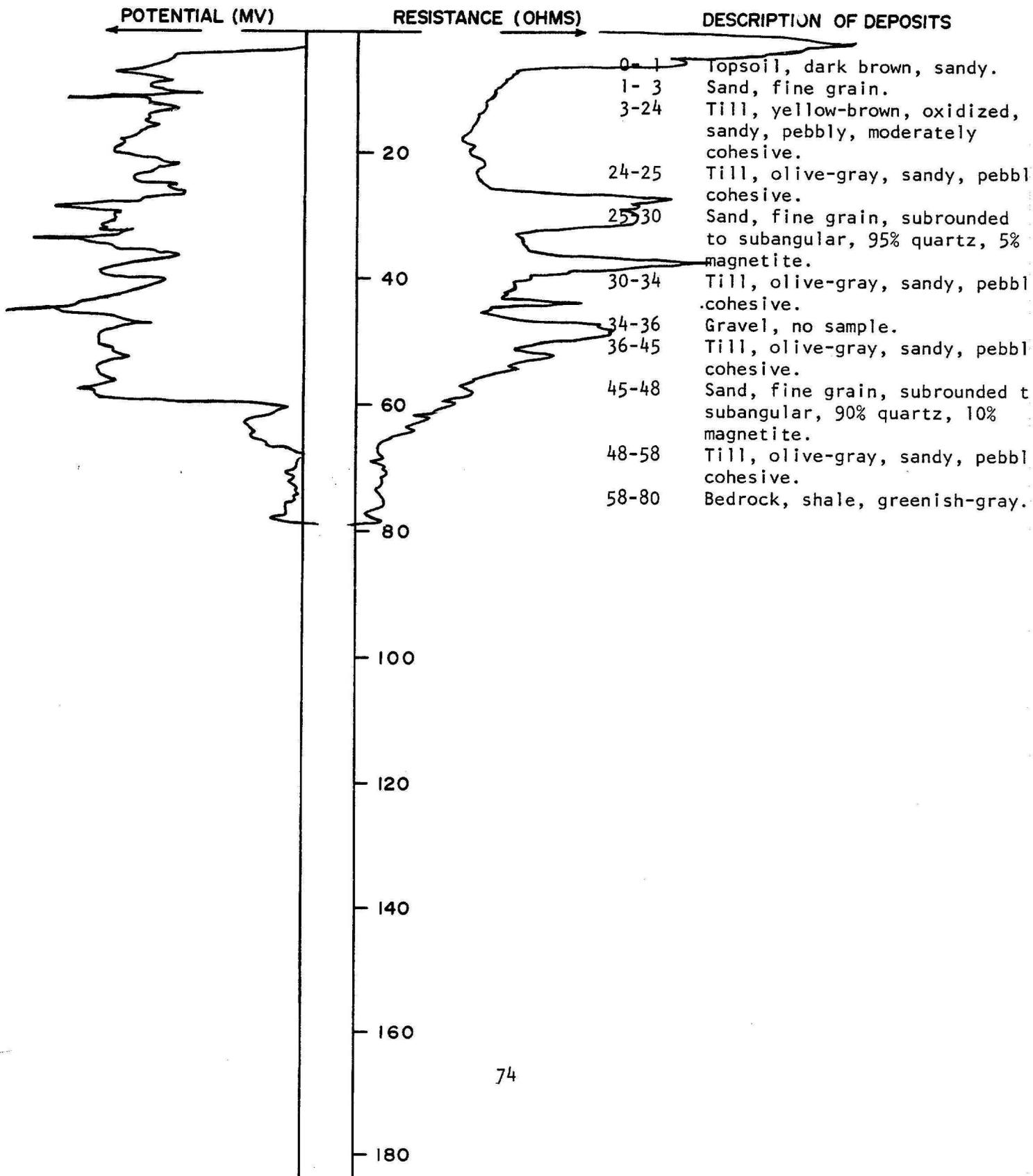
TEST HOLE 11084

LOCATION: 155-81-13ABB

DATE DRILLED: 9/19/79

ELEVATION: 1558
(FT, MSL)

DEPTH: 80
(FT)



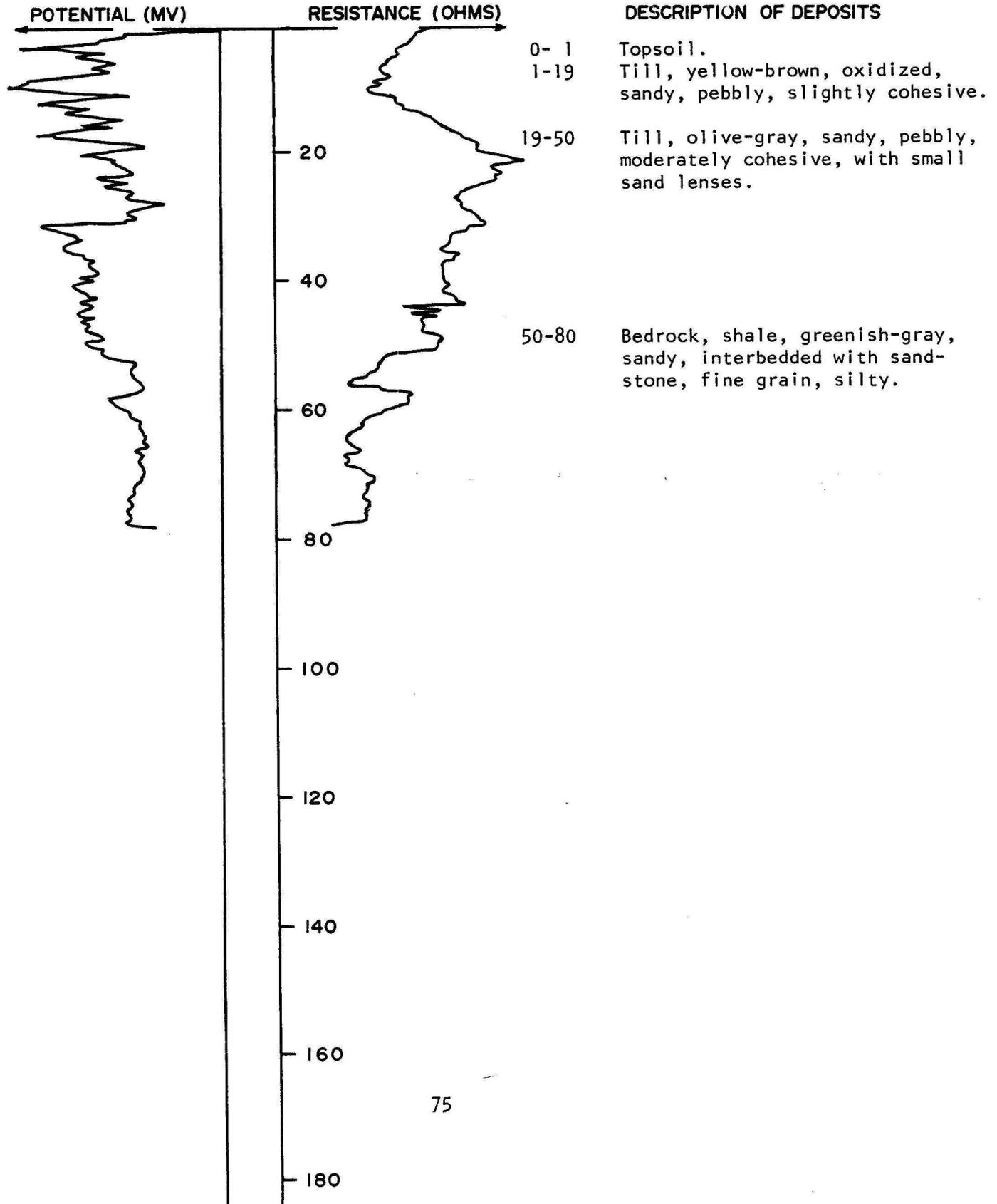
TEST HOLE 11073

LOCATION: 155-81-13BBB

DATE DRILLED: 9/17/79

ELEVATION: 1549
(FT, MSL)

DEPTH: 80
(FT)



