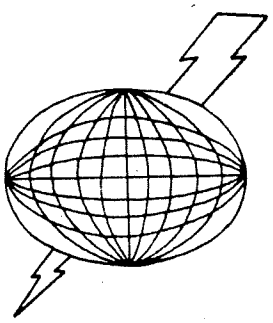
TELLURIC MAGNETOTELLURIC SURVEY
AT
BULLY CREEK PROSPECT
OREGON

for

AMAX EXPLORATION INC.

CHEVRON RESOURCES COMPANY

June 1981



TERRAPHYSICS
P.O. BOX 686
INVERNESS, CALIFORNIA 94937
(415) 669-1416

ABSTRACT

A telluric magnetotelluric (TMT) survey was conducted on the Bully Creek prospect, Oregon during the period 14 May to 9 June,1981.

Rotated tensor data were obtained at 16 base stations and 30 remote sites.

The data in the area of the hot springs suggest a complex structure consisting of a high resistive vertical structure adjacent to a conductive zone. Two and three dimensional effects are in evidence in the area.

The magnetic tipper indicates a north-south strike direction over most of the area.

A number of low resistivity zones (4 ohm meters) are indicated at depths of 7 to 15 kilometers over various parts of the survey area. There does not appear to be any clear connection between these low resistivity zones at depth and the surface hot springs.

TABLE OF CONTENTS

TERRAPHYSICS
P.O. Box 686
Inverness, California 94937
(415) 669-1416

August 8, 1981

Dear Art:

Enclosed are 4 complete copies of the Bully Creek TMT survey and one copy of the computer printouts. I also included the abstracts from the MT Workshop (USGS sponsor).
Similar report copies have been sent to Chevron.

Sincerely,

Aldo Mazzella

Introduction

Terraphysics conducted a telluric-magnetotelluric (TMT) survey at the Bully Creek prospect,Oregon on behalf of Amax Exploration Inc. and Chevron Resources Co. The field work was conducted during the period of 14 May to 9 June 1981.

Rotated tensor data were obtained at 16 base stations and 30 remote sites.

Survey Objective

The objective of the survey was to aid in the evaluation of the geothermal potential of the area.

Many geothysical techniques are used to evaluate a geothermal area. Since a decrease in resistivity usually occurs where the temperature of the earth increases, an electrical resistivity survey may be a useful diagnostic technique. The resistivity change with can be on the order of 2.5%/C (Keller and Frischknecht,1970). Consequently, resistivity decreases on the order of a factor of 5 or more may be associated with geothermal brines (Keller,1970). Intrinsic resistivity values of less than 10 ohm meters may be expected.

If a geothermal area is at a sufficiently high temperature that a vapor phase is present, higher electrical resistivity values are likely. Zohdy,et.al. (1973) report intrinsic resistivity values of about 75-150 ohm meters for a vapor-dominated layer in Yellowstone National Park.

Telluric-Magnetotelluric Instruments and Procedure

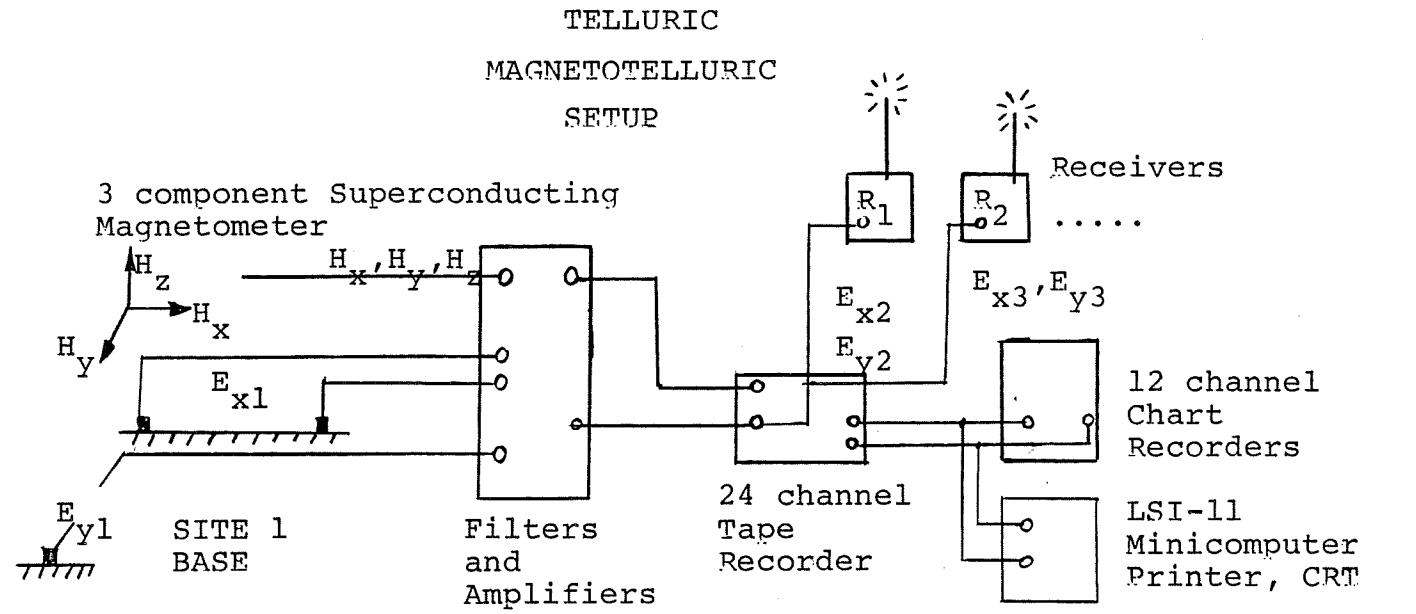
A schematic of the equipment and field setup is illustrated in figure 1. Five component MT data is obtained at the base station (two horizonal electric field components and three magnetic field components). At each remote site two orthogonal electric field components are measured. The data is filtered, amplified, and telemetered back to the base station where it is recorded on magnetic tape at the same time as the base station data. Seasoned lead strips are used for the electrodes for the electric field measurements and the magnetic field measurements are obtained with a superconducting magnetometer.

In general, a base station with magnetic field measurements is utilized for each setup. Typical distances between the base and remote stations is one to two kilometers.

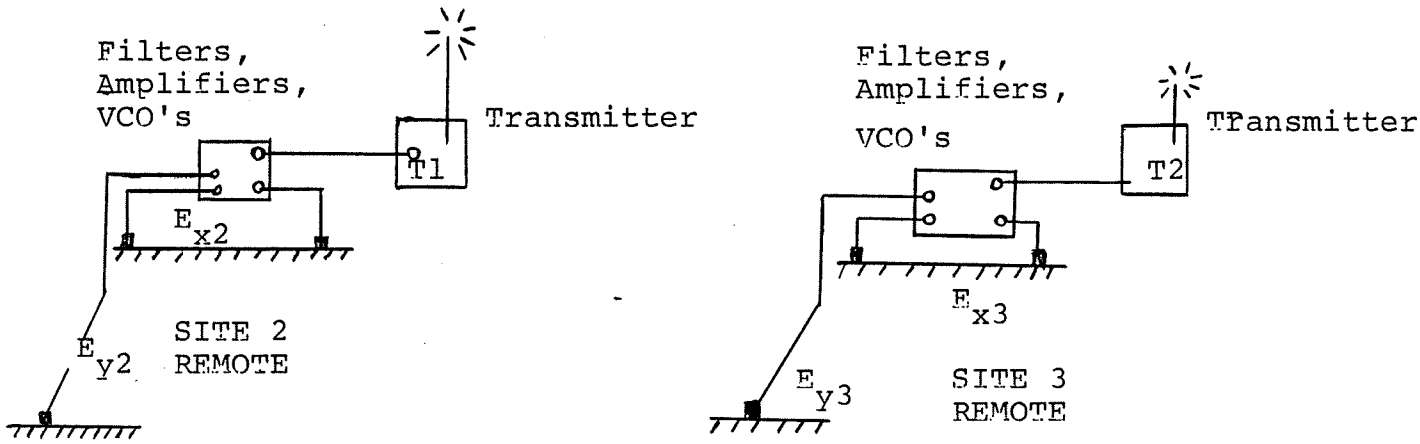
In order to solve for impedance tensors, the analog data from the magnetic tape is digitized (12 bits) and evaluated utilizing a LSI-11 DEC minicomputer. The computer system is mounted in the field instrument truck such that data may be processed in the field in real time.

The remote reference method of analysis was used, following a technique described by Gamble et.al.(1978). The remote station data are treated as tensors and evaluated using the base station magnetic fields. In this work, the electric fields were used as the references to calculate the cross powers. This method provides results without bias errors, however poor results may occur if the electric fields are linearly polarized.

The computer analysis is separated into two parts utilizing Gamble's (1979) computer programs. The first program digitizes the data (12 bits) into segments 1024 points long. The segment is tapered, Fourier transformed, and the cross powers are calculated.



MAGNETOTELLURIC SETUP



TELLURIC SETUP

Figure 1. Magnetotelluric-Telluric Instruments

The process is repeated for subsequent data sets with the option of rejecting any segment due to noise spikes or signal level saturations. The accumulated average cross power values are stored. This process can be performed in real time. After a data run is completed the second computer program utilizes the average cross powers and calculates the impedances, principal axis directions, rotated apparent resistivity values, skewness, impedance phases, tippers, and tipper strike directions.

The principal axis direction is calculated such that the impedance tensor quantity $|Z_{xy}|^2 + |Z_{yx}|^2$ is maximized. This defines the direction for the principal impedance terms Z_{xy}' and Z_{yx}'. For a two dimensional structure, the diagonal terms Z_{xx}' and Z_{yy}' are zero at this rotation angle. An indication of the three dimensional nature of the area can be represented by the ratio of the magnitude of the rotated diagonal to off diagonal terms. This is called the skewness, S.

$$S = \frac{|Z_{xx}' + Z_{yy}'|}{|Z_{xy}' - Z_{yx}'|}$$

Principal apparent resistivity values are calculated from

$$\rho_x = 0.2\ T\ |Z_{xy}'|^2 \qquad \text{and}$$

$$\rho_y = 0.2\ T\ |Z_{yx}'|^2$$

where T is the period in seconds.

The vertical magnetic field is utilized to determine the strike direction. For a normal incident plane wave over a two dimensional structure, the vertical magnetic field arises only from the TE Mode, H_x field perpendicular to strike (Vozoff, 1972).

We assume $H_z = AH_x + BH_y$ and calculate a rotation direction such that A is maximized.

For the two dimensional case $H_z = A'H_x'$ and the rotated X axis defines a direction perpendicular to strike. In the present work the strike direction is indicated in the computer printout. The magnitude of the vertical field, A', the tipper, gives some indication of any lateral resistivity variations.

