UNITED STATES DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

Some reconnaissance-type electrical surveys of Timber Mountain Caldera, Nye County, Nevada

by

Charles J. Zablocki
Denver Federal Center
MS 964, Box 25046
Denver, CO 80225

Open-file report 79-1695
1979

Some reconnaissance-type electrical surveys of Timber Mountain Caldera, Nye County, Nevada

by

Charles J. Zablocki
U.S. Geological Survey
Denver, Colorado

Introduction

As part of the U.S. Geological Survey's program of evaluating various media in the Nevada Test Site as potential radioactive waste respositories, several reconnaissance-type electrical surveys were made in the Timber Mountain dome and caldera region located on the western edge of the Nevada Test Site (fig. 1).

A significant criterion in assessing potential sites is the degree of water permeability of the rocks to depths of about 1 kilometer. Electrical resistivity measurements are a sensitive indicator of the amount of water contained in rocks. They can, however, only provide indirect information about fluid permeability and little about the dynamics of fluid flow. As a generalization, very high resistivities imply very low permeability and porosity, whereas low or medium values might imply that a rock unit contains large amounts of meteoric water in open fractures.

The presence of clay minerals, particularly in a crystalline rock, also drastically reduces the rock resistivity. In such rocks, the presence of clay minerals would imply that the rock was, or is, water permeable enough to have altered the primary minerals, and hence, might indicate a nonsuitable environment.

Timber Mountain is a structural dome made up of more than 800 meters of ash-flow tuffs. The geologic setting of this area is described in detail by Byers and others (1976). Previous physical-properties measurements on samples of these rocks (chiefly, the Ammonia Tanks Member of the Timber Mountain Tuff of Miocene age) have indicated that some parts of this medium may meet some of the various established criteria for a suitable repository. The objective of these reconnaissance-type electrical surveys was to determine the gross, in-situ distribution of the electrical properties, from which, some generalization could be made about water content and the textural homogeneity of these rocks.

Methods and Techniques

Three types of reconnaissance electrical methods were used in these studies in which they all utilized natural electromagnetic fields as sources.

Telluric current J-mapping

This technique has been thoroughly described (Keller and Frischknecht, 1966). Summarized briefly, two orthogonal pairs of electrodes (here, N-S and E-W) were laid out on the ground surface to detect the electric field that results from telluric currents, that in turn, are induced by fluctuations in the Earth's magnetic field (micropulsations). The orthogonal electric fields were recorded on a portable X-Y potentiometric chart recorder whose input was band-pass filtered to accept signals with periods ranging between 15 to 45 seconds. The recorded two components form an elliptical trace on the chart. The area of the trace inclosed by the elliptical pattern is proportional to the average resistivity of the medium in the vicinity of the measuring station.

A base station was established at the summit of Timber Mountain and 7 roving stations were occupied within and immediately outside of the caldera during July 1977. During a series of measurements at a rover station, portable radios were used to insure that simultaneous records were obtained at both the base and roving station.

As no magnetic field components are measured in this type of survey, the data can not be interpreted in terms of apparent resistivities as in magnetotelluric surveys. Only relative resistivities can be computed by comparing the ratio of the average areas of the obtained ellipses at the base and rover stations.

Telluric Profiling

This technique is described by Beyer (1977). The telluric voltages are measured on a portable X-Y potentiometric chart recorder from two pairs of electrodes (here, 250 m in length) that are in a colinear array rather than in an orthogonal array as used in the J-mapping procedure. If the electric fields are of the same magnitude and phase, then the recorded trace forms a straight line with a slope of +1. A measure of the slope (tangent) is equal to the ratio of the two electric fields. The square of this ratio in turn is proportional to the ratio of the average resistivities of the media beneath the two electrode arrays. The electrode arrays are leap-frogged along a traverse so that the ratios can be referenced back to the starting station and the relative electric field strength at each measuring station can be determined.

Audiomagnetotelluric (AMT)

The AMT method and the instrumentation used in this study are described by Hoover and others, (1978). Orthogonal horizontal electric and magnetic components resulting from distant lightning strokes (spherics) are measured at frequencies between 7.5 hz and several kilo hertz. The square of the ratio of the electric and magnetic field is proportional to the apparent resistivity at the measured frequency. For a uniformly conductive half space, the measured resistivities will be the same. However, since the depth of penetration of the electromagnetic waves is proportional to the square root of the ratio of resistivity to the frequency of the impinging wave, the measured resistivity will differ at different frequencies in a non homogeneous earth. Lower frequencies will tend to sense the resistivities at greater depths than at higher frequencies. The higher frequencies will respond to the resistivities at shallower depths.

A major distinction between the AMT method and the telluric methods is that apparent resistivities can be computed and not just relative values.

Results and Discussion

The averaged values of the relative resistivities obtained from the telluric J-mapping survey are shown in figure 2. The values, normalized to the base station at the Timber Mountain summit, varied between 1.04 to 0.16. The limited amount of data obtained over this large region allow only for some qualitative statements to be made about the geoelectric setting. The region towards the east side of Timber Mountain is about 5 times more conductive than the area at, and immediately west of, the summit or in the extreme north side of the caldera. As these measurements are sensitive to the rocks at depths greater than 800 meters, the lower values on the east side may indicate that the rocks here have a higher water-filled porosity (both fracture and interstitial) and shallower water tables than those in the other areas.

Two telluric profiles were obtained in this study. One profile consisting of 19 stations, extended from the east side of Timber Mountain, along Cat Canyon Pass, to about one kilometer west of the western boundary of the Nevada Test Site (fig. 2). The resulting profile (fig. 3) shows that except for the region to the east of the summit, the profile is fairly smooth and that the largest resistivities are near the summit. This would imply that in the summit regions, the rocks may be less fractured and that the local water table may be deeper than in the eastern area; consistent with extrapolated piezometric data obtained from some drill hole measurements (W. W. Dudley, oral commun., 1978).

The ratio of the relative electric fields between the summit and the easternmost profiling station is 2.28. The square of this value is proportional to the relative resistivities at these two locations and has a value of 5.3 (fig. 3). This value correlates quite well with the relative value obtained between the summit J-mapping base station (16) and the roving station that was located near the telluric profiling station no. 1 (0.2).

A shorter telluric profile was made that crossed the lateral projection of a near-by exposed microgranitic ring dike located about 2 km south of Cat Canyon (fig. 2). The resulting profile (fig. 4) shows that the variations in the electric fields are not too large (1.5:1) and would indicate that there is not a large electrical contrast between these dikes and their host rocks. The relative lows near stations 2 and 5 appears to correlate with mapped faults that intercept the traverse at a near-normal angle.

During January 1978, an AMT survey of the Timber Mountain area was contracted by the U.S. Geological Survey. The purpose of the survey was to acquire reconnaissance data to aid in determining whether the major faults in the area are conductive and thereby permeable to ground water.

The results of this contracted survey were subsequently found to be of poor quality due to a low-sensitivity magnetic field sensor and a lack of an adequate circuit design to discriminate between meaningful natural-field signals and random noise.

The shortcomings of this survey were further substantiated when measurements were repeated at six of the contractor's stations in April 1978 using the U.S. Geological Survey's AMT system. The resurveyed six stations (fig. 5) extended from just east of the caldera (station T-5) to the eastern flank of Timber Mountain in Cat Canyon (T-19). Plots of the apparent resistivities versus frequency derived from the N-S and E-W oriented electric-field sensors are shown in figures 6 through 11. The general absence of useable signals between 100 Hz and a few kilohertz during the survey period does not allow for making a quantitative geoelectric sounding interpretation. The general absence of useable signals was due in part to noise associated with power transmission lines in the area coupled with low natural signal strengths that normally occur during the winter months. It is noted, however, that except for the two easternmost stations T-5 and T-8 (fig. 5), the apparent resistivities generally increase with lower frequencies. This observation would imply that the rocks are more resistive at depth, which in turn, would suggest that the deeper rocks are more competent (fewer open fractures).