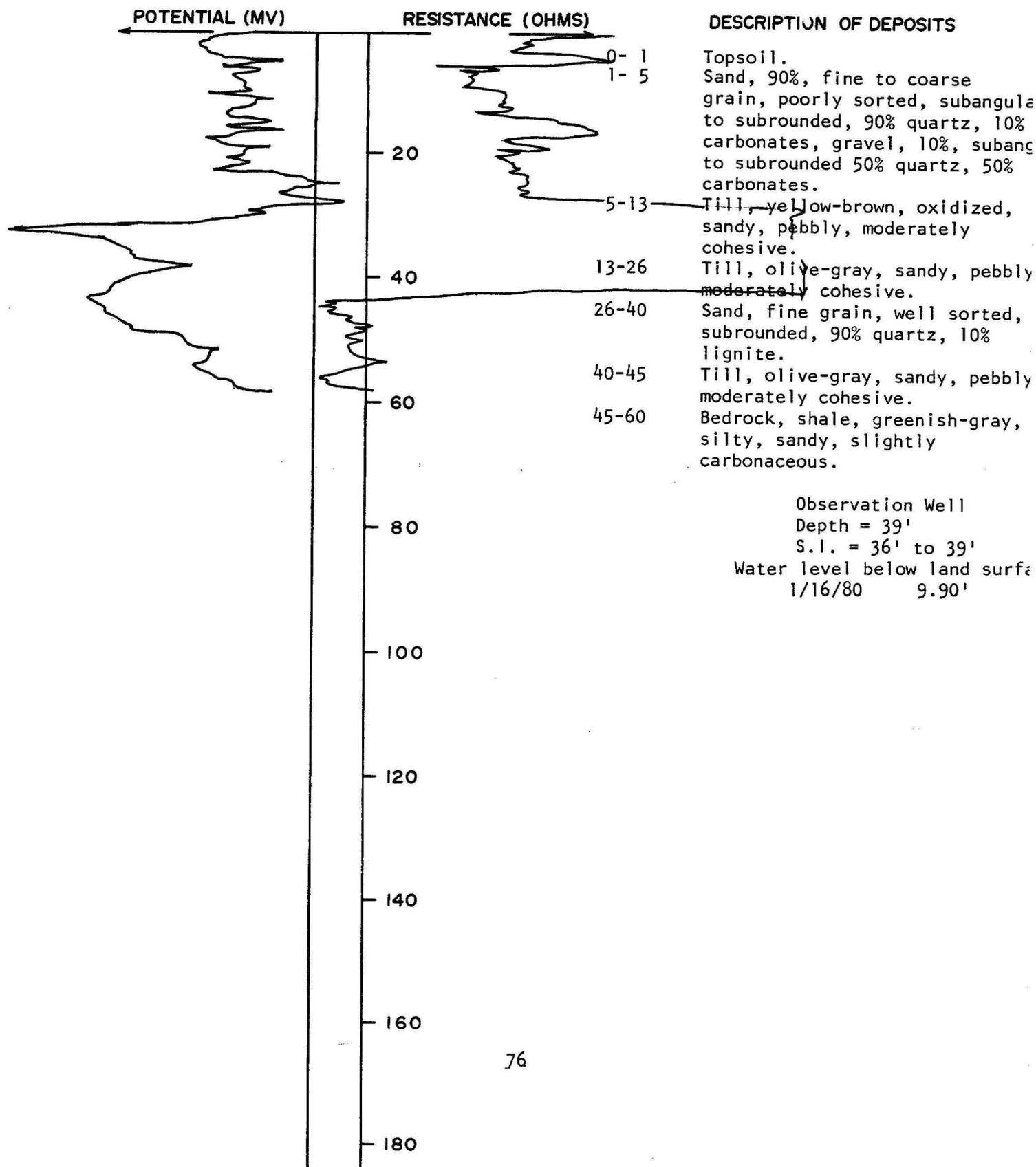
TEST HOLE 11112

LOCATION: 155-81-14BAA

DATE DRILLED: 9/26/79

ELEVATION: 1545.2
(FT, MSL)

DEPTH: 60
(FT)



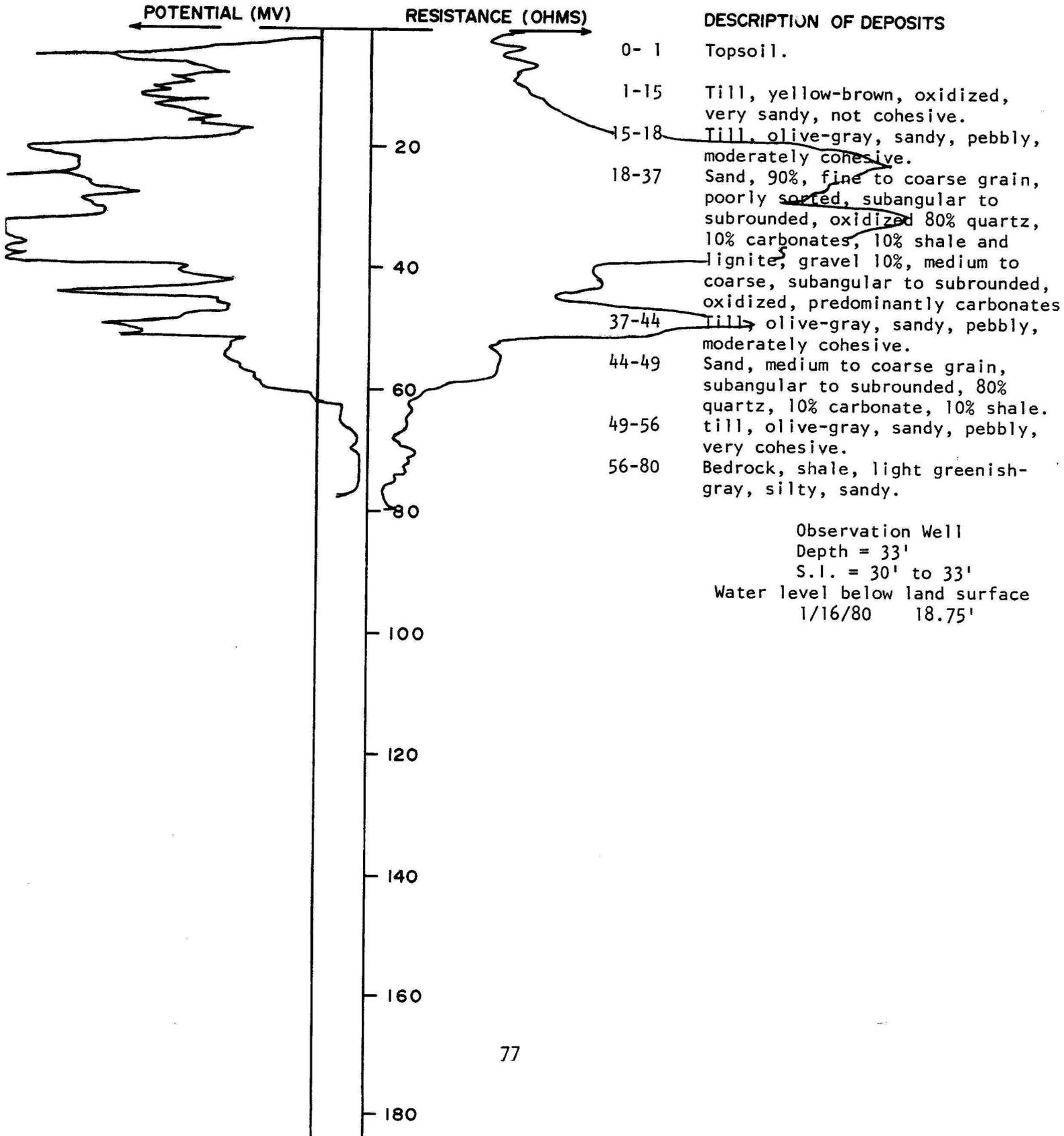
TEST HOLE 11071

LOCATION: 155-81-14BBB

DATE DRILLED: 9/17/79

ELEVATION: 1554.4
(FT, MSL)

DEPTH: 80
(FT)



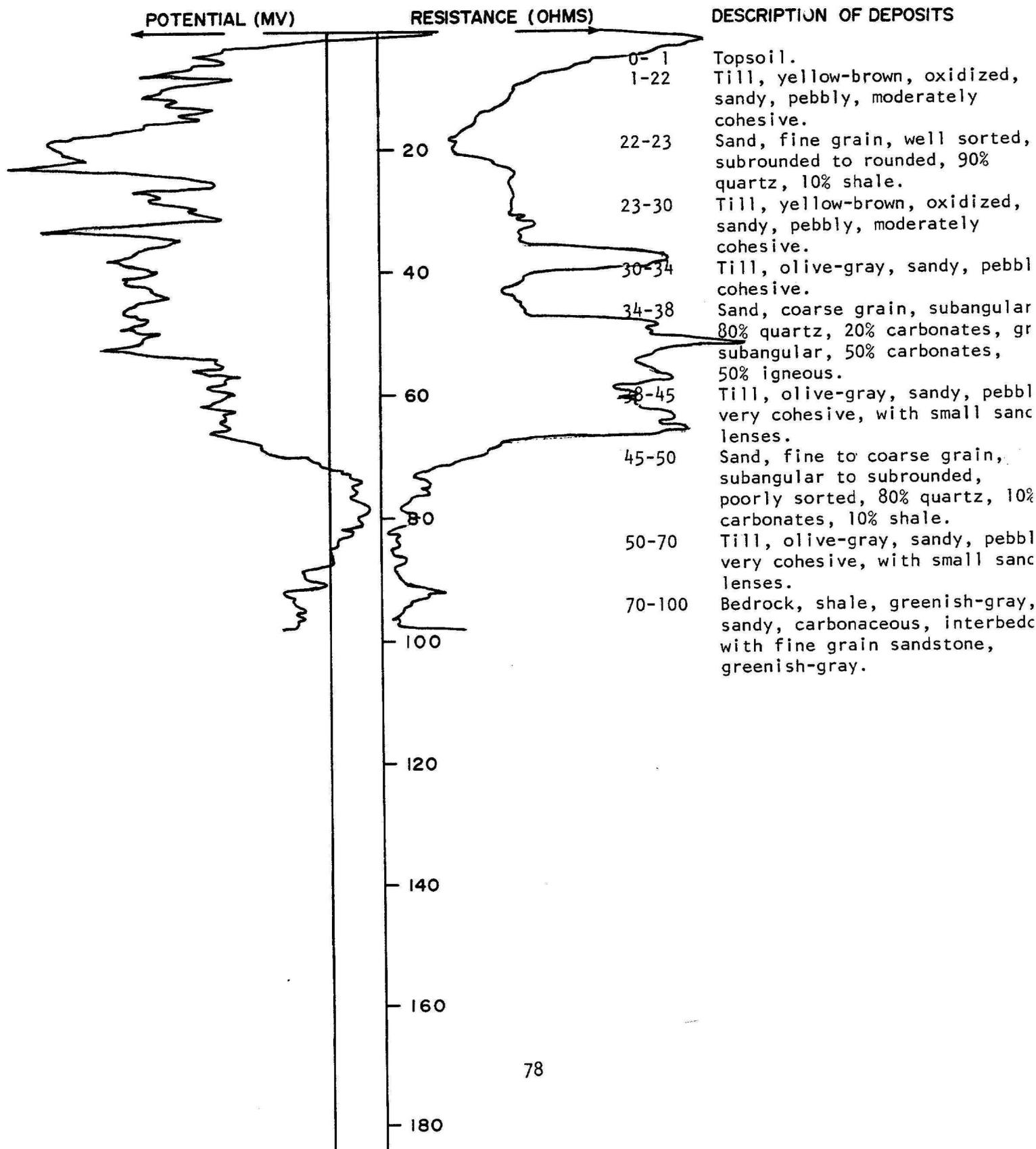
TEST HOLE 11096

LOCATION: 155-81-14BBC

DATE DRILLED: 9/21/79

ELEVATION: 1575
(FT, MSL)

DEPTH: 100
(FT)