Monitoring different frequency bands provides various depth information. An indication of the depth penetration is sometimes given by the apparent skin depth, δ_a. This is defines as the depth where the amplitude of the electric field has fallen to 1/e of its value at the surface and is calculated from the expression

$$\delta_a = 503 \left(\frac{\rho_a}{f}\right)^{\frac{1}{2}}$$

where ρ_a is the apparent resistivity in ohm meters, f the frequency in HZ, and the resulting skin depth is in meters. The lower the frequency, the deeper the penetration.

The actual sensing depths are usually much less than the skin depths. Complete model solutions are required to determine the intrinsic properties and depths. Two dimensional computer modelling would be required to interpret the results if significant lateral variations occur. However a preliminary interpretation can be obtained with a one dimensional model based upon the TE Mode apparent resistivity data. The rational for this approach is that for a deep sounding, the TE Mode is less affected by near surface lateral changes than the TM Mode (Patrick and Bostick, 1969). In the present work a continuous one dimensional inversion method described by Bostick, 1976, was used.

Field Operations

In the present survey, telluric dipoles of 200 meters in length were used in an "L" configuration. Two dipoles were shorted in length due to difficult access (the river and a steep gully). The dipoles were orientated north-south and east-west.

The field system filters prewhitened the spectrum such that data could be obtained wide band from 0.01 to 16 Hz. From 2 to 10 hours of data were recorded for each setup. After elimination of poor sections of data, this resulted in about 1½ hours of processed data. Two overlapping frequency bands were used, 0.01 to 1 Hz and 0.16 to 16 Hz. A summary of the processed data is indicated in Table I.

A test was initially conducted at station 2M to expand the data to 200 Hz. A higher frequency low pass shield was successfully tested on the magnetometer. The frequency band was increased from 16 to 320 Hz. After about 9 days, however, a lower frequency shield had to be used because of increased spheric activity. Since the amplitude of the higher frequency data was found to be much greater than the lower frequency data, gain changes would be required to obtain data over the entire frequency band. Since this involved a considerable amount of time driving between the stations, it was decided to obtain the higher frequency data at only a few closed spaced sites. This plan was abandoned when extremely poor weather put the project far behind schedule. Rain, lightning and/or strong winds were encountered on 9 out of 23 field days.

Other delays in the field work were caused by rattlesnakes throughout the area, locked gates,lack of permission to pass over certain areas and difficult terrain with muddy,slick trails and roads.
Some delays were also encountered when periodic spikes were observed on the magnetic data on a number of days. They lasted from ½ to 1½ hours and were sufficiently large to interrupt the survey.

TABLE I

MAGNETOTELLURIC PROCESSED DATA

High frequency band sample period 0.02 seconds, 1024 points/segment

Low frequency band sample period 0.3 seconds, 1024 points/segment

STATIONS	#Segments High Band 16 to .16 Hz	#Segments Low Band 1 to 0.01 Hz	Data Quality
1M,1A,1B	218	30	Good-Fair
2M,2A,2B	208	21	Good-Fair High Skew 2B
3M,3A,3B	182	14	Good-Fair
4M,4A,4B	174	19	Good High Skew 4B
5M,5A,5B	127	8	Good-Fair
6M,6A,6B	148	11	Good
7M,7A,7B	123	20 8	Good-7M,7A High Skew 7M,7A, 7B Fair-Poor-7B
8M,8A,8B	212	23	Good-Fair High Skew 8M
9M,9A,9B	144 178	14	Good
10M,10A, 10B	216	16	Good-Fair
11M,11A, 11B	216	19	Good
12M,12B	166 83	19 7	Fair
13M,13A, 13B	217	20	Fair
14M,14A, 14B	216	20	Good-Fair
15M,15B	204	20	Good-Fair
17M,17A,17B	167	15	Fair-Poor

The source of this noise was not determined, it may be associated with military activity at Mountain Home Air Force Base or commerical airline traffic overhead approaching the Boise, Idaho airport. Both these areas are within 100 miles of the survey area.

At some of the stations there does not appear to be a very good agreement between the slope of the resistivity curve and the phase at the highest frequencies, typically > 10 Hz [this is according to the expression ϕ (phase) $= -45^{\circ}\left(1 - \frac{\partial \ln \rho}{\partial \ln T}\right)$] .

There does not appear to be any consistent pattern or bias between the expected and actual behavior. The poor agreement is not understood, it may be due to local cultural noise.
On some occasions, segments of data were excluded when it appeared that the game warden was in the area and his mobile radio transmissions were being picked up.

The personnel stayed at the Tapadera Motel in Ontario, Oregon during the field work. Commuting time to the survey area varied from about 40 to 90 minutes each way depending upon the location of the stations. Travel time between sites on a given setup varied from a few minutes up to 3 hours.

Specific vehicles used on the survey were a Ford 3/4 ton 4 wheel drive instrument vehicle, a Dodge 4 wheel drive powerwagon and an equipment trailer.

Composition of the Crew

A detailed summary of the work and personnel is documented in Appendix B. The personnel involved on the project are listed below:

A. Mazzella	Geophysicist	Survey, instruments, data processing
J. Malloy	Field Assistant	Survey, wire crew

Data

The locations of the stations and the approximate directions of the tipper strike and TE Mode rotated axis for the band 10-50 seconds are indicated in Plate 1. Plots of the data and one dimensional inversions are presented in the second binder. Data points are plotted that only meet the following criteria:

1) skewness ≤ 0.5 and
2) phase between 0 and -90 degrees.

The rotated apparent resistivity values, rotation angles, skewness, phases, tipper and tipper strike directions are plotted for each station for periods from 0.06 to 100 seconds.

Data with skewness values up to 1.0 were accepted and plotted for the following stations: 2B, 4B, 7M, 7A, 7B, 8M, 15M and 15B.

The interpreted resistivity sections based upon a one dimensional TE Mode inversion along lines AA', BB', CC', DD', EE' and FF' are plotted in plates 2 through 7. The TM Mode inversion along the same lines are plotted in plates 8 through 13.

A comparsion of data obtained with base station and remote sites interchanged is presented in Appendix A.

Discussion of Data

Resistivity values ranging from less than 1 to over 2000 ohm meters are observed over the survey area.

The data in the area of the hot springs suggest a complex structure consisting of a high resistivity vertical structure (2000 ohm meters) adjacent to a conductive zone (2 ohm meters), see the TM Mode sections in plates 9 and 13 along lines BB' and FF'. The TE Mode results indicate a different picture, indicating that two dimensional effects should be taken into consideration for a more valid interpretation of the area. A number of grounded metal fences were encountered in the survey area. Some of these are indicated in Plate 1. These were fairly close to stations 5M and 5A in the

hot springs area. No corrections were made to the data for any possible effects of these fences.

The tipper indicates a north-south strike over the hot springs area and over most of the survey area.

A number of low resistivity zones (< 4 ohm meters) are indicated at depths ranging from 7 to over 15 kilometers in the TE Mode interpretation over various part of the project area. One fairly large zone occurs to the north in the area of stations 11M,14B 15M and 15B (note: fairly high skewness values occur for 15M and 15B). Another zone lies to the northeast in the area of stations 13M,13A to 10A. Additional low resistivity zones lie to the south of the hot springs along line AA'. These may be reflecting some lateral distant side effects, a conductive strata at depth or some geothermal potential. There does not appear to be any clear connection between these low resistivity zones at depth and the surface hot springs.

The above interpretations were based upon one dimensional models, two and three dimensional effects are present suggesting that at least two dimensional modelling may aid in the interpretation of the structure and any geothermal potential.

REFERENCES

Bostick,F.X., 1977, Paper presented at Geothermal Workshop at the University of Utah, U.S.G.S. contract no. 14-08-0001-G359

Keller,G.V., 1970, Induction Methods in Prospecting for Hot Water, United Nations Symposium, Pisa, Italy.

Keller, G.V. and Frischknecht, F.C., 1970, Electrical Methods in Geophysical Prospecting, Pergamon Press, Inc.

Gamble,T.D., Goubau,W.M.,and Clarke,J., 1978, Magnetotellurics with a remote magnetic reference. Lawrence Berkeley Laboratory, LBL-7032

Gamble,T.D., private communication, 1979; also see
Koch,R.H.,Goubau,W.M., Gamble,T.D., Miracky,R.F. and Clarke,J., 1978, Minicomputer for in-field Processing of Magnetotelluric Data, Lawerence Berkeley Laboratory, LBL-8648, Annual Report 1978, p.7.

Patrick,F.W. and Bostick,F.X.,1969, Magnetotelluric Modeling Techniques, Technical Report No. 59, Electronics Research Center, University of Texas, Austin, Texas.

Sims, W.E.,and Bostick, F.X., 1969, Methods of Magnetotelluric Analysis , Technical Report No. 58, Electrical Geophysical Research Laboratory, Electronics Research Center, University of Texas, Austin, Texas.

Vozoff, K., 1972, The Magnetotelluric Method in the Exploration of Sedimentary Basins, Geophysics, Vol. 37, No. 1.

Zohdy, A.A.R., Anderson,L.A., Müffler, L.J.P., 1973, Resistivity, Self-Potential, and Induced Polarization Surveys of a Vapor-Dominated Geothermal System, Geophysics, Vol. 38, No. 6, p. 1130.

APPENDIX A

A test of the uncertainity associated with the extrapolation of the magnetic field to the remote sites was provide on one setup where there appeared to be a significant resistivity change between the base (9M) and a remote site (9A). The remote site was reoccupied as a base site (17M). The following stations are equivalent and the data are plotted on figures 2 through 5: 9M = 17B, 9A = 17M. The data quality of setup 17 was not as good as that of setup 9, however there is a fairly good agreenment in the resistivity values, rotation angles,skewness and phases for both the sites. The large resistivity separation between the TE and TM Modes is supported by both the 9A and 17M data (figure 2). This separation is not evident at the 9M,17B site. The distance between 9M and 9A was about 1.9 KM.