The spread in values between the N-S and E-W AMT resistivity versus frequency plots suggest that some large-scale electrical anisotrophy may exist in these areas caused by near-vertical conductive faults and, or, lateral lithologic changes. Ideally, if the rocks were laterally isotropic and horizontally layered, the derived resistivities would be independent of azimuth. As the measuring system used in this study can only determine scalar rather than tensor values, we can not determine the magnitude and direction of the principal resistivities.

The rms values of apparent resistivity ($\sqrt{\rho_{NS} \cdot \rho_{EW}}$) derived from the N-S and E-W directions for 7.5 Hz are shown in figure 2. A profile of these values at 7.5 and 27 Hz are shown projected along an east-west line in figure 12. It is seen that there is a sharp transition from low resistivities east of station 8 to larger values to the west of station 9. The transition occurs near Fortymile Canyon and may indicate the presence of a thicker section of competent rock toward Timber Mountain.

The rms value of about 400 ohm-meters for the resistivity near the east end of the previously mentioned telluric profile in Cat Canyon would extrapolate to about 2000 ohm-meters at the summit. This is based on the telluric measurements that indicated that the eastern flank of Timber Mountain is about five times less resistive than the summit and the assumption that the 400 ohm-meter zone measured at 7.5 Hz remains unchanged to depths on the order of a few kilometers. If the summit region would have a resistivity of 2000 ohm-meters down to depths of at least 1 Km, then this would imply that the ash flows and possibly the underlying intrusive rocks are fairly tight, containing little water, and little or no clay minerals.

Conclusions

Although the amount of data obtained in these reconnaissance electrical studies were limited, they have provided some inferences regarding the gross water content of the volcanic rocks in the Timber Mountain caldera region. The telluric profiling measurements indicated that the surficially mapped faults and fractures do not contain appreciable amounts of water at shallow depths as evidenced by the lack of sharp, high amplitude gradients along the Cat Canyon traverse. Similarly, the inferred high resistivity (2000 ohm-m) in the summit region would imply that the interstitial and fracture porosity of these rocks is extremely low to depths of about 1 kilometer.

As part of a regional geoelectric program in support of a regional hydrologic study of the Nevada Test Site and surrounding areas, some contracted magnetotelluric and galvanic DC resistivity soundings will be sited on Timber Mountain in March 1979. These additional data will provide further insights into the geoelectric setting of this area.

Should further interest in this area develop in the future, the data reported herein will provide control in designing a more comprehensive electric/electromagnetic study.

References

Beyer, J. H., 1977, Telluric and D.C. resistivity techniques applied to the geophysical techniques applied to the geophysical investigation of Basin and Range geothermal systems, Part I--The E-field ratio telluric method: Lawrence Berkeley Laboratory Univ. of Calif./Berkeley, LBL-6325 1/3; Ph.D. thesis, 135 p.

Byers, F. M., Jr., Carr, W. J., Orkild, P.P., Quinlivan, W. D., and Sargent, K. A., 1976, Volcanic suites and related cauldrons of Timber Mountain-Oasis Valley Caldera Complex, Southern Nevada: U.S. Geological Survey Professional Paper 919, 70 p.

Hoover, D. B., Long, C. L., and Senterfit, R. M., 1978, Audio-magnetotelluric investigations in geothermal areas: Geophysics, v. 43, no. 7, p. 1501-1514.

Keller, G. V., and Frischknecht, F. C., 1966, Electrical methods in geophysical prospecting: New York, Pergamon Press, 517 p.

Figure Captions

Figure 1.--Index map showing location of Timber Mountain (diagonal lines) on west side of Nevada Test Site, Nevada.

Figure 2.--Locations and measurement results from reconnaissance electromagnetic surveys in the Timber Mountain caldera region. Values at J stations (circles) are relative resistivities compared to the base station (L) at summit. Values at AMT stations (X) are rms apparent resistivities at 7.5 Hz.

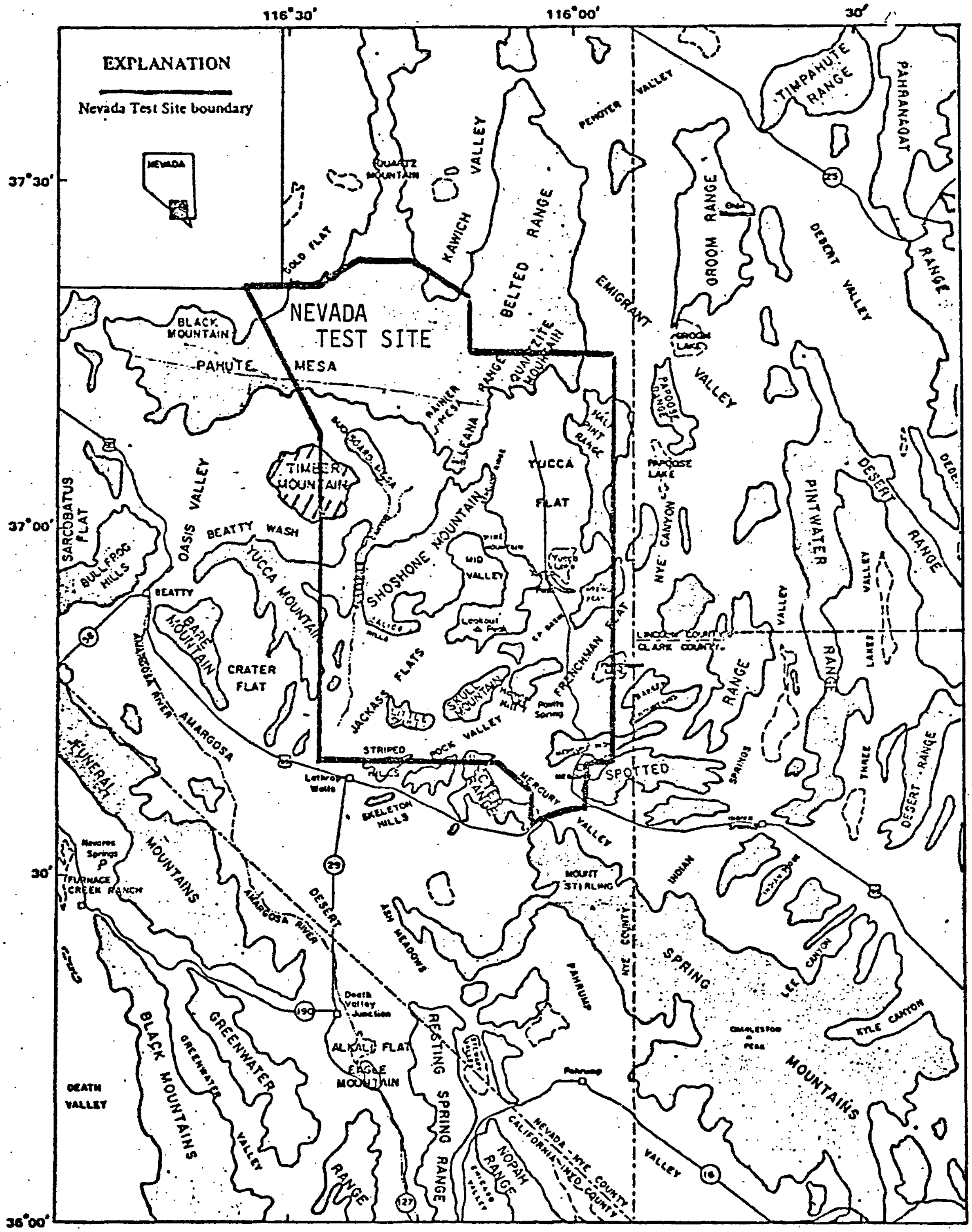
Figure 3.--Telluric electric field profile obtained along Cat Canyon traverse shown in figure 2.