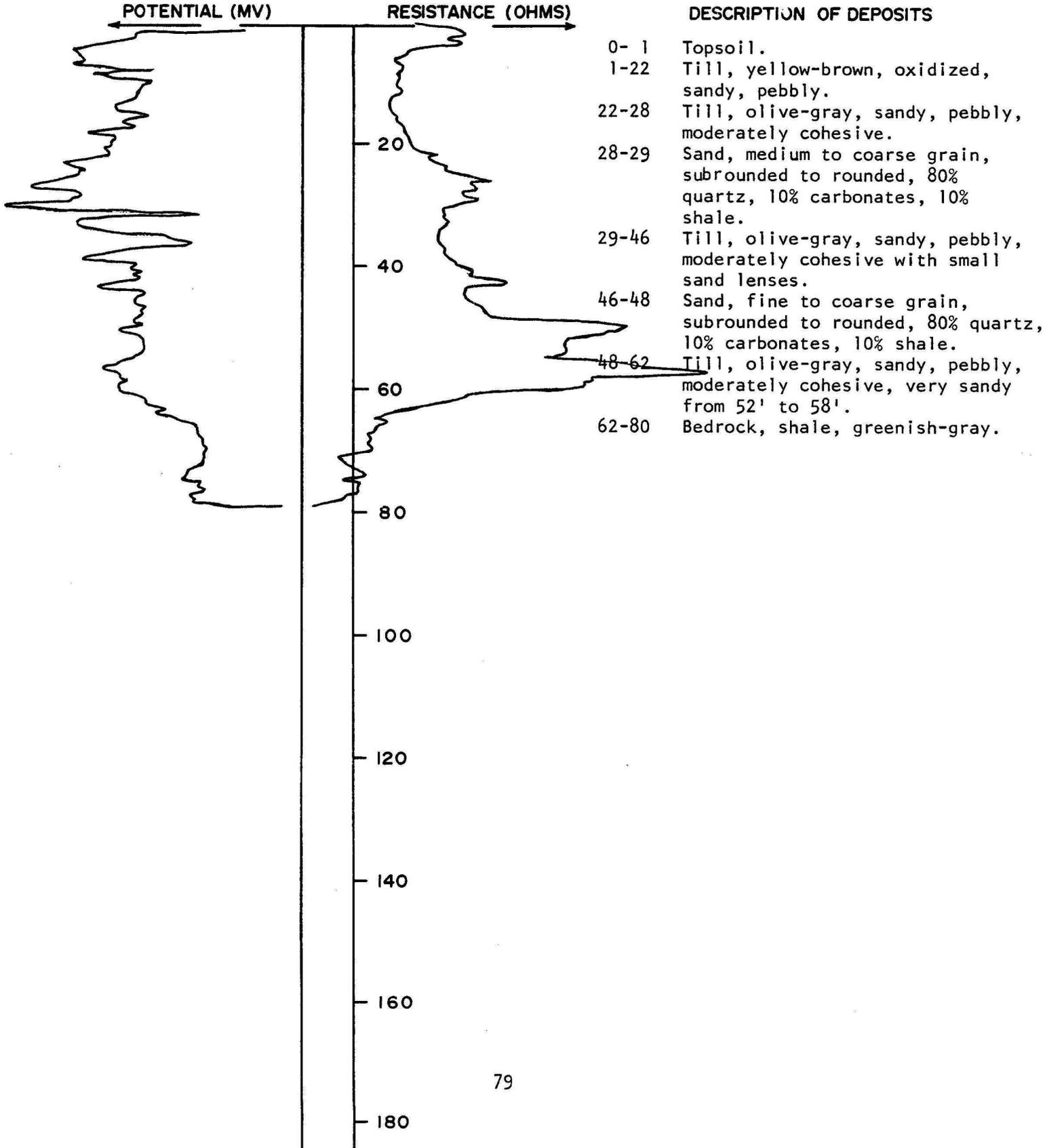
TEST HOLE 11078

LOCATION: 155-81-14BCB

DATE DRILLED: 9/18/79

ELEVATION: 1565
(FT, MSL)

DEPTH: 80
(FT)



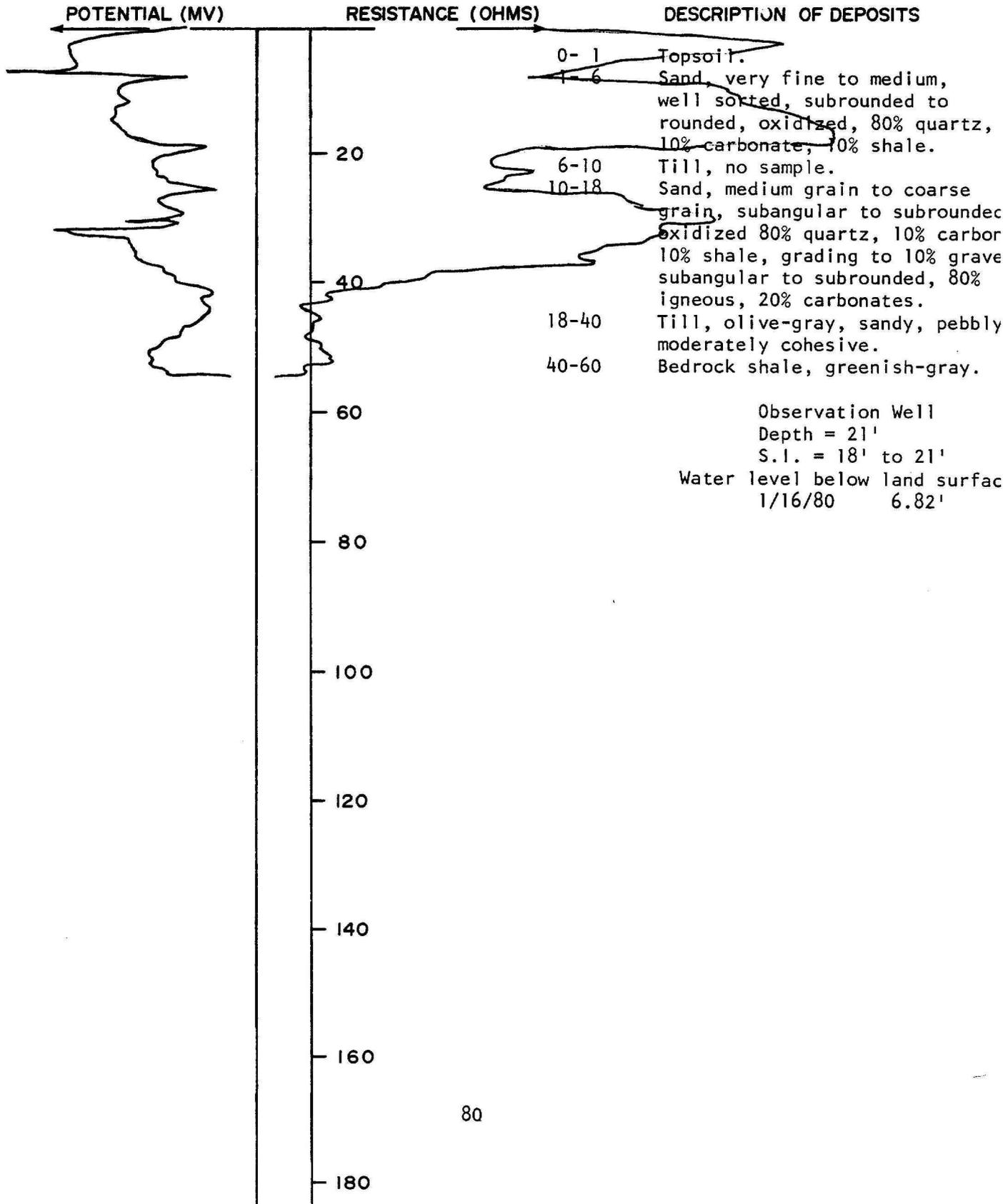
TEST HOLE 11079

LOCATION: 155-81-14CBC

DATE DRILLED: 9/18/79

ELEVATION: 1564.1
(FT, MSL)

DEPTH: 60
(FT)