PROFILE "P" BULLY CREEK, OREGON

STATIONS X,Y 9A ; ⊗,Ⓨ 17M

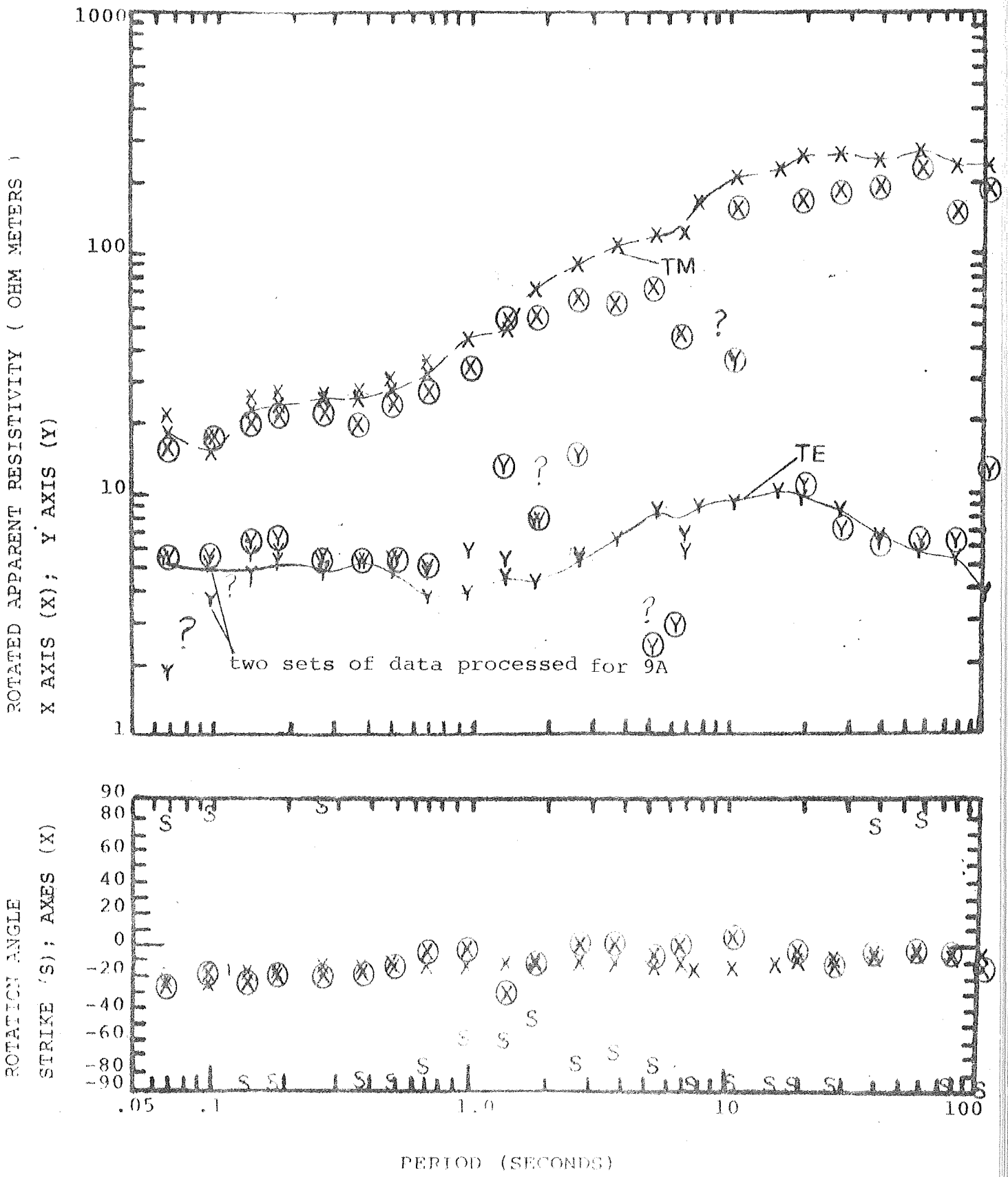


Figure 2. Comparsion of data with remote (9A) site occupied as a base site (17M).

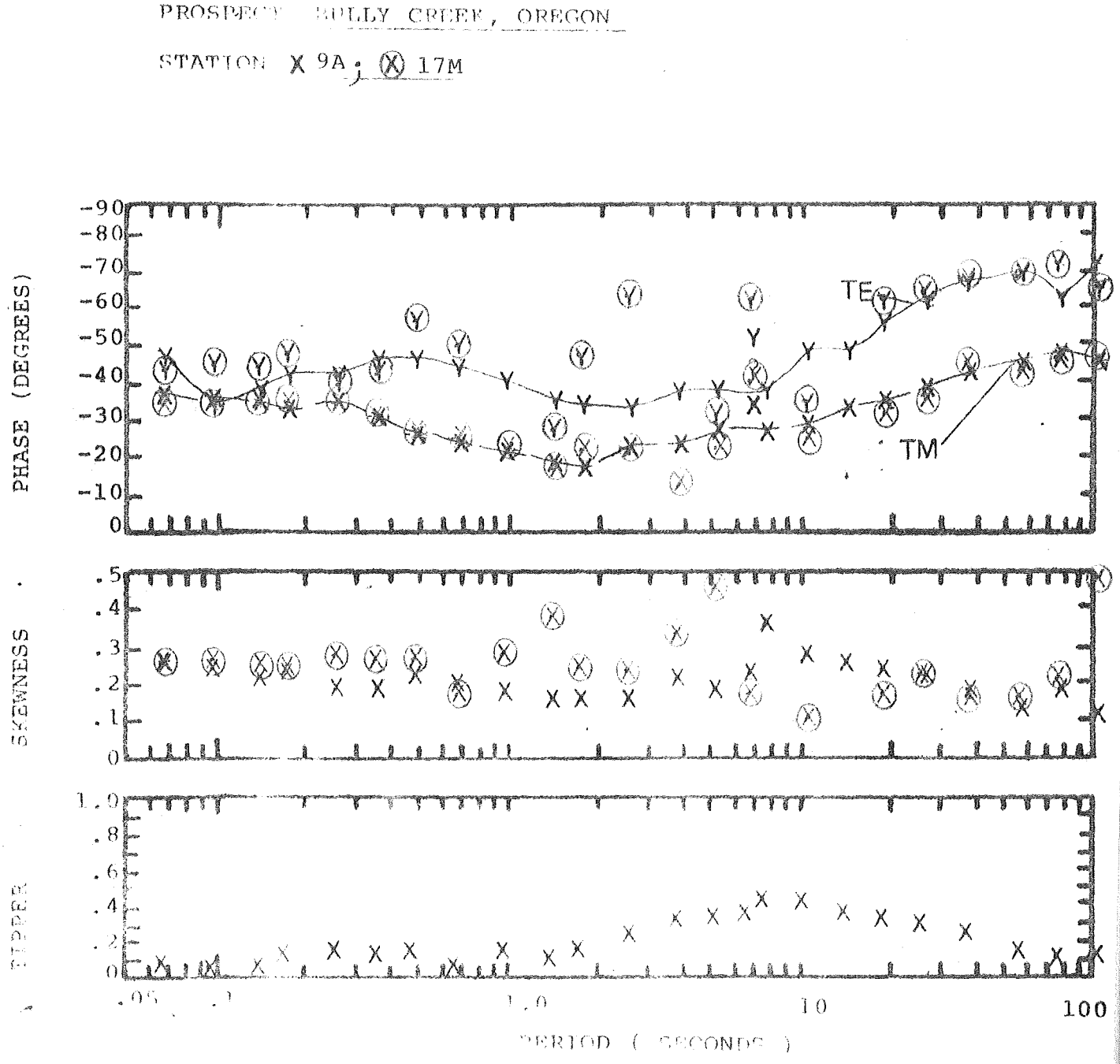


Figure 3. Comparison of data with remote site (9A) reoccupied as a base site (17M).

PROSPECT BULLY CREEK, OREGON

STATION X 9M ; ⊗ 17B

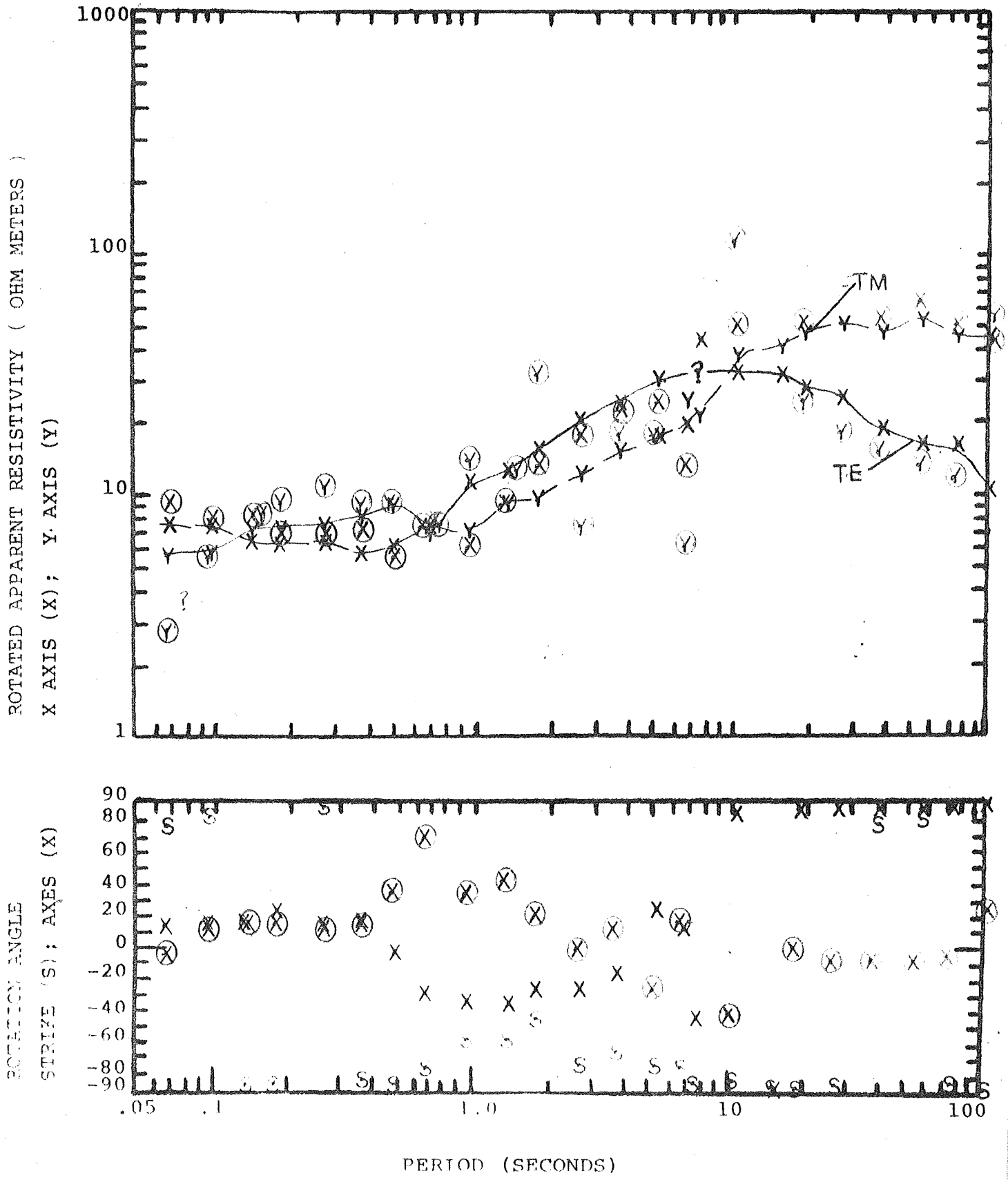


Figure 4. Comparsion of data with a remote site (17B) occupied as a base site (9M).