Figure 4.--Telluric electric field profile obtained along ring-dike traverse shown in figure 2.

Figure 5.--Map showing the locations of a portion of the sites occupied for AMT measurements by the contractor. The six circled sites (T-5, -8, -9, -11, -12, and -19) are those reoccupied using the Survey's AMT system.

Figure 6-11.--Apparent resistivity vs frequency plots obtained from Survey AMT measurements at locations shown in figure 5.

Figure 12.--Profiles of rms values of AMT-derived apparent resistivity at 7.5 and 27 Hz projected along an east-west line from stations T-5 to T-19 shown in figure 5.



116°30'
116°00'
30'
37°30'
37°00'
30'
36°00'
EXPLANATION
Nevada Test Site boundary
NEVADA
NEVADA TEST SITE
PAHUTE MESA
BLACK MOUNTAIN
GOLD FLAT
QUARTZ MOUNTAIN
KAWICH VALLEY
BELTED RANGE
EMIGRANT VALLEY
GROOM RANGE
GROOM LAKE
TIMPAHUTE RANGE
PAHRANAGAT RANGE
DESERT VALLEY
PAPOOSE RANGE
PAPOOSE LAKE
RAINIER MESA
QUARTZITE MOUNTAIN
HALFPINT RANGE
YUCCA FLAT
TIMBER MOUNTAIN
SARCOBATUS FLAT
OASIS VALLEY
BEATTY WASH
BULLFROG HILLS
BEATTY
YUCCA MOUNTAIN
SHOSHONE MOUNTAIN
MID VALLEY
BARE MOUNTAIN
CRATER FLAT
JACKASS FLATS
SKULL MOUNTAIN
FRENCHMAN FLAT
ROCK VALLEY
STRIPED HILLS
MERCURY
SPOTTED RANGE
PINTWATER RANGE
DESERT RANGE
THREE LAKES VALLEY
INDIAN SPRINGS VALLEY
NYE CANYON
LINCOLN COUNTY
CLARK COUNTY
AMARGOSA RIVER
AMARGOSA DESERT
FUNERAL MOUNTAINS
FURNACE CREEK RANCH
Lathrop Wells
SKELETON HILLS
MERCURY VALLEY
MOUNT STIRLING
ASH MEADOWS
Death Valley Junction
ALKALI FLAT
EAGLE MOUNTAIN
RESTING SPRING RANGE
PAHRUMP
Pahrump
SPRING MOUNTAINS
LEE CANYON
KYLE CANYON
CHARLESTON PEAK
NYE COUNTY
NEVADA - NYE COUNTY
CALIFORNIA - INYO COUNTY
NOPAH RANGE
PAHRUMP VALLEY
DEATH VALLEY
BLACK MOUNTAINS
GREENWATER RANGE
GREENWATER VALLEY
95
190
127
160
0 10 20 30 MILES
0 10 20 30 KILOMETERS

Fig. 1

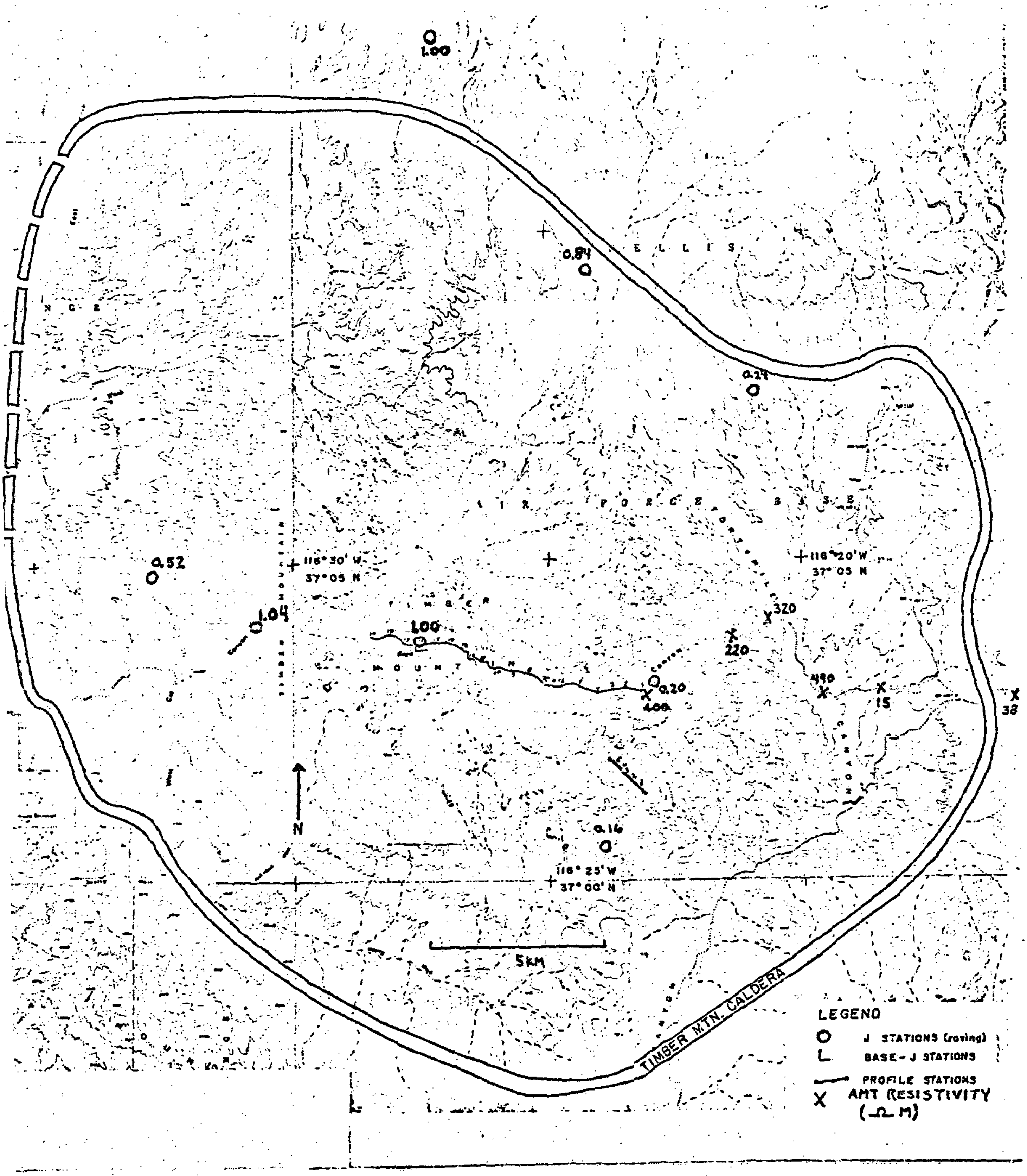
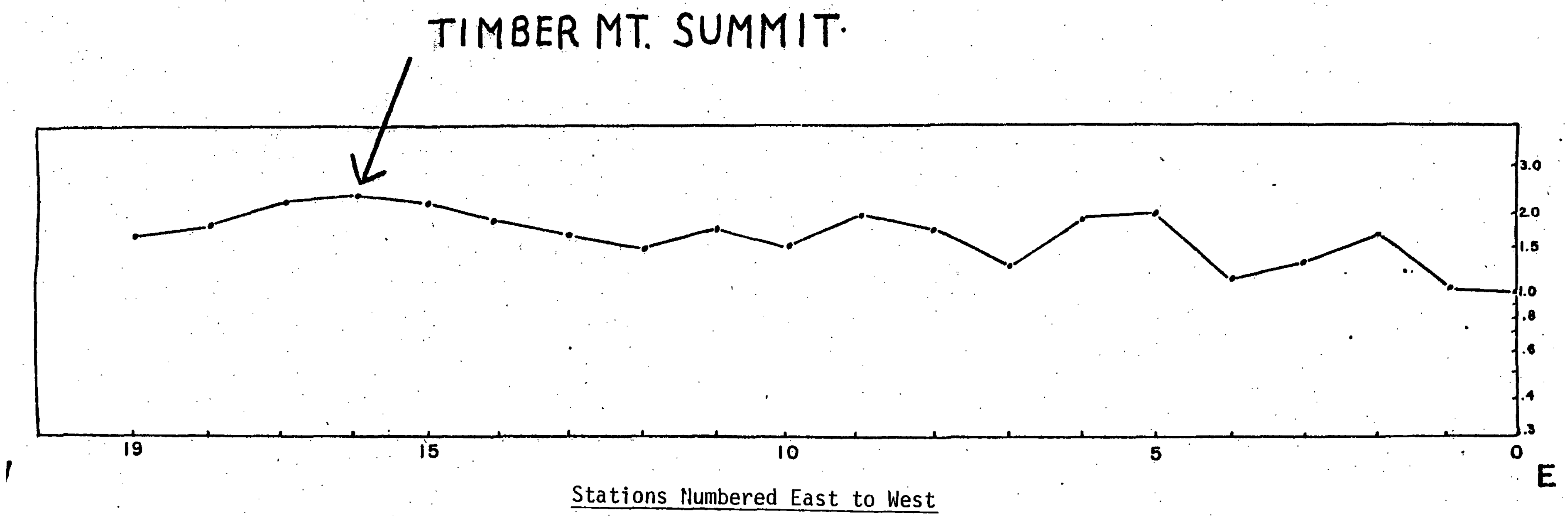