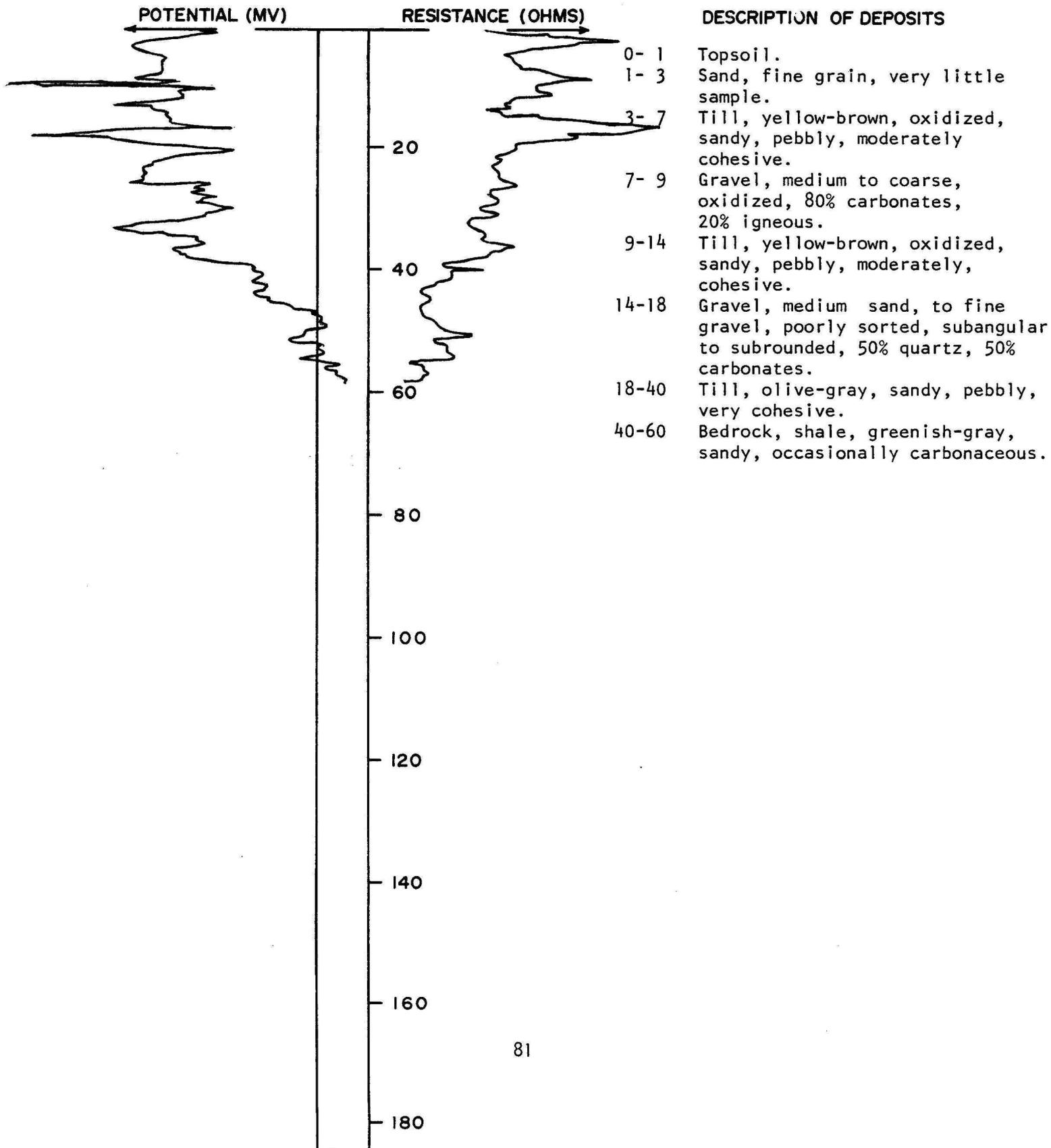
TEST HOLE 11097

LOCATION: 155-81-15AAA

DATE DRILLED: 9/21/79

ELEVATION: 1550
(FT, MSL)

DEPTH: 60
(FT)



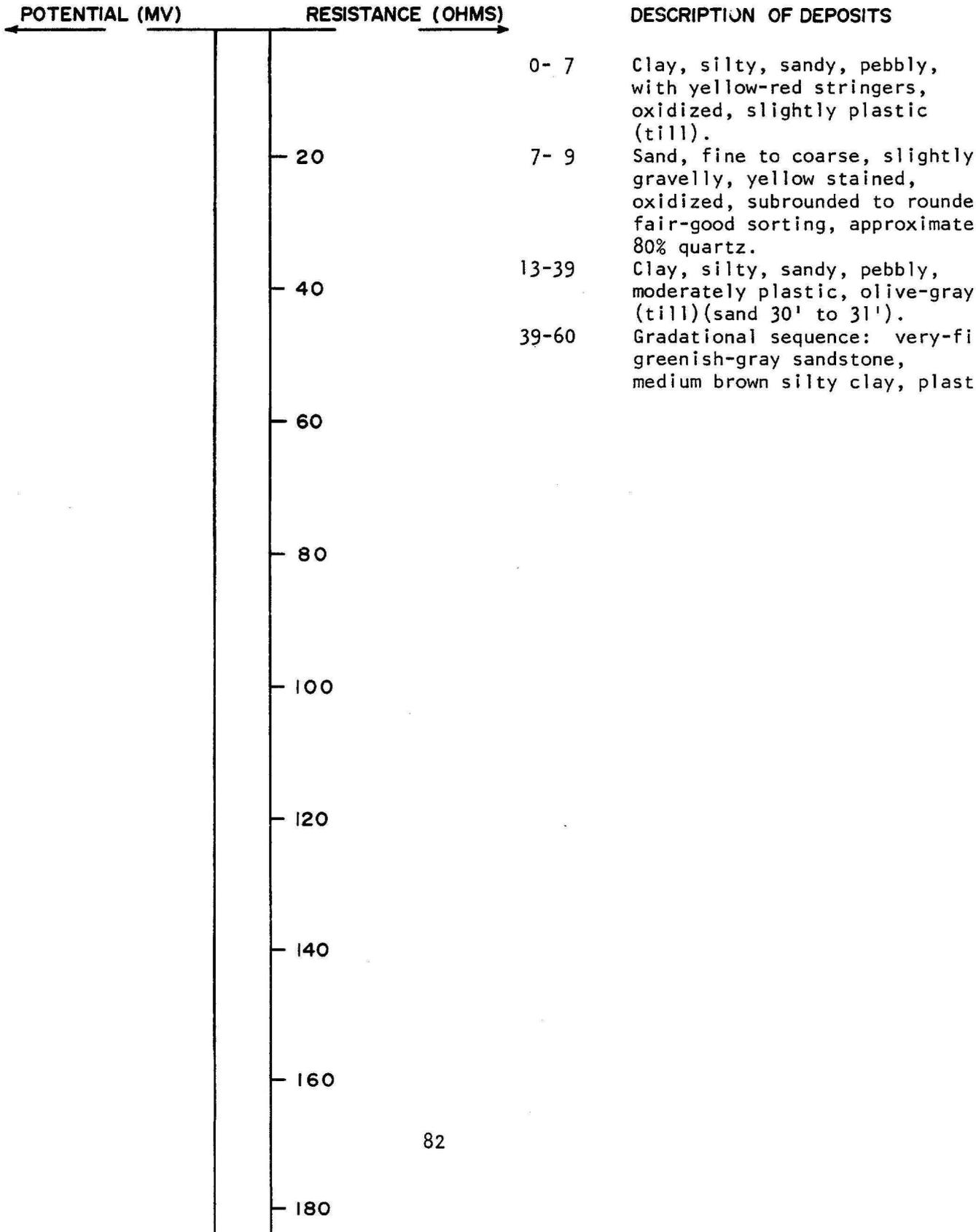
TEST HOLE 9561

LOCATION: 155-81-15bbb

DATE DRILLED: 5/20/76

ELEVATION: 1550
(FT, MSL)

DEPTH: 60'
(FT)



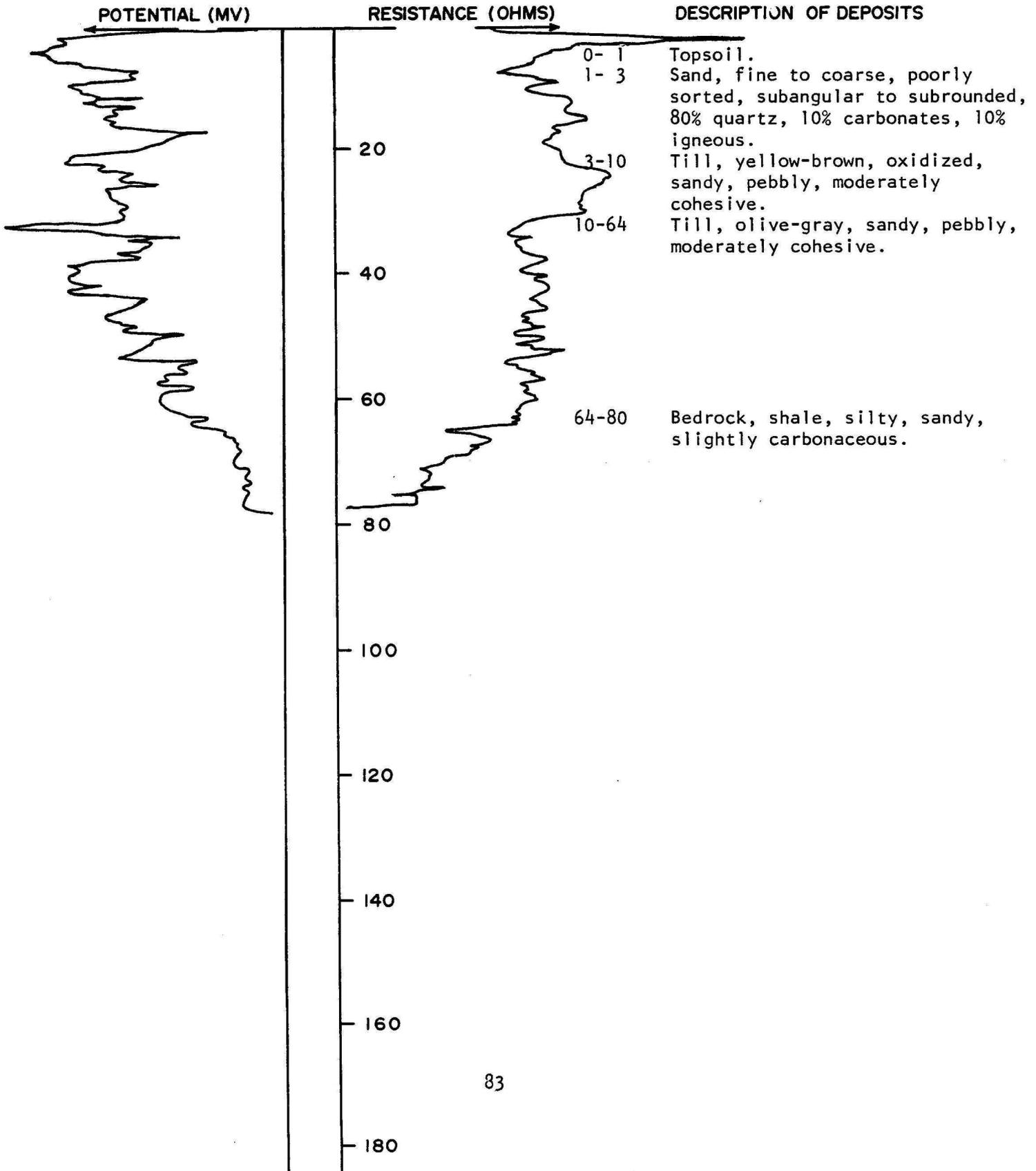
TEST HOLE 11109

LOCATION: 156-81-06AAD

DATE DRILLED: 9/26/79

ELEVATION: 1570
(FT, MSL)

DEPTH: 80
(FT)