PROSPECT BULLY CREEK, OREGON

STATION X 9M ; ⓧ 17B

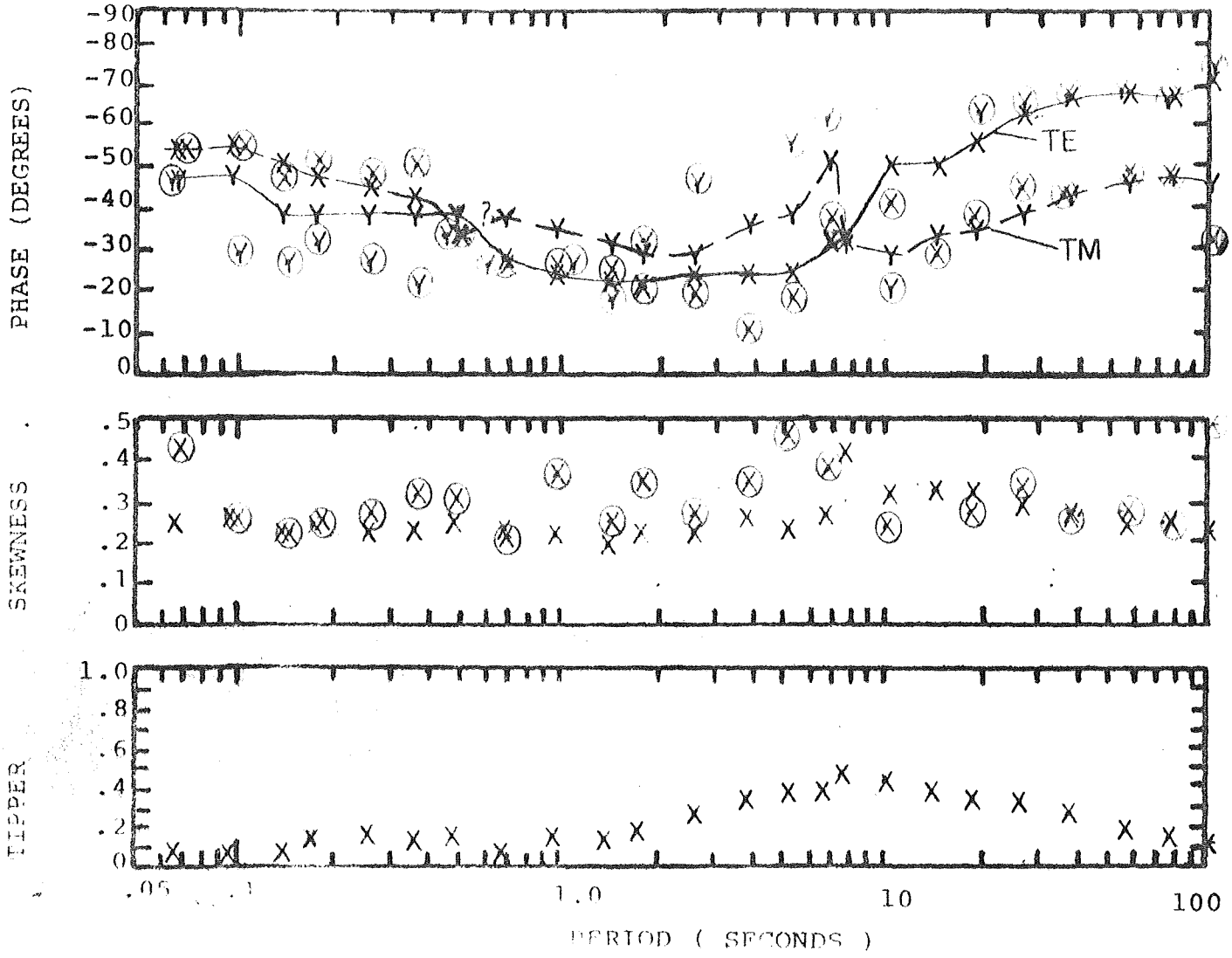


Figure 5. Comparsion of data with a remote site (17B) occupied as a base site (9M)

OPERATIONS SUMMARY

MONTH
MAY 1981

TERRAPHYSICS

PROJECT BULLY CREEK, OREGON

CHARGE	DAY	TECHNIQUE	TOTAL STATIONS	LOCATIONS	PERSONNEL MAZZELLA	PERSONNEL MALLOY
1M	13	Mobilization		and preparation to Ontario, Oregon	X	X
1M	14	"		" " " " "	X	X
1 S	15	TMT	--	Survey area, setup dipoles 2M,2A,2B contact John Jordan	X	X
1 S	16	TMT	3	Data 2M,2A,2B, pickup dipoles; survey,setup 6M,6A,6B	X	X
1 S	17	TMT	3	Data 6M,6A,6B pickup dipoles; survey setup 9M,9A,9B Rattlesnakes in area.	X	X
½ S ½ D	18	TMT	--	Rain in morning, go to field, roads very muddy, slick, slow driving, complete 9M setup dipoles	X	X
1 S	19	TMT	some	Data 9M,9A,9B ligntning storm coninues, survey #12 setup Locked Gate	X	X
1 Down	20			Raining hard all morning, process setup 9 data, need more long period		
1 S	21	TMT	3	Data 9M,9A,9B pickup 9B dipoles; survey setup 17A	X	X
1 S	22	TMT	3	Data 17M,17A, 17B (17M=9A, 17B=9M, 17A new site, only way to pickup 17A site since gate to 12M is locked. pickup all dipoles, survey setup 11M,11A,11B	X	X
1 S	23	TMT	3	Data 11M,11A,11B, pickup dipoles;survey setup 14M,14A,14B Rough road to 14M, very steep hill to 14A	X	X
1 S	24	TMT	--	Attempt data 14 setup, light rain all morning,lightning by noon some data,not enough		

Totals Mobilization 2
Survey 8½
Down 1½

T - TELLURICS SP - SELF POTENTIAL MT - MAGNETOTELLURICS

R - D.C. RESISTIVITY EM - ELECTROMAGNETIC (ACTIVE)

MONTH

May 1981

TERRAPHYSICS

PROJECT BULLY CREEK OREGON

CHARGE	DAY	TECHNIQUE	TOTAL STATIONS	LOCATIONS	PERSONNEL: MAZZELLA	PERSONNEL: MALLOY
1 S	25	TMT	3	Data 14M,14A,14B pickup dipoles; survey setup 13M,13A,13B	X	X
1 S	26	TMT	--	Attempt data 13M,13A,13B very windy, no data, survey setup 10M,10A,10B	X	X
1 S	27	TMT	6	Data 13M,13A,13B pickup dipoles; Data 10M,10A,10B long day crew member pulls muscle in leg. Police and traffic foul up data segments on setup 10.	X	X
1 S	28	TMT	-	Survey and setup 7M,7A,7B, setup electronics 7A check telemtry Takes 1½ hours to drive from 7A to 7M, 11 hour day- 8 hours driving	X	X
1 S	29	TMT	3	Data 7M,7A,7B pickup dipoles; survey setup 8M,8A,8B	X	X
1 S	30	TMT	-	Attempt data 8M,8A,8B Lightning storm 9:30 A.M.,survey #3, survey, setup 5M heavy rain starts 3P.M,winds 40mph plus	X	X
1 S	31	TMT	3	Data 8M,8A,8B pick up dipoles; setup 5M,5A,5B. Cattle get into field where 5M previously setup destroy wires, untangle wires and resetup 5M	X	X
1 S	1	TMT	3	Data 5M,5A,5B pick up dipoles, Strange noise pickup on 5A east-west dipole only- replace wire, electrode, and new hole no difference. 5A is directly over hot springs- lots of corrosion observed on dipole wire. Survey setup 3M,3A,3B	X	X
1 S	2	TMT	3	Data 3M,3A,3B light rain intermittent all morning- one shower steady for about 30 minutes soaks everything , wait until everything dries out. pick up dipoles. Survey setup 4M,4A,4B Very steep hill to 4M, long drive between 4M and 4A	X	X

Totals Survey 9 days

T - TELLURICS SP - SELF POTENTIAL MT - MAGNETOTELLURICS

R - D.C. RESISTIVITY EM - ELECTROMAGNETIC (ACTIVE)

MONTH

June 1981

TERRAPHYSICS

PROJECT BULLY CREEK OREGON

CHARGE	DAY	TECHNIQUE	TOTAL STATIONS	LOCATIONS	PERSONNEL: MAZZELLA	PERSONNEL: MALLOY
1 S	3	TMT	3	Data 4M,4A,4B Periodic spikes on magnetometer- knocks it out of lock long recording time, pick up dipoles; survey setup 1M,1A,1B - lots of traffic in area of reservior relocate sites	X	X
1 S	4	TMT	3	Data 1M,1A,1B survey setup 12M,12B Rattlesnakes in deep grass slow walking out dipole wires. Survey setup 15M,15B very rough road to top , equipment truck almost rolls over on side of hill- big boulders. Can't see site to west from top. Cancel west station.	X	X
1 S	5	TMT	2	Data 12M,12B, pickup dipoles Thunderhead clouds building all morning rains fairly heavy in afternoon- lightning storm Rains off and on throughout the night	X	X
1 S	6	TMT	2	Data 15M,15B pickup dipoles;thunderhead clouds all around	X	X
1M	7	Demobilization back to California and unload equipment				
1M	8	"		" " " " " " return liquid He dewar	X	

Totals Mobilization 2
Survey 4

T - TELLURICS SP - SELF POTENTIAL MT - MAGNETOTELLURICS

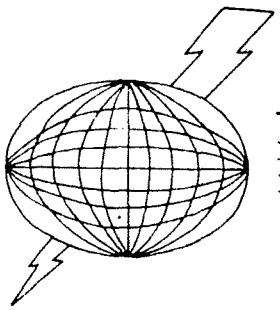
R - D.C. RESISTIVITY EM - ELECTROMAGNETIC (ACTIVE)

TELLURIC MAGNETOTELLURIC DATA BULLY CREEK PROSPECT OREGON

for

AMAX EXPLORATION, INC.
and
CHEVRON RESOURCES CO.