TIMBER MTN. CALDERA
1.00
0.84
0.24
0.52
1.04
1.00
0.20
400
320
220
490
15
38
0.16
116° 30' W
37° 05' N
116° 20' W
37° 05' N
116° 25' W
37° 00' N
5KM
N
LEGEND
J STATIONS (roving)
BASE-J STATIONS
PROFILE STATIONS
AMT RESISTIVITY
(Ω M)

Fig. 2

$$\frac{E_{16}}{E_0} = \frac{2.28}{1} \; ; \; \frac{\rho_{16}}{\rho_0} \propto \left(\frac{E_{16}}{E_0}\right)^2 = 5.3$$



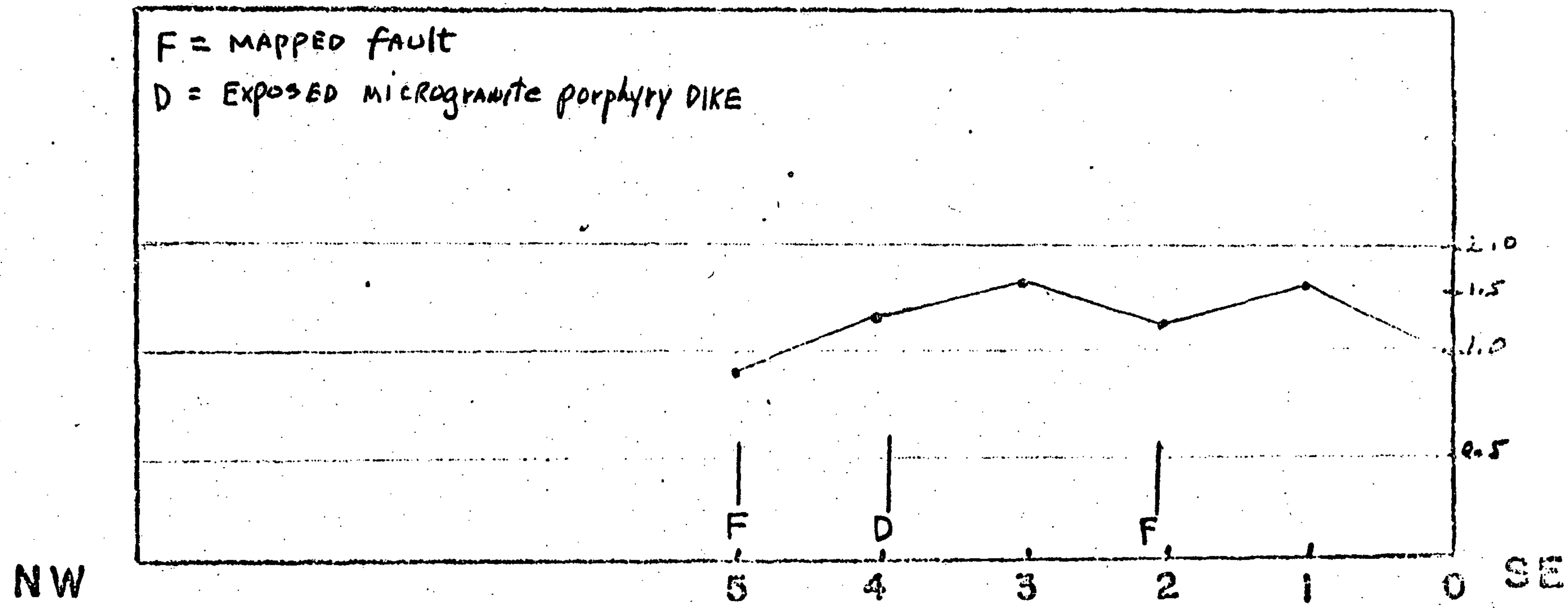
TIMBER MOUNTAIN

CAT CANYON TRAVERSE

0 500 1500

Meters

Fig. 3



TIMBER MOUNTAIN
RING DIKE TRAVERSE

NEVADA TEST SITE 1977
TELLURIC PROFILE

250 Meters

Fig. 4

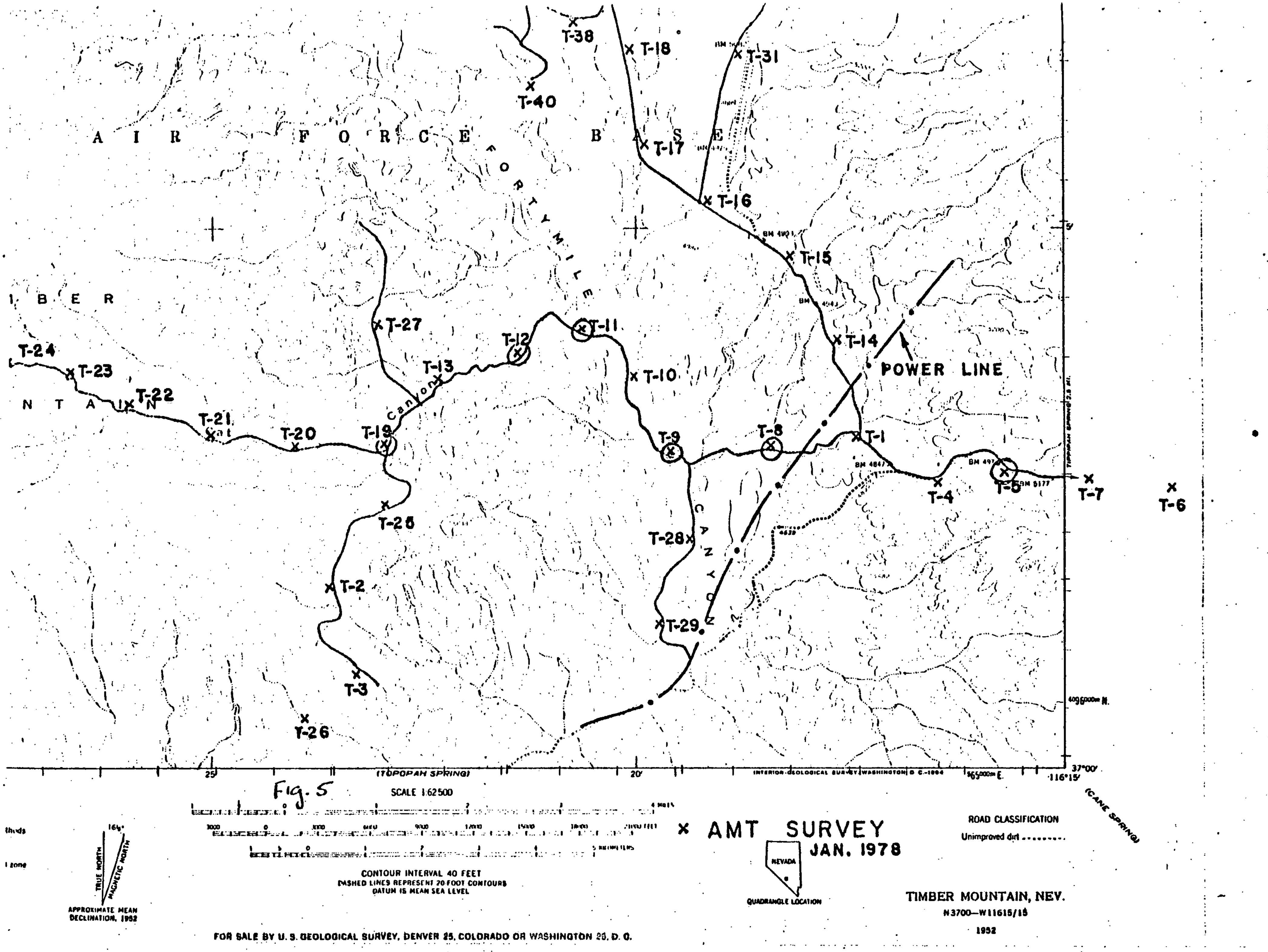
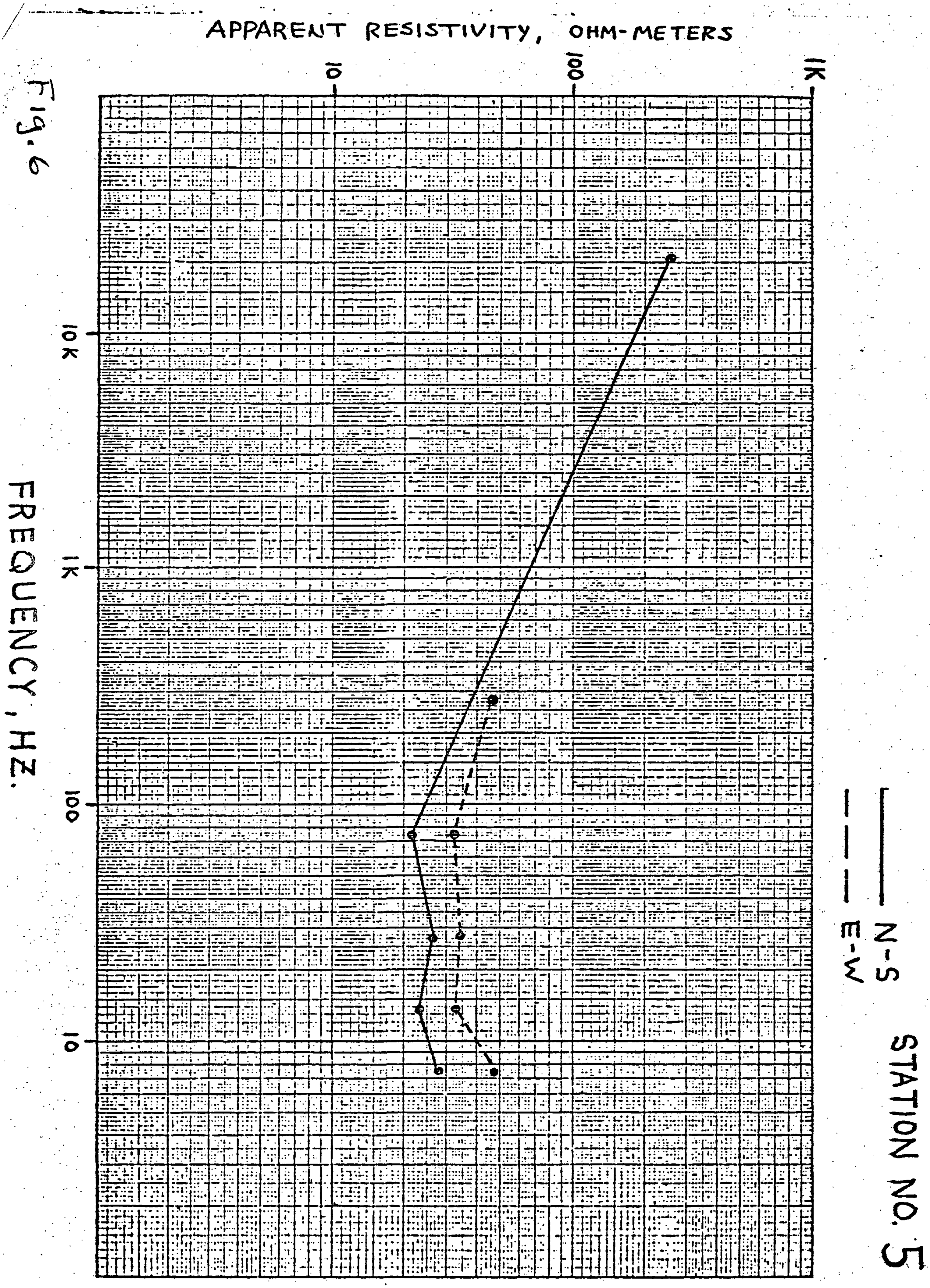
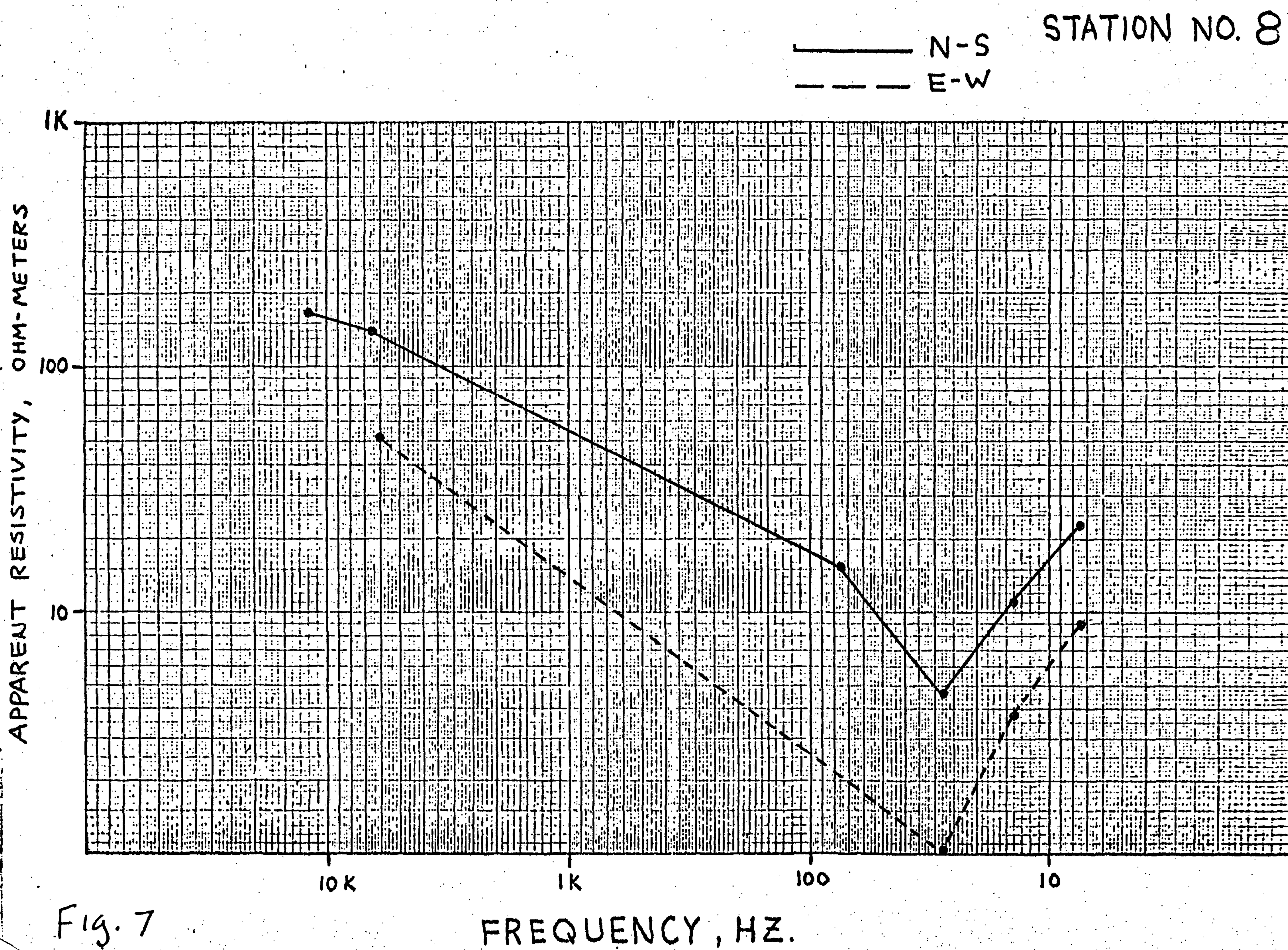