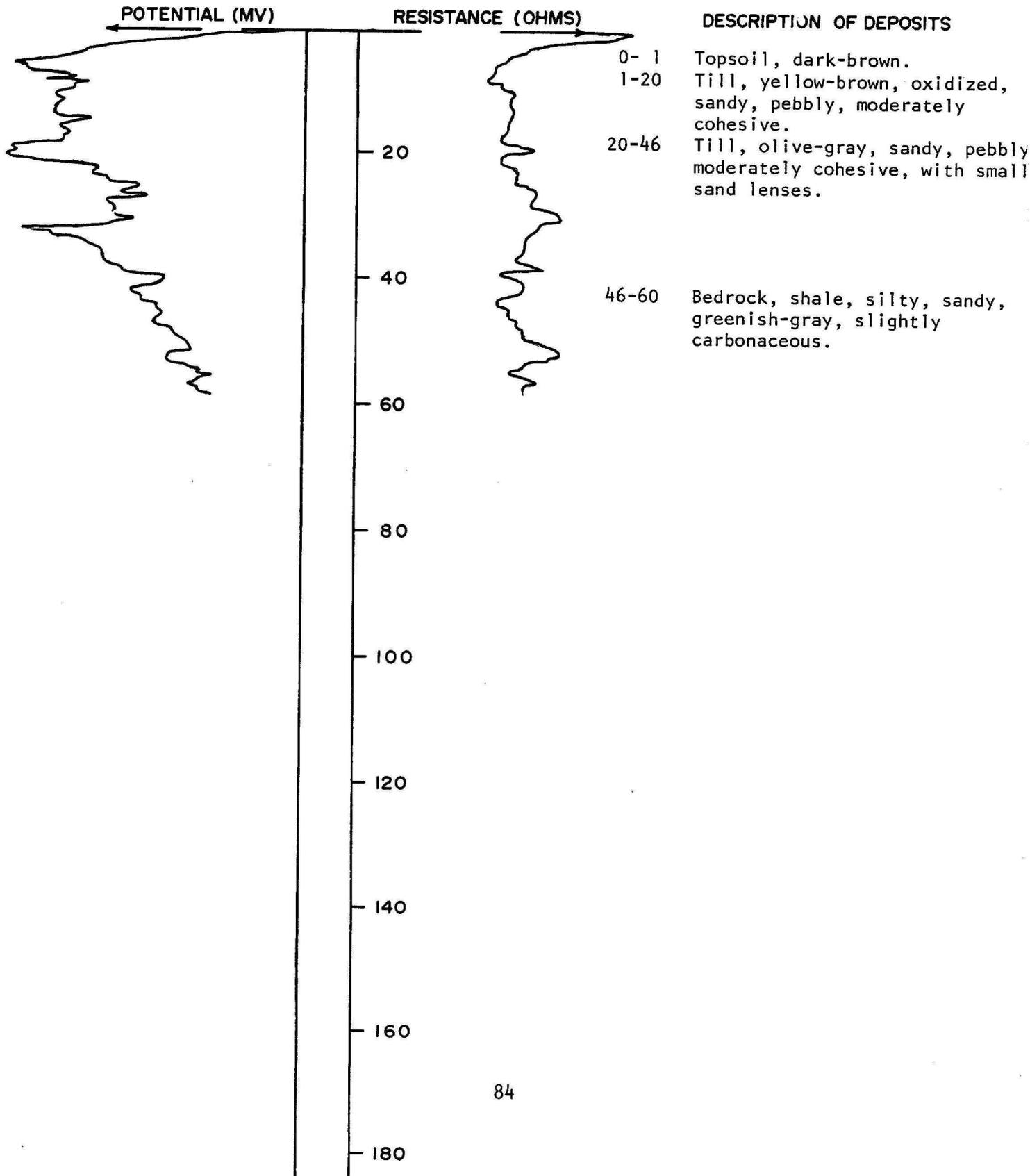
TEST HOLE 11110

LOCATION: 156-81-06DDA

DATE DRILLED: 9/26/79

ELEVATION: 1560
(FT, MSL)

DEPTH: 60
(FT)



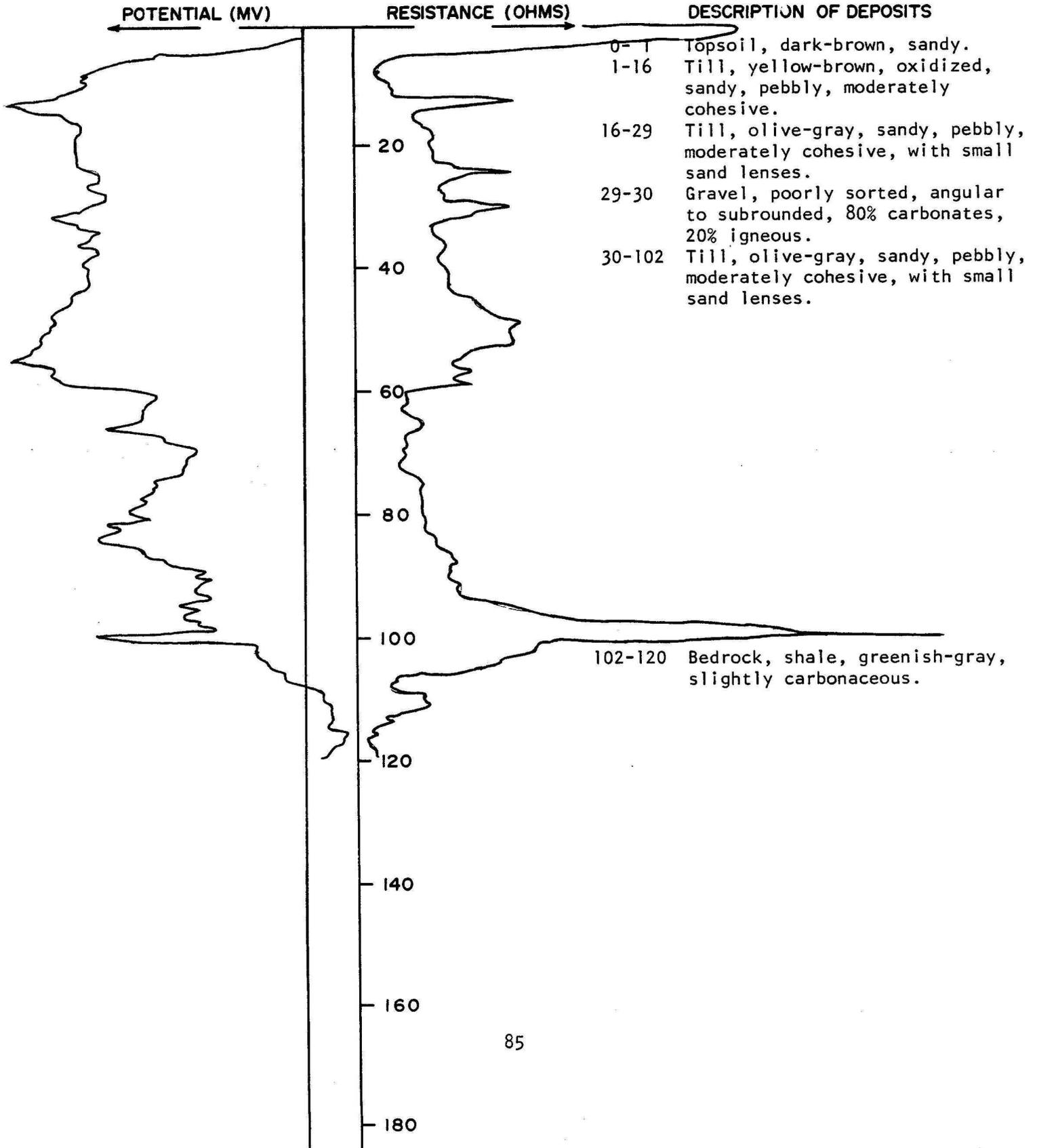
TEST HOLE 11106

LOCATION: 156-81-19DDA

DATE DRILLED: 9/26/79

ELEVATION: 1585
(FT, MSL)

DEPTH: 120
(FT)