June 1981



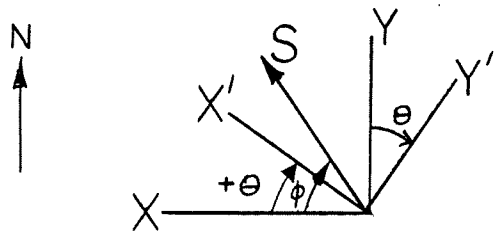
TERRAPHYSICS
P.O. Box 686
Inverness, California 94937
(415) 669-1416

Data on the following pages are plotted for those points where

1) skewness < 0.5 and
2) the phase lies between 0 and -90 degrees

Note: data points were allowed for skewness values up to 1.0 for the following stations: 2B, 4B, 7M, 7A, 7B, 8M, 15M, and 15B.

The following reference coordinate axes were used for all the stations : positive X axis to the west and positive Y axis to the north.
Angles are measured clockwise positive from the X axis.



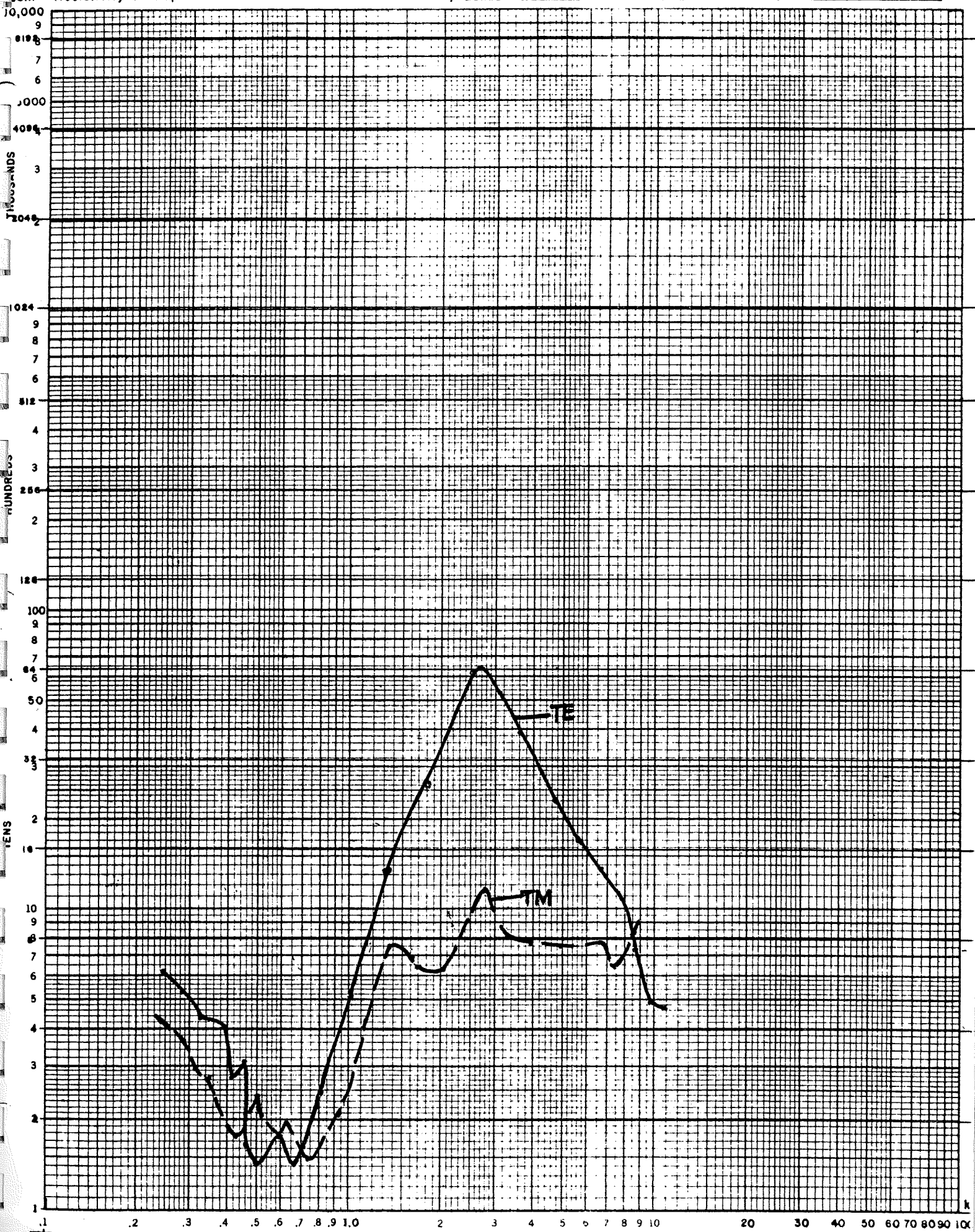
PLATES

The plates are in the pocket at the end of the report.

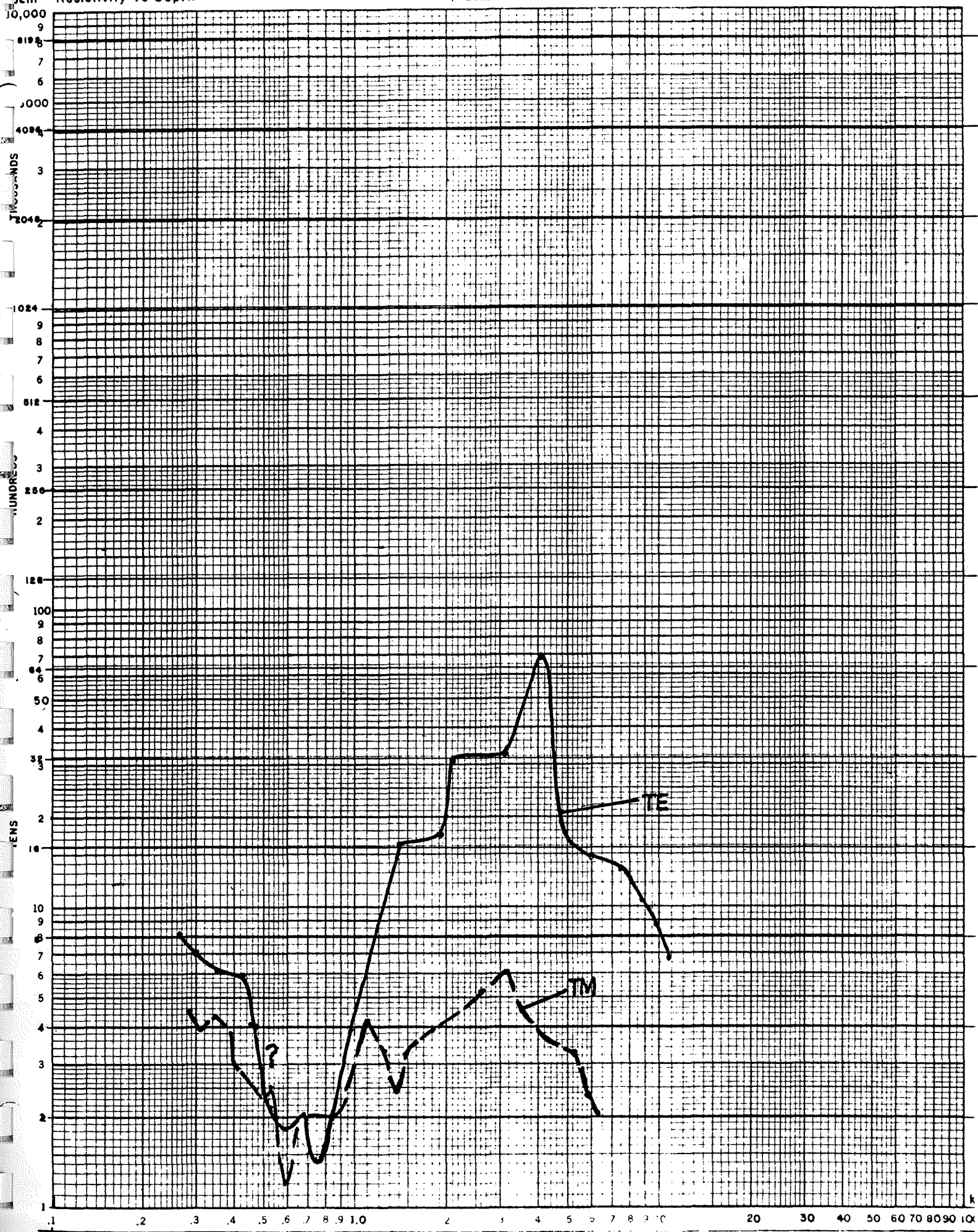
TABLE OF CONTENTS

Pages 1 to 44 contain the one dimensional inversions of the data, both TE and TM Modes.

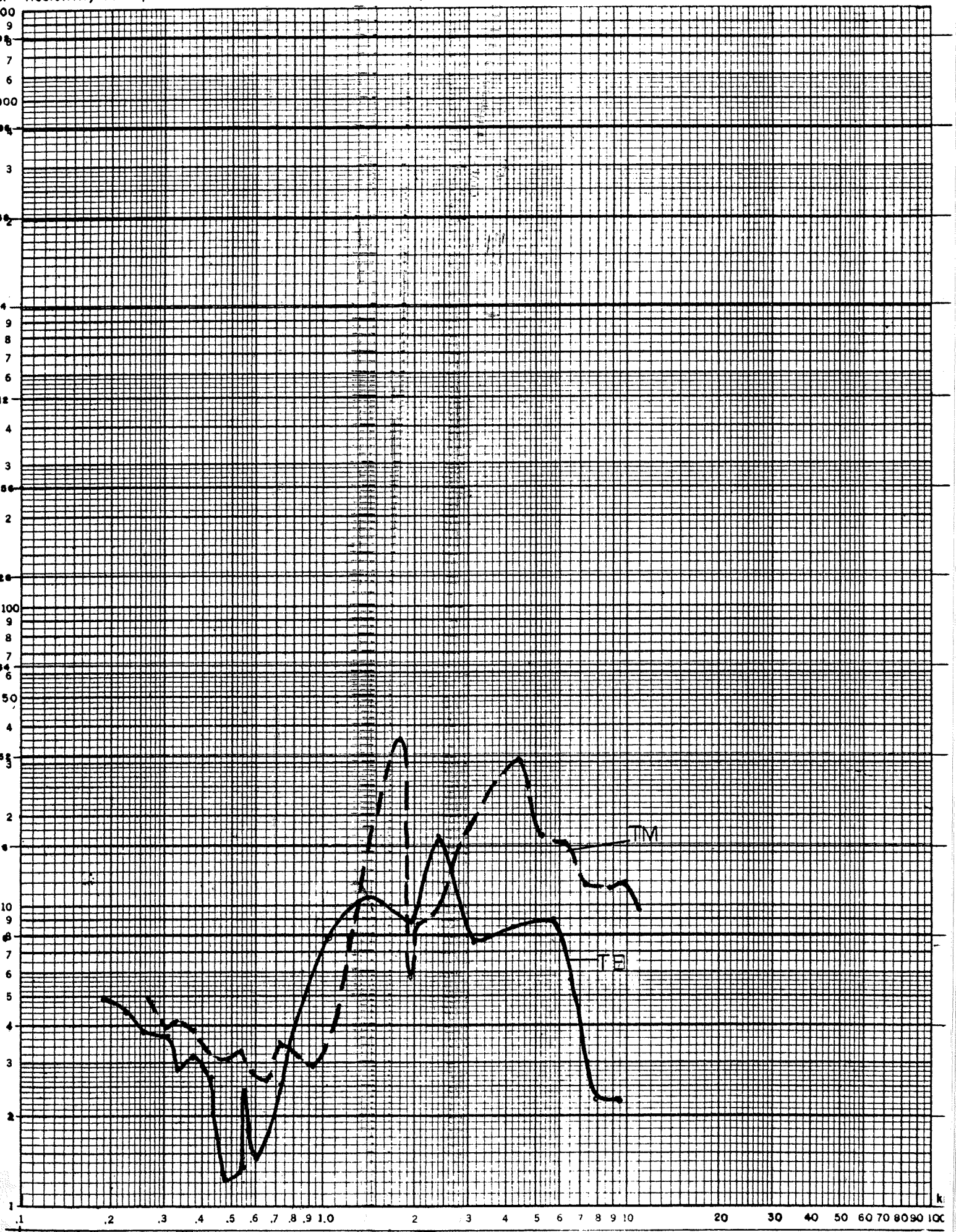
Ωm Resistivity vs Depth Proj. Bully Creek, OR Station 1M