AIR FORCE BASE
FORTYMILE
CANYON
Canyon
POWER LINE
T-1
T-2
T-3
T-4
T-5
T-6
T-7
T-8
T-9
T-10
T-11
T-12
T-13
T-14
T-15
T-16
T-17
T-18
T-19
T-20
T-21
T-22
T-23
T-24
T-25
T-26
T-27
T-28
T-29
T-31
T-38
T-40
(TOPOPAH SPRING)
(CANE SPRING)
SCALE 1:62500
CONTOUR INTERVAL 40 FEET
DASHED LINES REPRESENT 20 FOOT CONTOURS
DATUM IS MEAN SEA LEVEL
APPROXIMATE MEAN DECLINATION, 1952
TRUE NORTH
MAGNETIC NORTH
× AMT SURVEY
JAN. 1978
NEVADA
QUADRANGLE LOCATION
ROAD CLASSIFICATION
Unimproved dirt
TIMBER MOUNTAIN, NEV.
N3700—W11615/15
1952
FOR SALE BY U. S. GEOLOGICAL SURVEY, DENVER 25, COLORADO OR WASHINGTON 25, D. C.

Fig. 5

Fig. 6

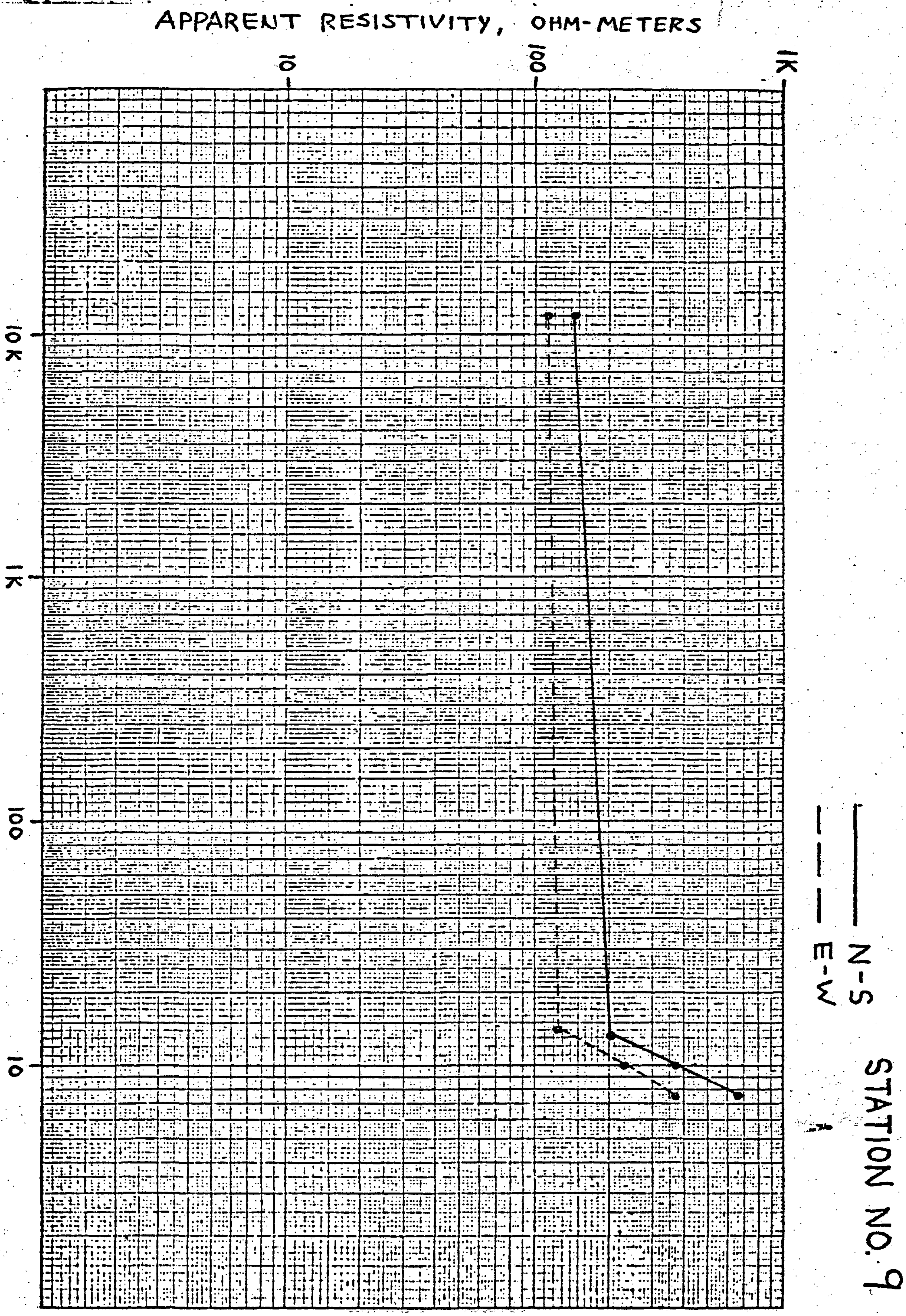

APPARENT RESISTIVITY, OHM-METERS
10
100
1K
FREQUENCY, HZ.
10K
1K
100
10
N-S
E-W
STATION NO. 5



STATION NO. 8
N-S
E-W
1K
100
10
APPARENT RESISTIVITY, OHM-METERS
10 K
1K
100
10
FREQUENCY, HZ.