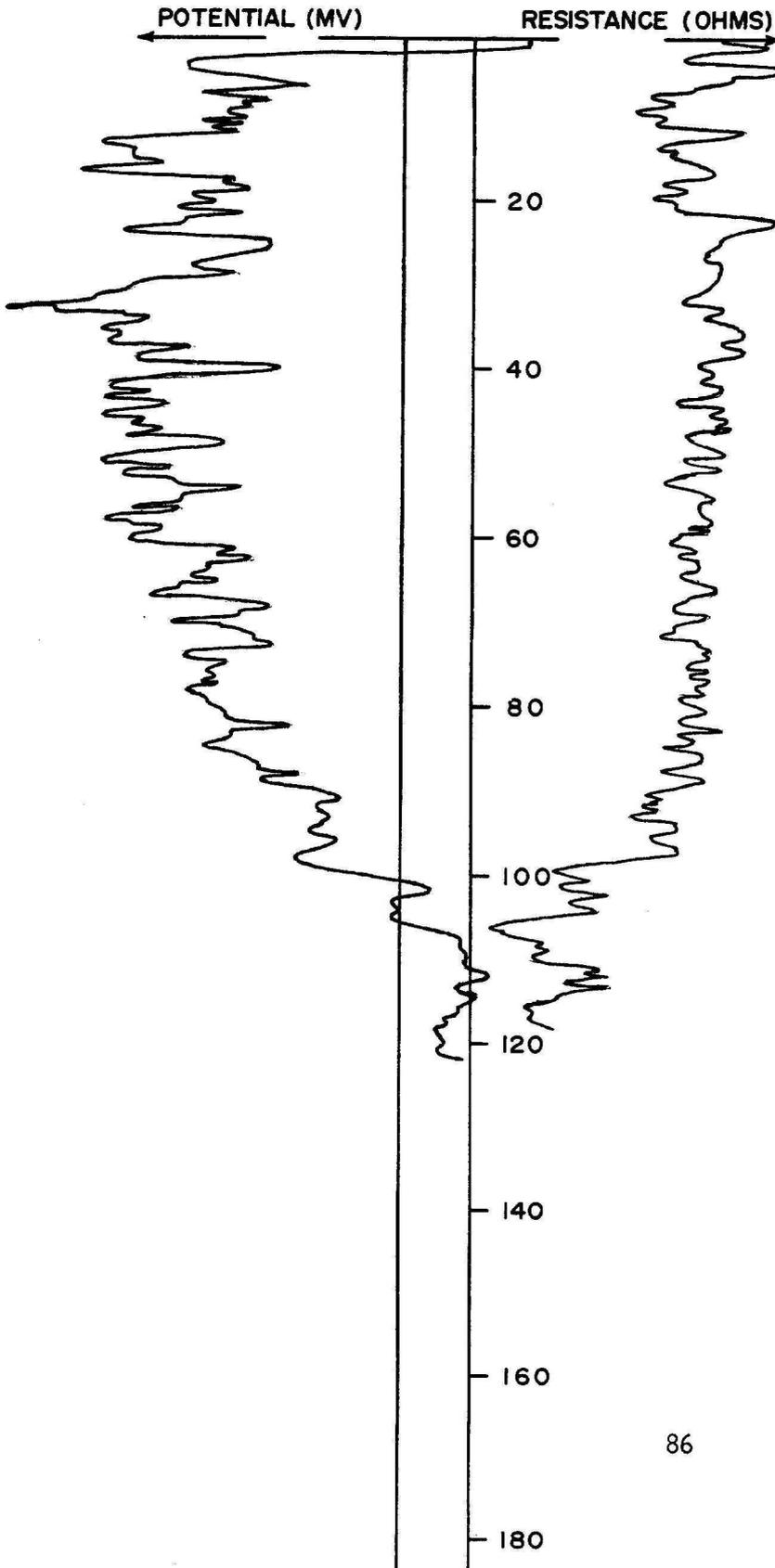
TEST HOLE 11107

LOCATION: 156-81-29BBC

DATE DRILLED: 9/26/79

ELEVATION: 1580
(FT, MSL)

DEPTH: 120
(FT)



DESCRIPTION OF DEPOSITS

- 0-1 Topsoil.
- 1-10 Till, yellow-brown, oxidized, sandy, pebbly, moderately cohesive, with small sand lens
- 10-96 Till, olive-gray, sandy, pebbly, moderately cohesive.
- 96-120 Bedrock, shale, greenish-gray, silty, sandy, slightly carbonaceous.

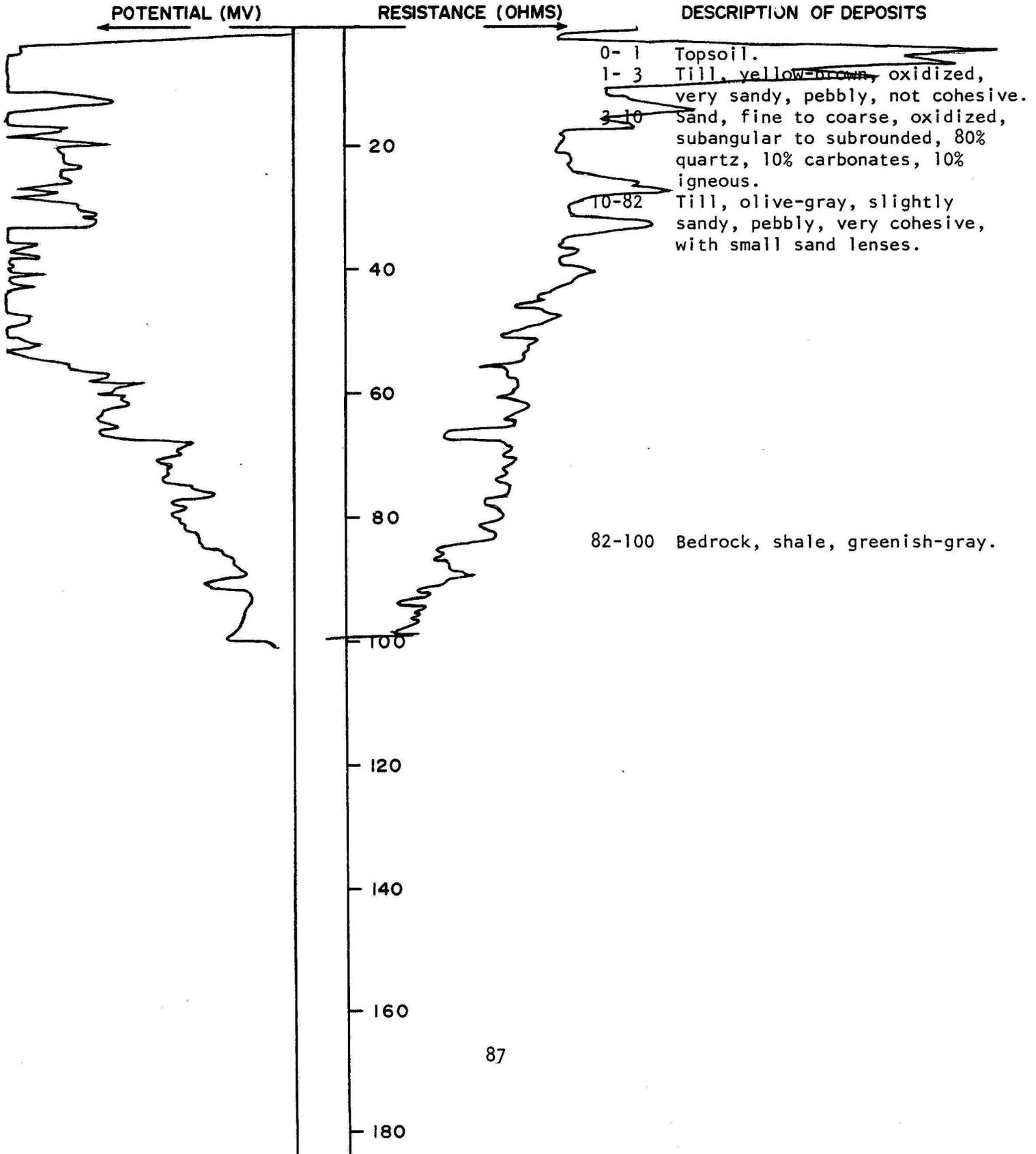
TEST HOLE 11108

LOCATION: 156-81-31ADA

DATE DRILLED: 9/26/79

ELEVATION: 1575
(FT, MSL)

DEPTH: 100
(FT)



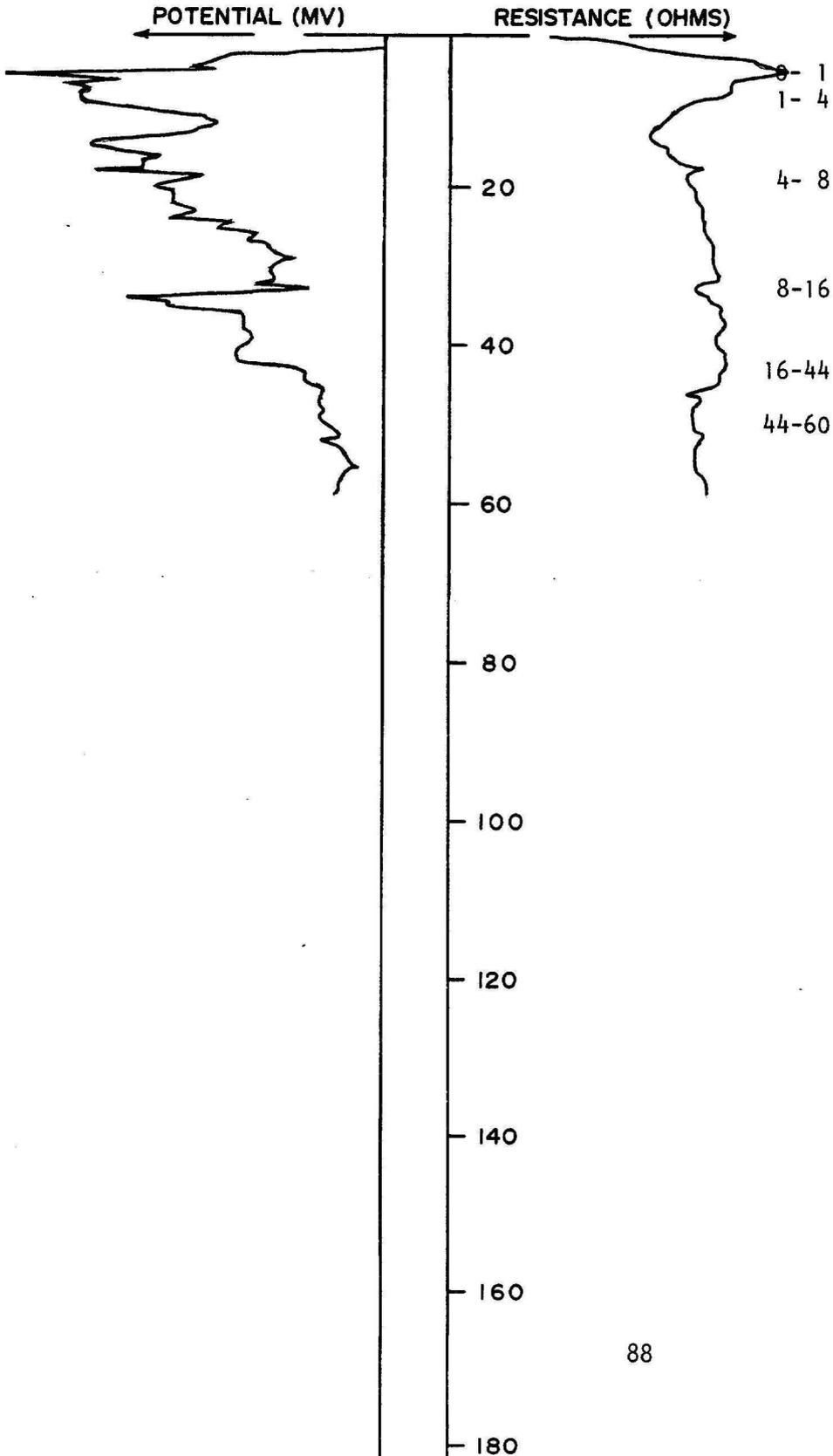
TEST HOLE 11104

LOCATION: 156-81-35CCC

DATE DRILLED: 9/25/79

ELEVATION: 1535
(FT, MSL)

DEPTH: 60
(FT)



DESCRIPTION OF DEPOSITS

- 0-1 Topsoil, dark-brown, sandy.
- 1-4 Till, yellow-brown, oxidized, sandy, pebbly, moderately cohesive.
- 4-8 Sand, fine to coarse grain, poorly sorted, subangular to subrounded, 80% quartz, 10% shale, 10% carbonates.
- 8-16 Till, yellow-brown, oxidized, sandy, pebbly, moderately cohesive.
- 16-44 Till, olive-gray, sandy, pebbly, very cohesive.
- 44-60 Bedrock, shale, greenish-gray.