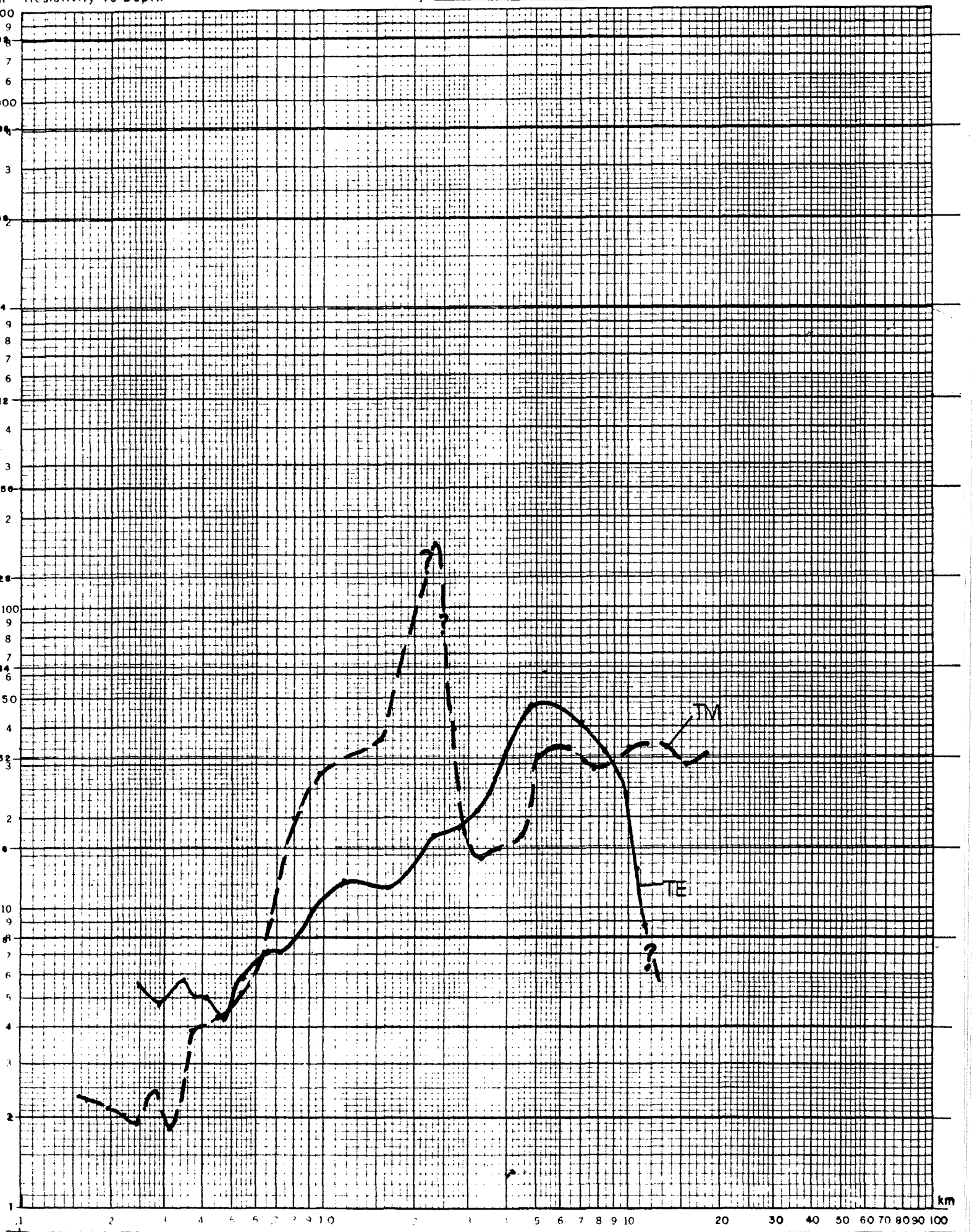
Ωm Resistivity vs Depth Proj. BULLY CREEK, OR Station 1A



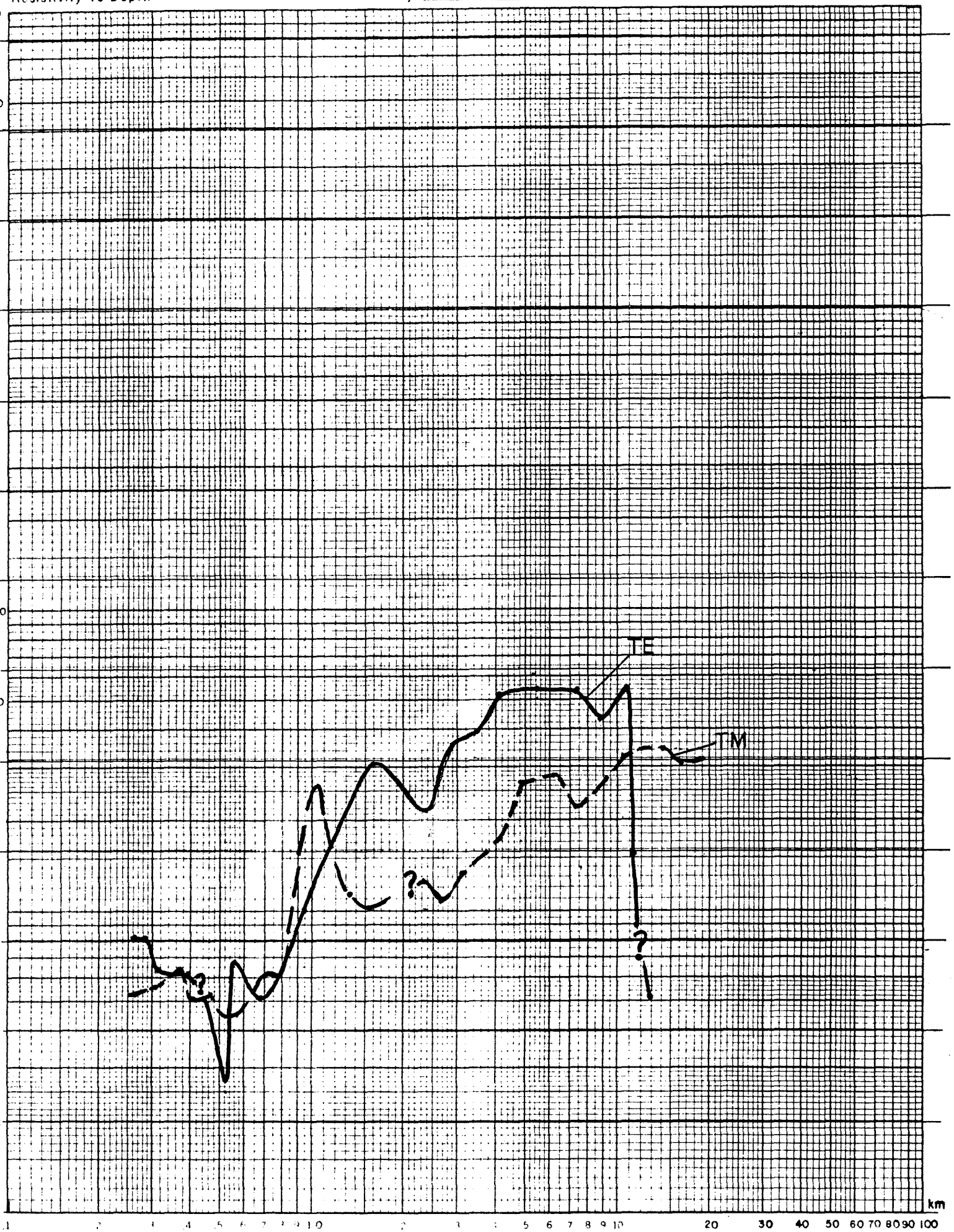
2m Resistivity vs Depth Proj. BULLY CREEK, OR Station 1B