Fig. 7

Fig. 8



APPARENT RESISTIVITY, OHM-METERS
10
100
1K
FREQUENCY, HZ.
10K
1K
100
10
N-S
E-W
STATION NO. 9

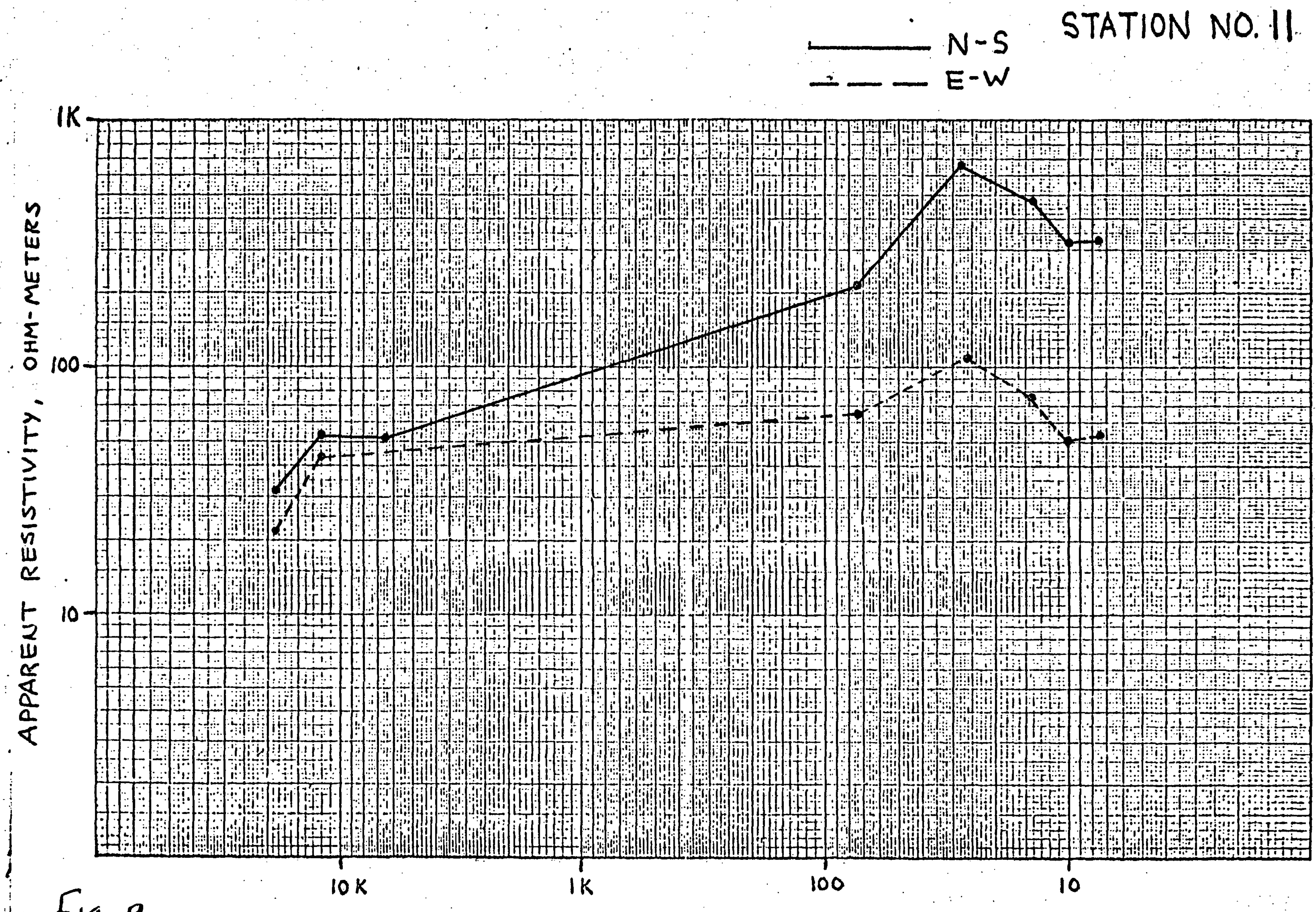

STATION NO. 11
N-S
E-W
APPARENT RESISTIVITY, OHM-METERS
1K
100
10
10K
1K
100
10
FREQUENCY, HZ.

Fig. 9

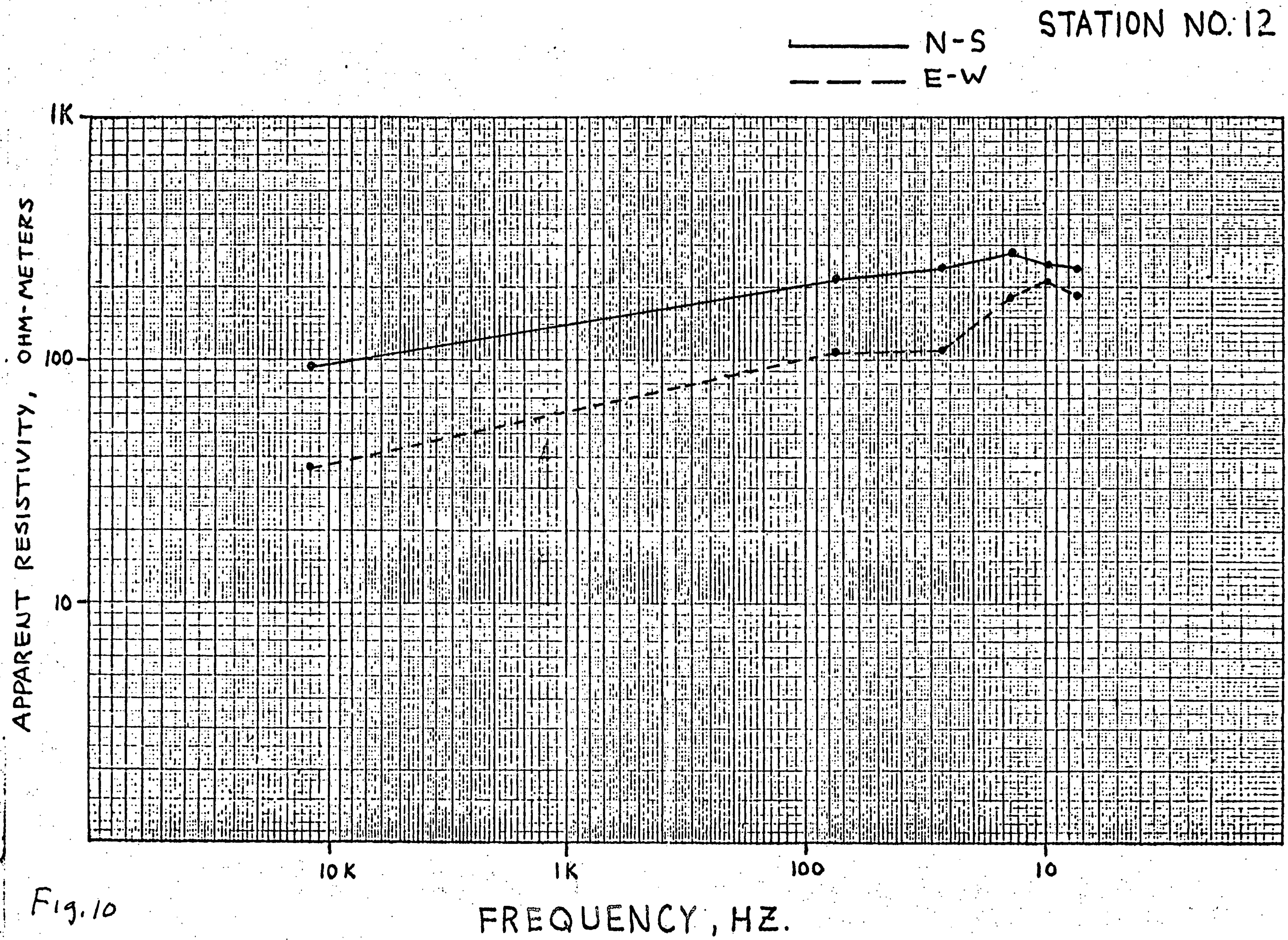

STATION NO: 12
N-S
E-W
APPARENT RESISTIVITY, OHM-METERS
1K
100
10
10K
1K
100
10
FREQUENCY, HZ.