TEST HOLE 11105

LOCATION: 156-81-36CCC

DATE DRILLED: 9/25/79

ELEVATION: 1547.3 to top of well
(FT, MSL)

DEPTH: 60
(FT)

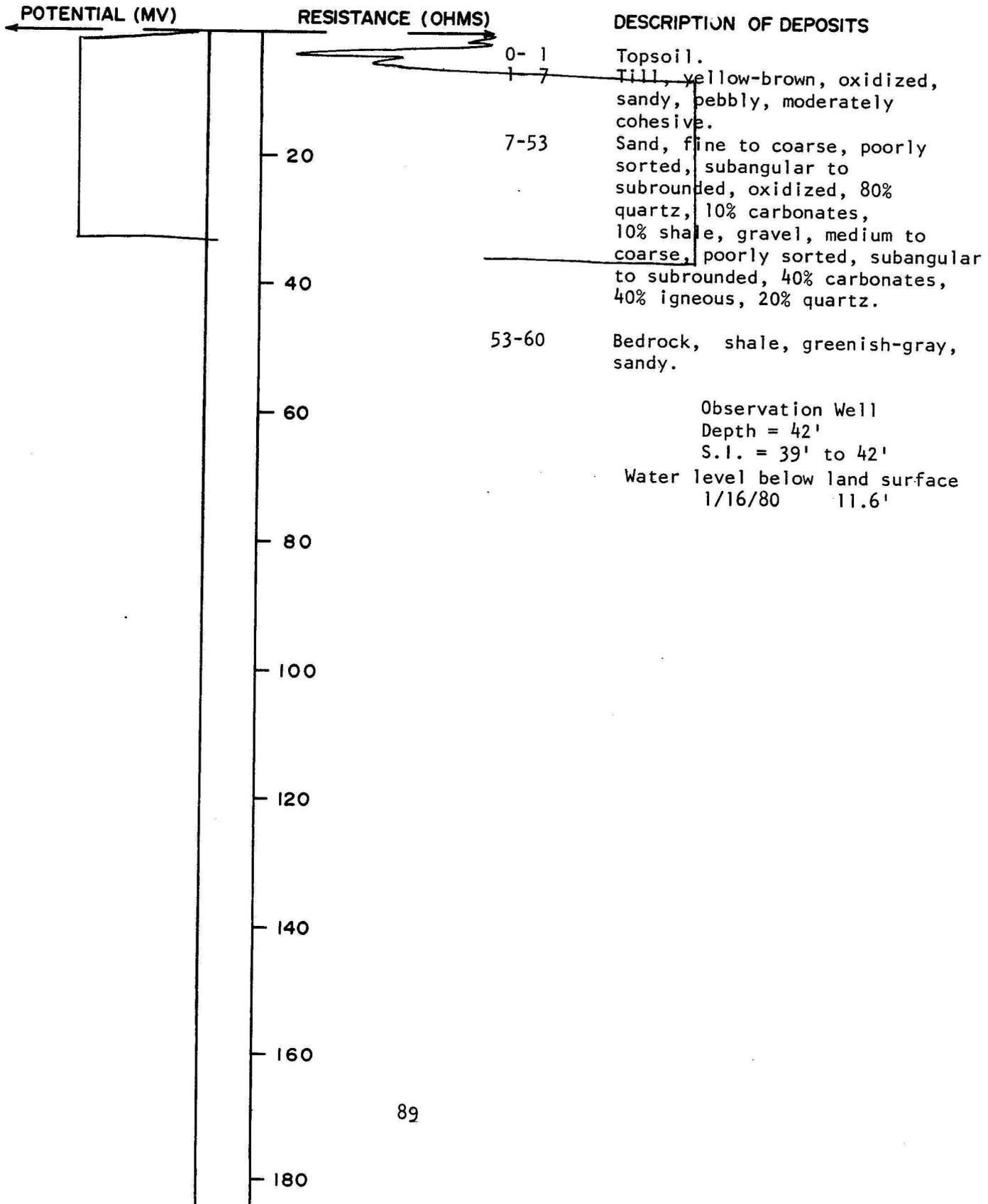
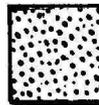