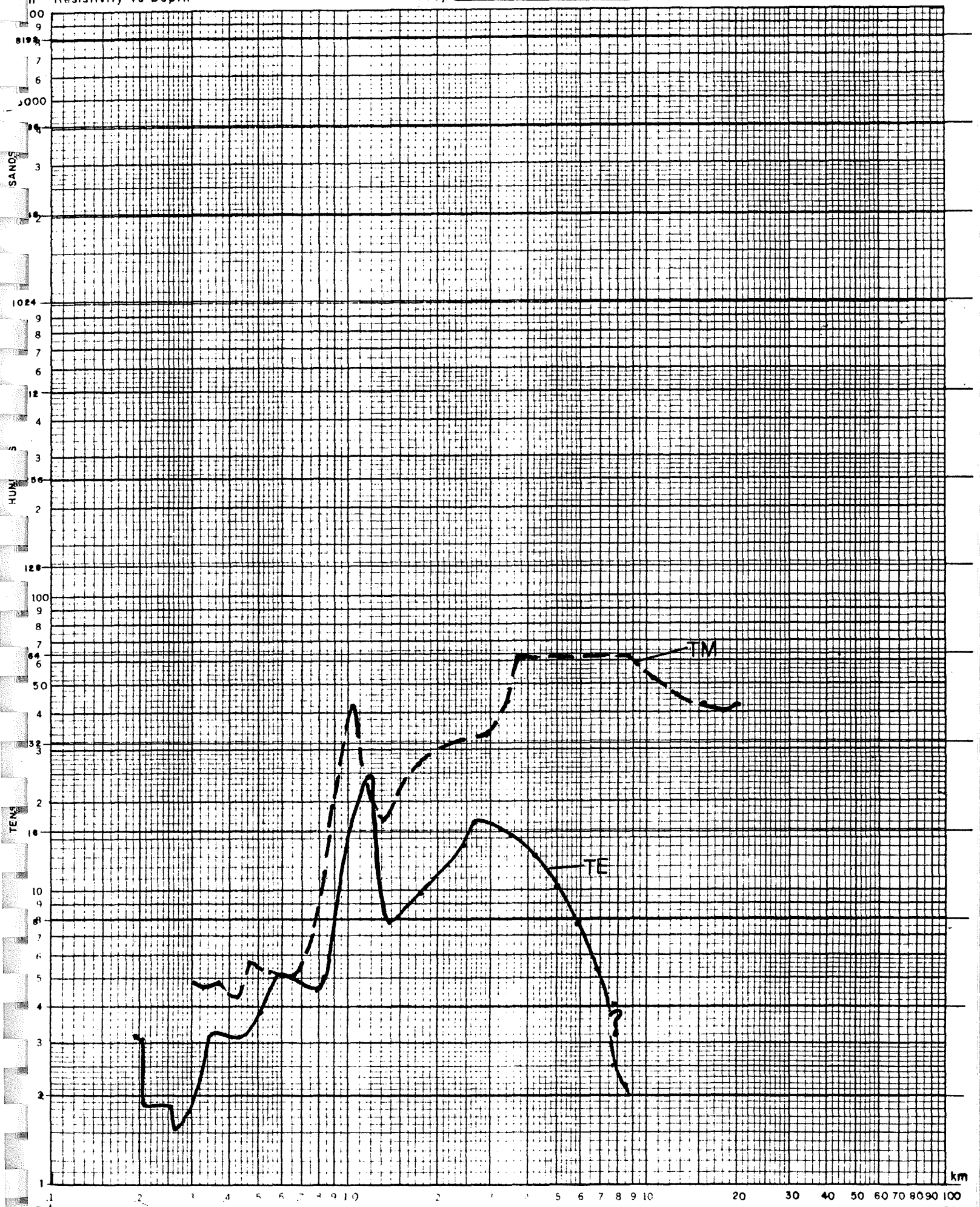
Resistivity vs Depth Proj BULLY CREEK, OR Station 2M