Fig. 10

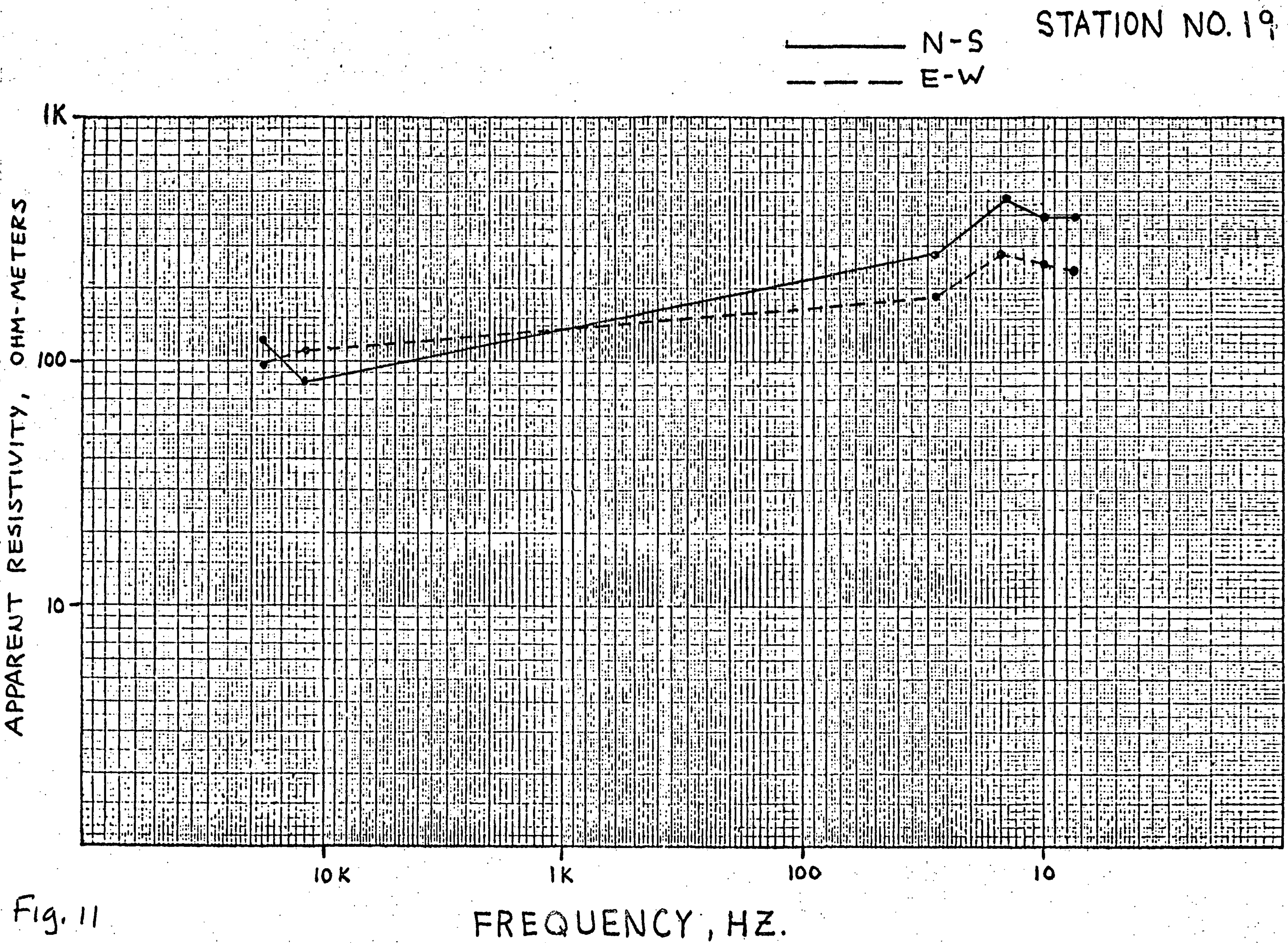

STATION NO. 19
N-S
E-W
1K
100
10
APPARENT RESISTIVITY, OHM-METERS
10K
1K
100
10
FREQUENCY, HZ.

Fig. 11

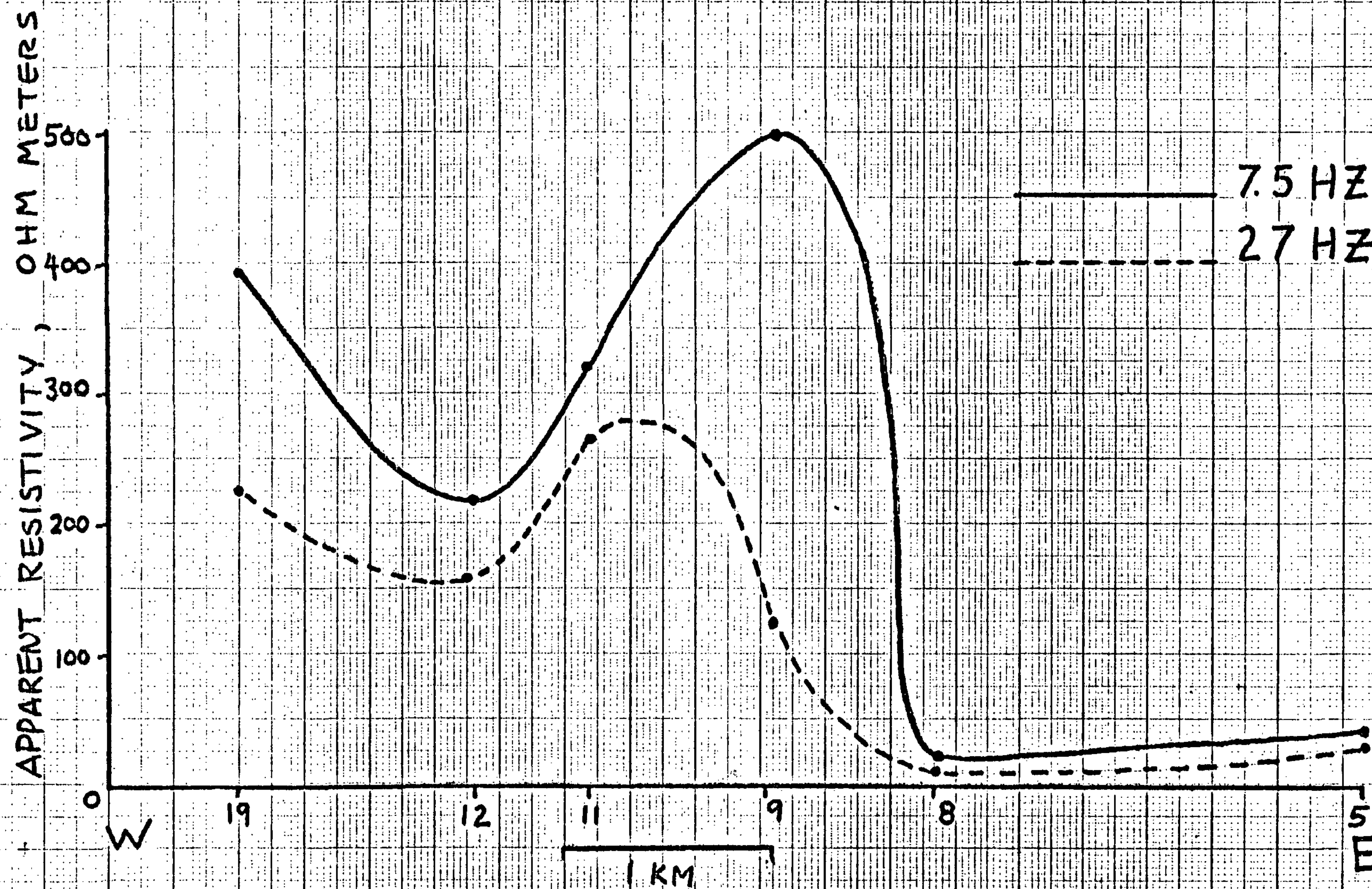

APPARENT RESISTIVITY, OHM METERS
500
400
300
200
100
0
W
19
12
11
9
8
5
E
1 KM
7.5 HZ
27 HZ

Fig. 12