TABLE 2-CROSS SECTION

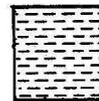
EXPLANATION OF LITHOLOGIC SYMBOLS



TILL

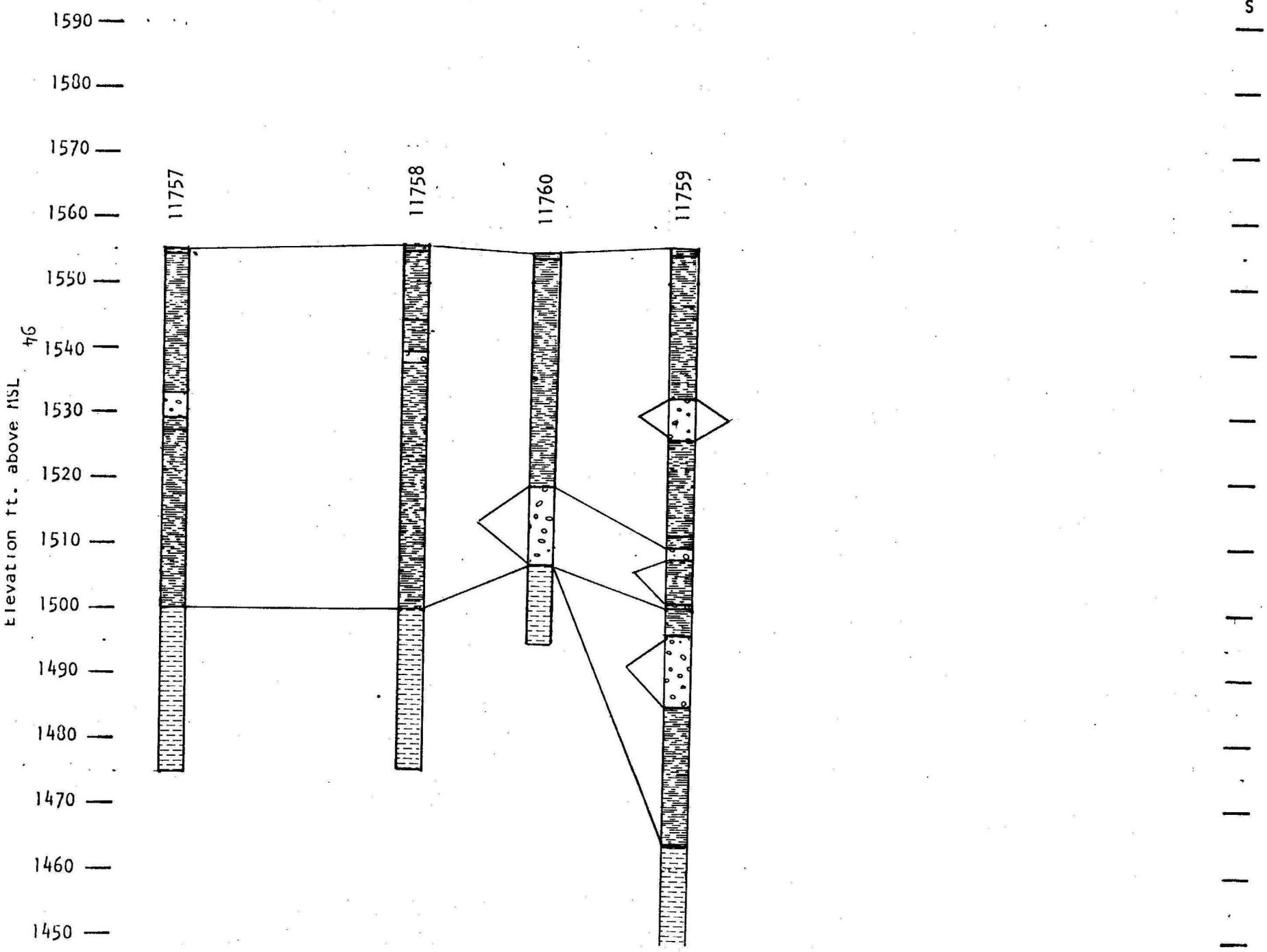


SAND & GRAVEL



BEDROCK

Cross Section D-D'
N

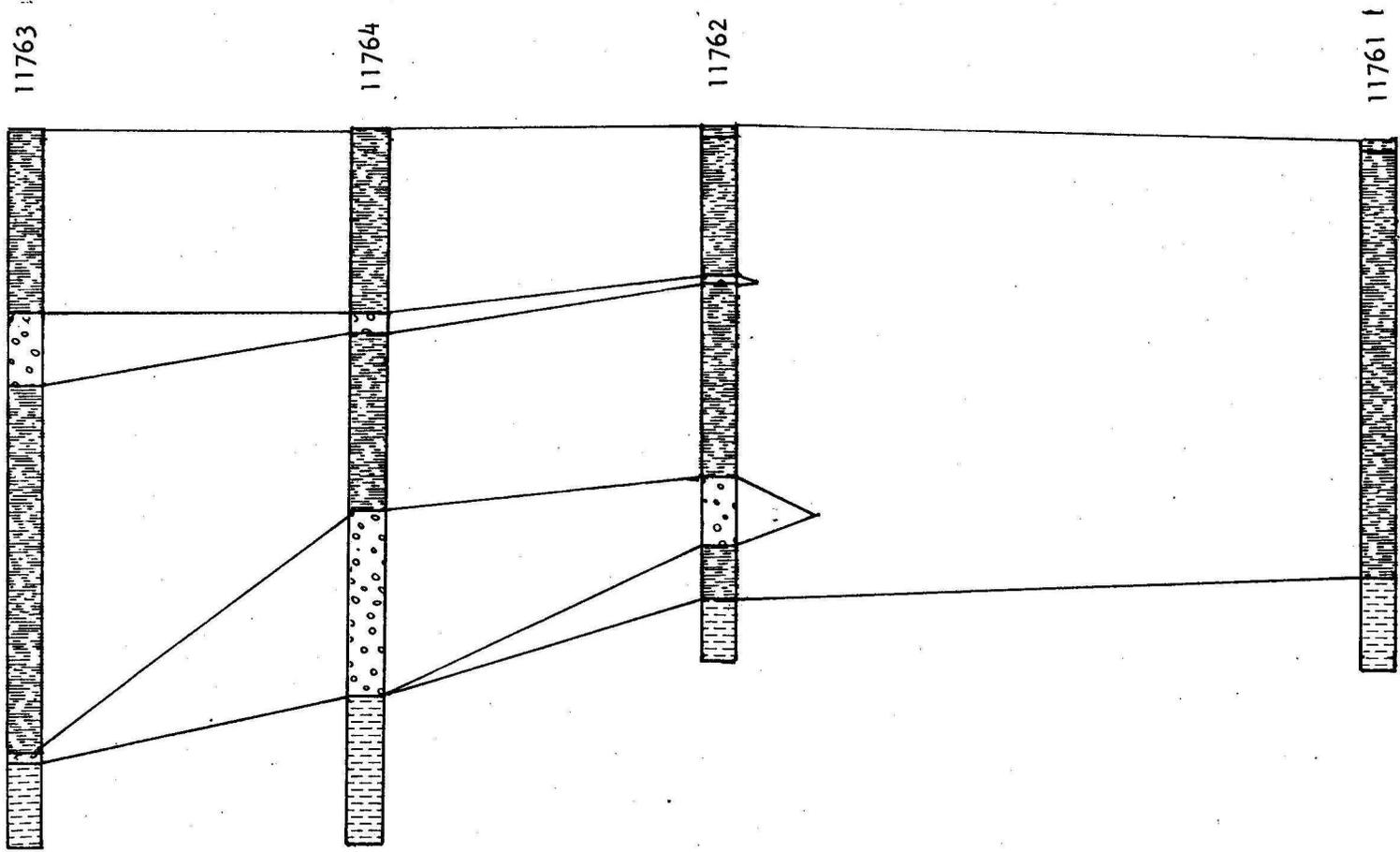


Cross Section E-E'

N

1590 —
1580 —
1570 —
1560 —
1550 —
1540 —
1530 —
1520 —
1510 —
1500 —
1490 —
1480 —
1470 —
1460 —
1450 —

Elevation ft. above MSL 56



S

TABLE 3 -- CHEMICAL ANALYSES
(Analytical results are in milligrams per liter except where indicated)

AQUIFERS Owner or Designation	Location	Depth of Well (feet)	Temp(F)	Date of Collection	(SiO ₂)	(Fe)	(Mn)	(Ca)	(Mg)	(Na)	(K)	(HCO ₃)	(CO ₃)	(SO ₄)	(Cl)	(F)	(NO ₃)	(B)	Total Hardness		Percent Sodium	S.A.R	Specific Conductance	pH	
																			as CaCO ₃	Noncarbonate					
NDSHC 9559	155-81-11ccc	36		5/24/76	28	.87	.1	75	32	110	5.8	475	0	160	8.4	.4	1.	.28	625	320	0	42%	2.7	1000	7.8
NDSHC 9559	155-81-11ccc	36		8/ 9/79	25	1.5	.14	71	25	140	5.6	503	0	160	3.8	.3	.6	.17	689	280	0	52%	3.6	1050	8.0
NDSHC 9560	155-81-11ccc	57		5/25/76	28	1.8	.08	63	23	280	5.2	551	0	390	19	.1	.1	.6	1100	250	0	70%	7.7	1600	8.0
NDSHC 9560	155-81-11ccc	57		8/ 9/79	27	4	.16	120	44	240	6.2	.550	0	530	21	.2	.6	.07	1340	480	29	52%	4.8	1840	7.9
NDSHC 11091	155-81-11ccc	53		10/ 3/79	28	.04	.06	62	18	330	6.1	501	0	470	27	.3	1.4	.29	1120	230	0	75%	9.5	1710	8.1
NDSHC 11080	155-81-13aaa No.	73		9/27/79	28	0	.16	85	6.8	43	3.9	269	0	100	6.2	.3	1.	.16	404	240	20	28%	1.2	600	8.1
NDSHC 11094	155-81-13aaa So.	68		9/27/79	25	.02	.04	78	16	120	4.7	349	0	200	11	.4	1.	.32	542	260	0	50%	3.2	906	8.1
NDSHC 11095	155-81-13aba	51		9/27/79	25	.16	.28	92	32	26	3.1	243	0	190	9.9	.3	1.	.13	447	360	160	13%	.6	668	8.1
NDSHC 11112	155-81-14baa	39		10/ 3/79	24	.12	.14	49	16	59	3.9	329	4	25	5.1	.3	1.	.13	337	190	0	40%	1.9	559	8.4
NDSHC 11071	155-81-14bbb	33		10/ 2/79	28	.08	.04	110	45	190	6.5	491	0	420	20	.2	.6	.16	980	460	57	47%	3.9	1450	8.1
NDSHC 11105	156-81-36ccc	42		10/ 3/79	25	.06	.12	130	74	50	5.6	357	0	400	11	.4	1.	.06	853	630	340	15%	.9	1190	8.1
NDSHC 11769	155-80-18ABBA	43		10/15/81	19	.81	1.8	170	120	54	10	309	0	710	28	.2	1.0	.3	1390	900	650	11%	.8	1640	7.9
NDSHC 11764	155-80-18ABAC	63		10/15/81	20	.8	.09	82	38	530	13	629	0	880	44	.2	8.8	.5	1820	360	0	75%	12	2600	8.1
NDSHC 11762	155-80-18ABCA	48		10/15/81	19	.86	.13	41	21	350	9.8	591	0	400	41	.4	4.6	.27	1090	190	0	79%	11	1690	8.1
NDSHC 11759	155-80-18ABCB	71		10/15/81	19	.45	.26	79	32	120	10	431	0	190	27	.2	1.6	.07	634	330	0	43%	2.9	959	8.0
NDSHC 11760	155-80-18ABCC	48		10/15/81	20	2.1	.18	86	33	110	8.7	509	0	130	25	.2	4.1	.1	620	350	0	40%	2.6	923	7.8

Table 4 -- Dissolved chemical constituents in water -- their effects upon usability and recommended concentration limits for domestic and municipal water supplies in North Dakota.

Constituent or Parameter	Effects of dissolved constituents on water use	Suggested limits for drinking water in North Dakota ¹	U.S. Public Health Service recommended limits for drinking water ²	Constituent or Parameter	Effects of dissolved constituents on water use	Suggested limits for drinking water in North Dakota ¹	U.S. Public Health Service recommended limits for drinking water ²
Silica (SiO ₂)	No physiological significance			Chloride (Cl)	Over 250 mg/l may impart a salty taste, greatly excessive concentrations may be physiologically harmful. Humans and animals may adapt to higher concentrations.		250 mg/l
Iron (Fe)	Concentrations over 0.1 mg/l will cause staining of fixtures. Over 0.5 mg/l may impart taste and colors to food and drink.		0.3 mg/l	Fluoride (F)	Fluoride helps prevent tooth decay within specified limits. Higher concentrations cause mottled teeth.	Limits of 0.9 mg/l to 1.5 mg/l	Recommended limits depend on average of daily temperatures. Limits range from 0.6 mg/l at 32°C. to 1.7 mg/l at 10°C.
Manganese (Mn)	Produces black staining when present in amounts exceeding 0.05 mg/l		0.05 mg/l	Nitrate (NO ₃)	Over 45 mg/l can be toxic to infants. Larger concentrations can be tolerated by adults. More than 200 mg/l may have a deleterious effect on livestock health		45 mg/l
Calcium (Ca) and Magnesium (Mg)	Calcium and magnesium are the primary causes of hardness. High concentrations may have a laxative effect on persons not accustomed to this type of water.			Boron (B)	No physiological significance. Greater than 2.0 mg/l may be detrimental to many plants		
Sodium (Na)	No physiological significance except for people on salt-free diets. Does have an effect on the irrigation usage of water.			Total dissolved solids	Persons may become accustomed to water containing 2,000 mg/l or more dissolved solids.	0-500 mg/l - low 500-1400 mg/l average 1400-2500 mg/l high over 2500 mg/l very high	500 mg/l
Potassium (K)	Small amounts of potassium are essential to plant and animal nutrition.			Hardness (as CaCO ₃)	Increases soap consumption, but can be removed by a water-softening system.	0-200 mg/l - low 200-300 mg/l average 300-450 mg/l high over 450 mg/l very high	
Bicarbonate (HCO ₃) and Carbonate (CO ₃)	No definite significance, but high bicarbonate content will impart a flat taste to water.			pH	Should be between 6.0 and 9.0 for domestic consumption		
Sulfate (SO ₄)	Combines with Calcium to form scale. More than 500 mg/l tastes bitter and may be a laxative	0-300 mg/l - low 300-700 mg/l - high over-700 mg/l - very high	250 mg/l	Specific Conductance	An electrical indication of total dissolved solids measured in micromhos per Centimeter at 25°C. Used primarily for irrigation analyses.		
Percent Sodium and Sodium Adsorption Ratio (SAR)	Indicate the sodium hazard of irrigation water.						

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