Resistivity vs Depth Proj BULLY CREEK, OR Station 2A

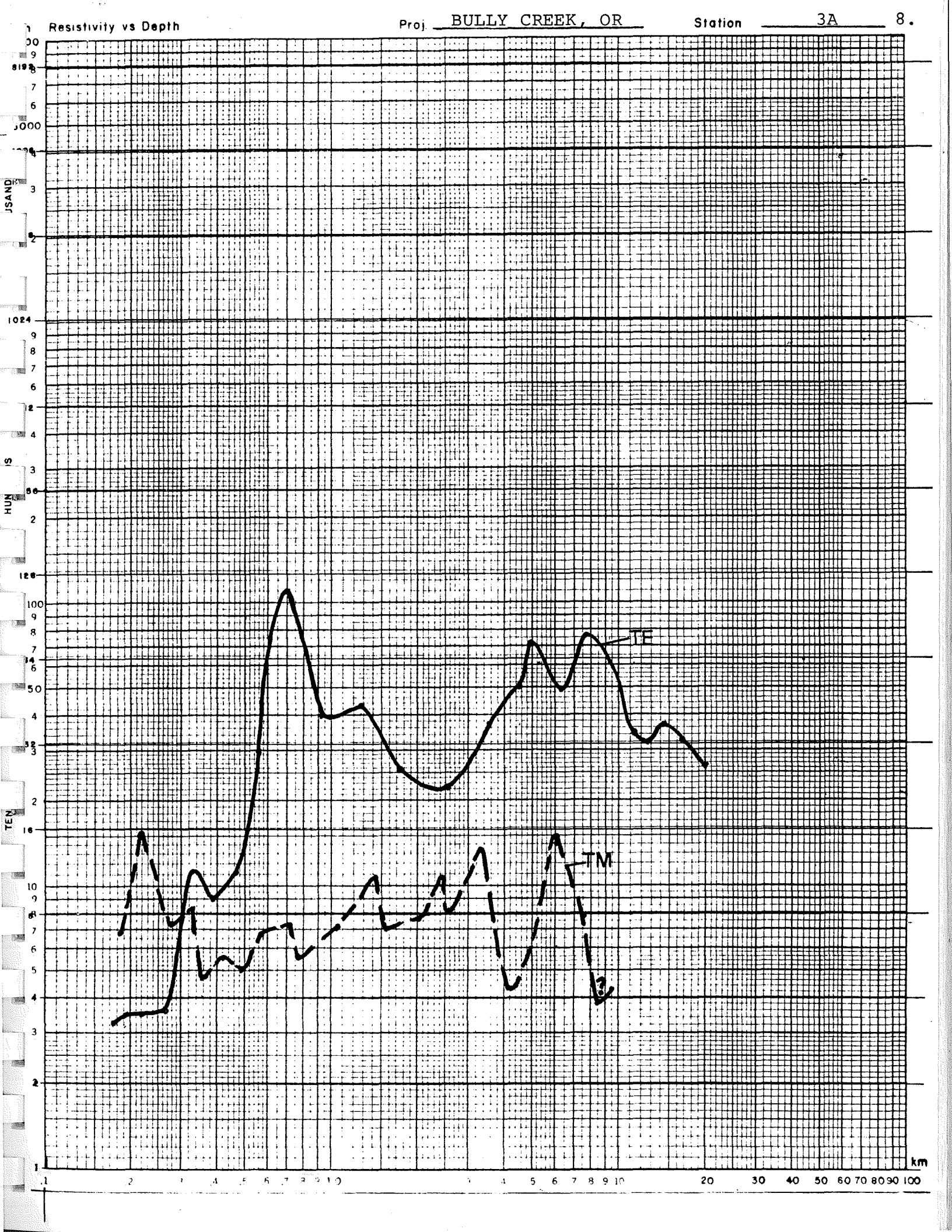


n Resistivity vs Depth Proj. BULLY CREEK, OR Station 2B

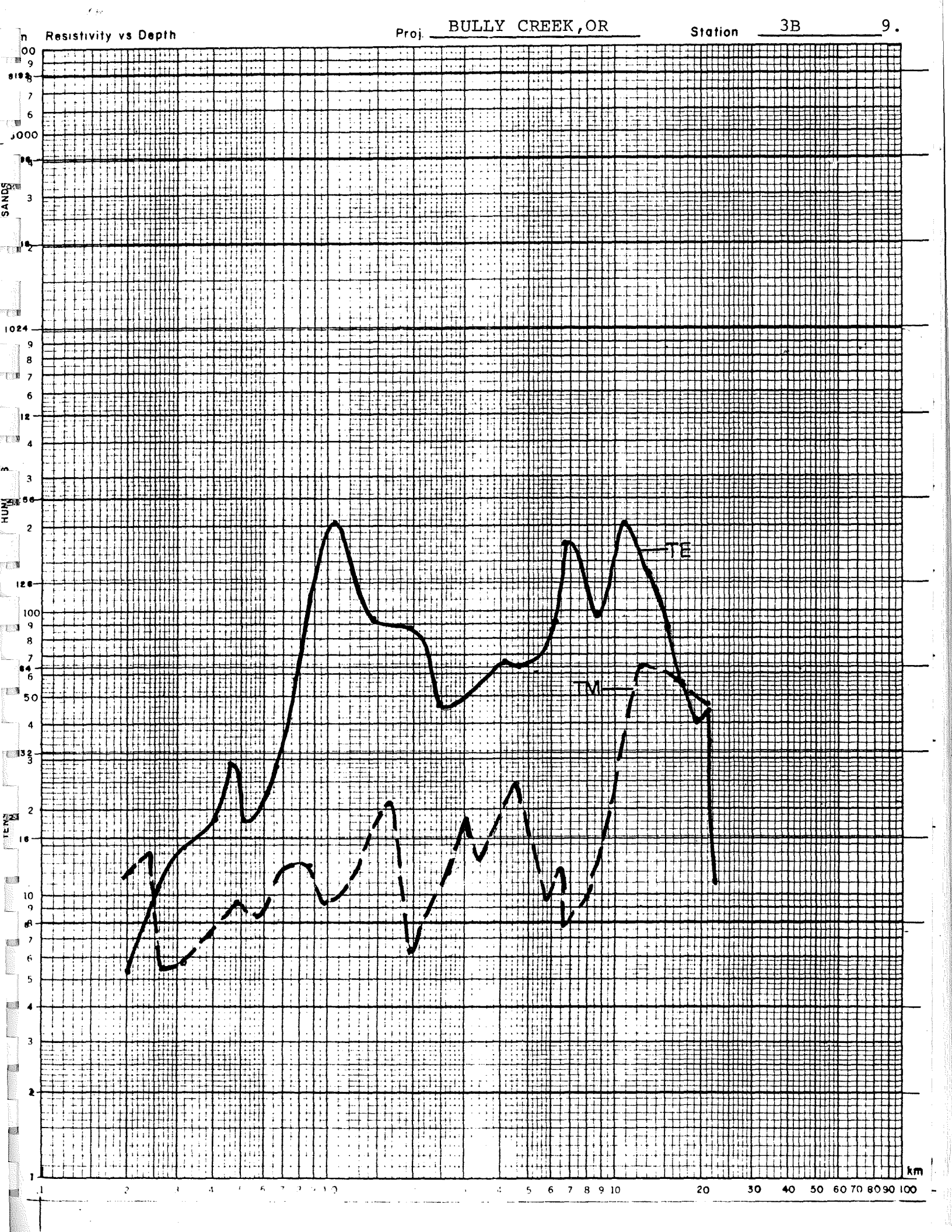


n Resistivity vs Depth Proj BULLY CREEK, OR Station 3M

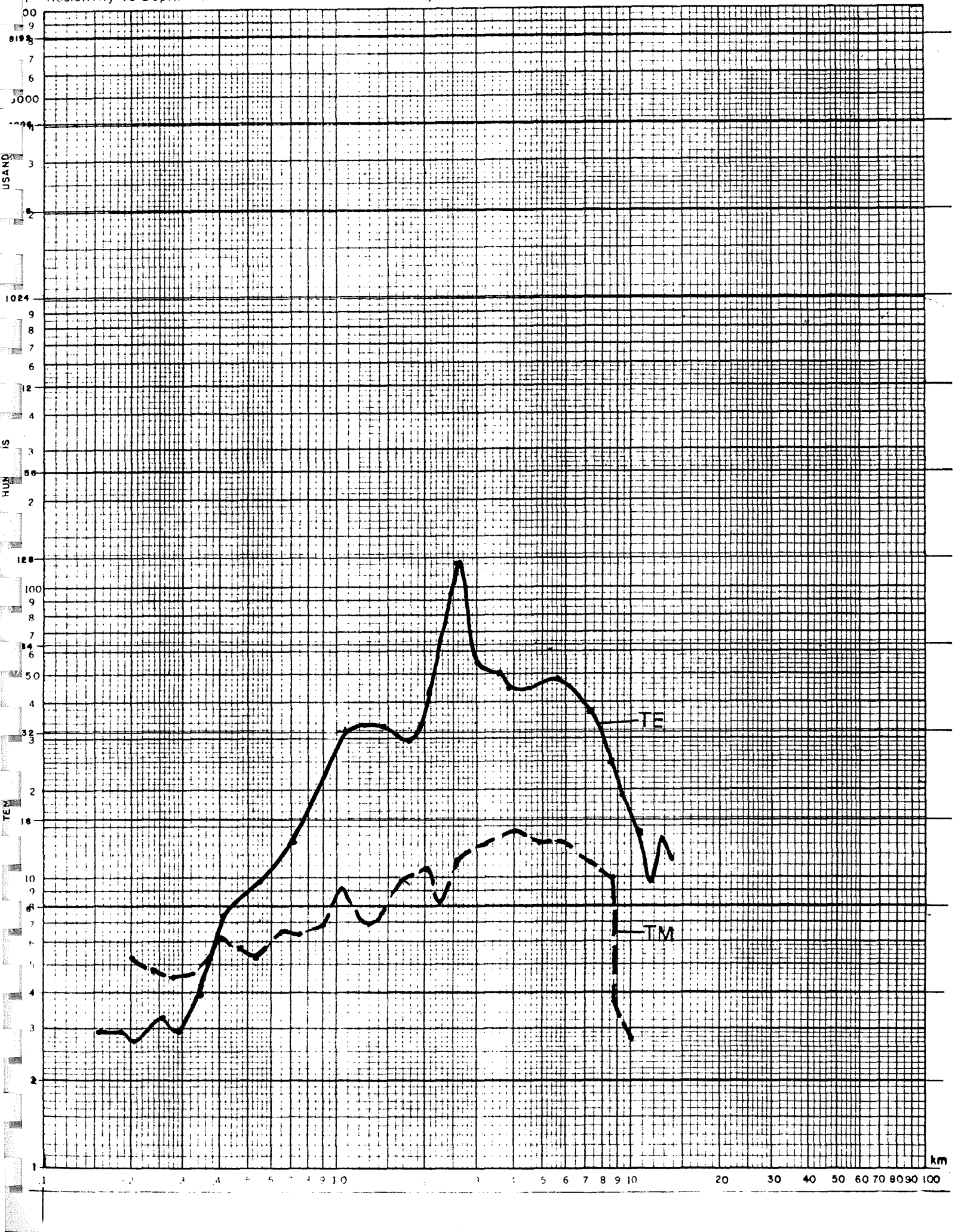
Resistivity vs Depth Proj. BULLY CREEK, OR Station 3A



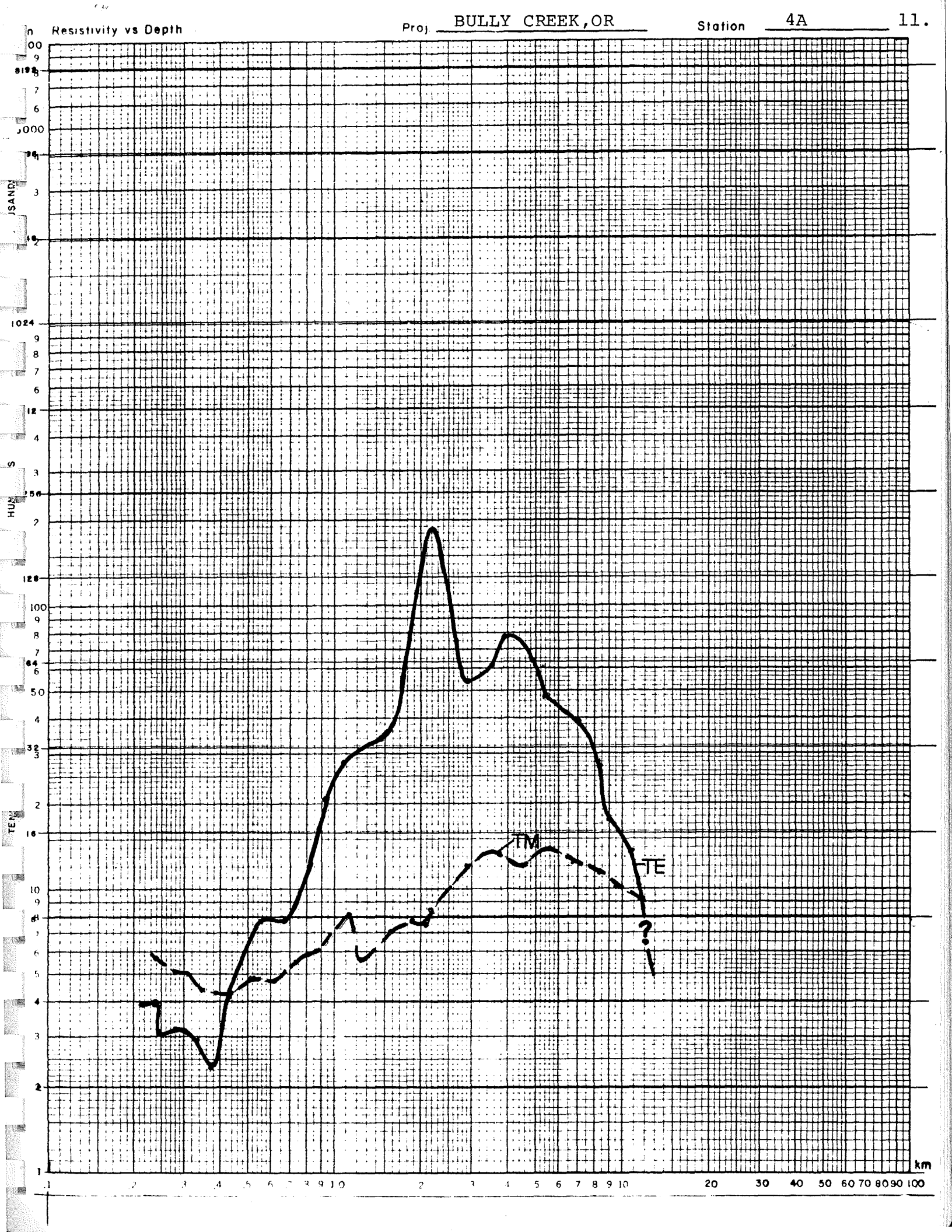
Resistivity vs Depth Proj. BULLY CREEK, OR Station 3B



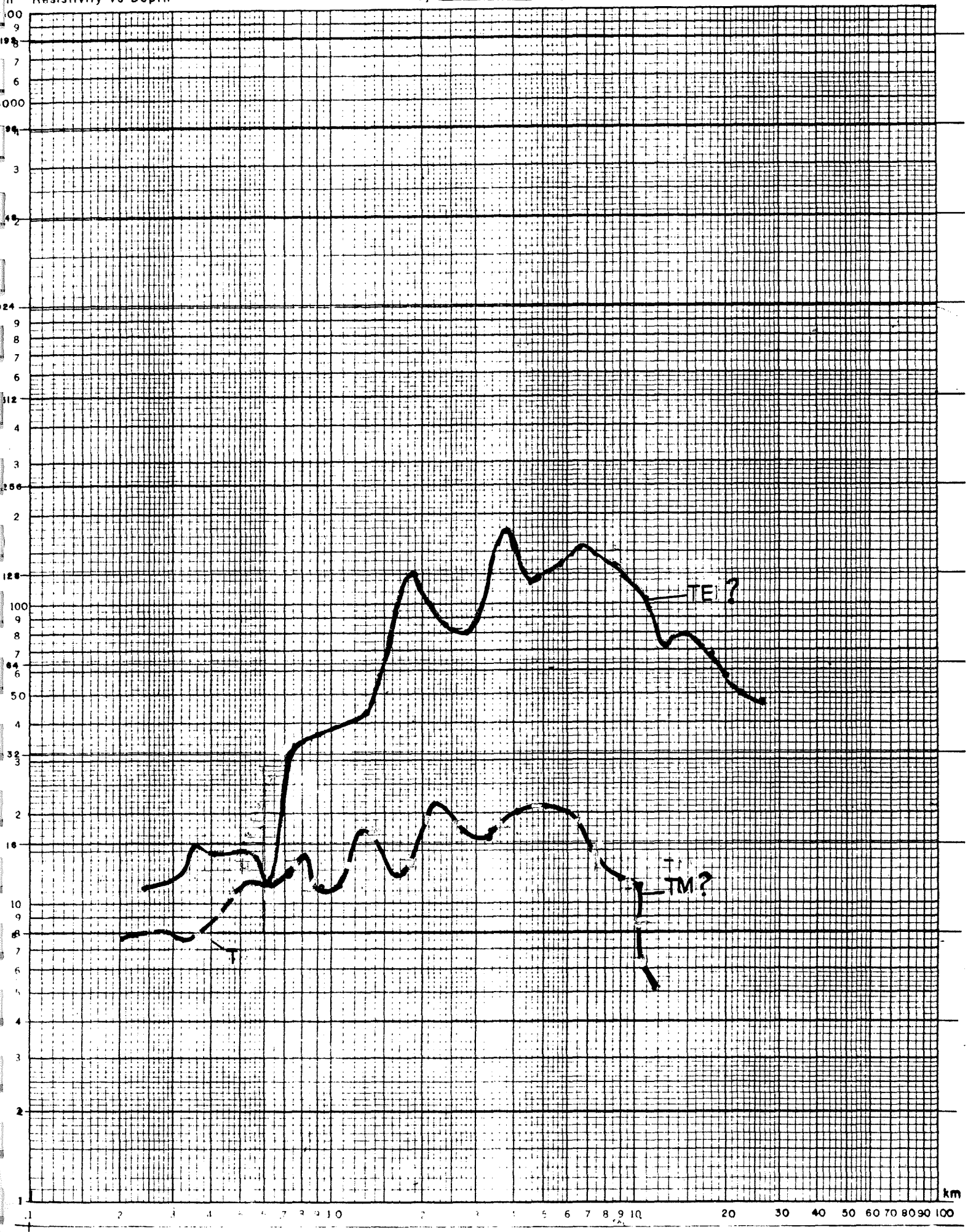
Resistivity vs Depth Proj BULLY CREEK,OR Station 4M 10.



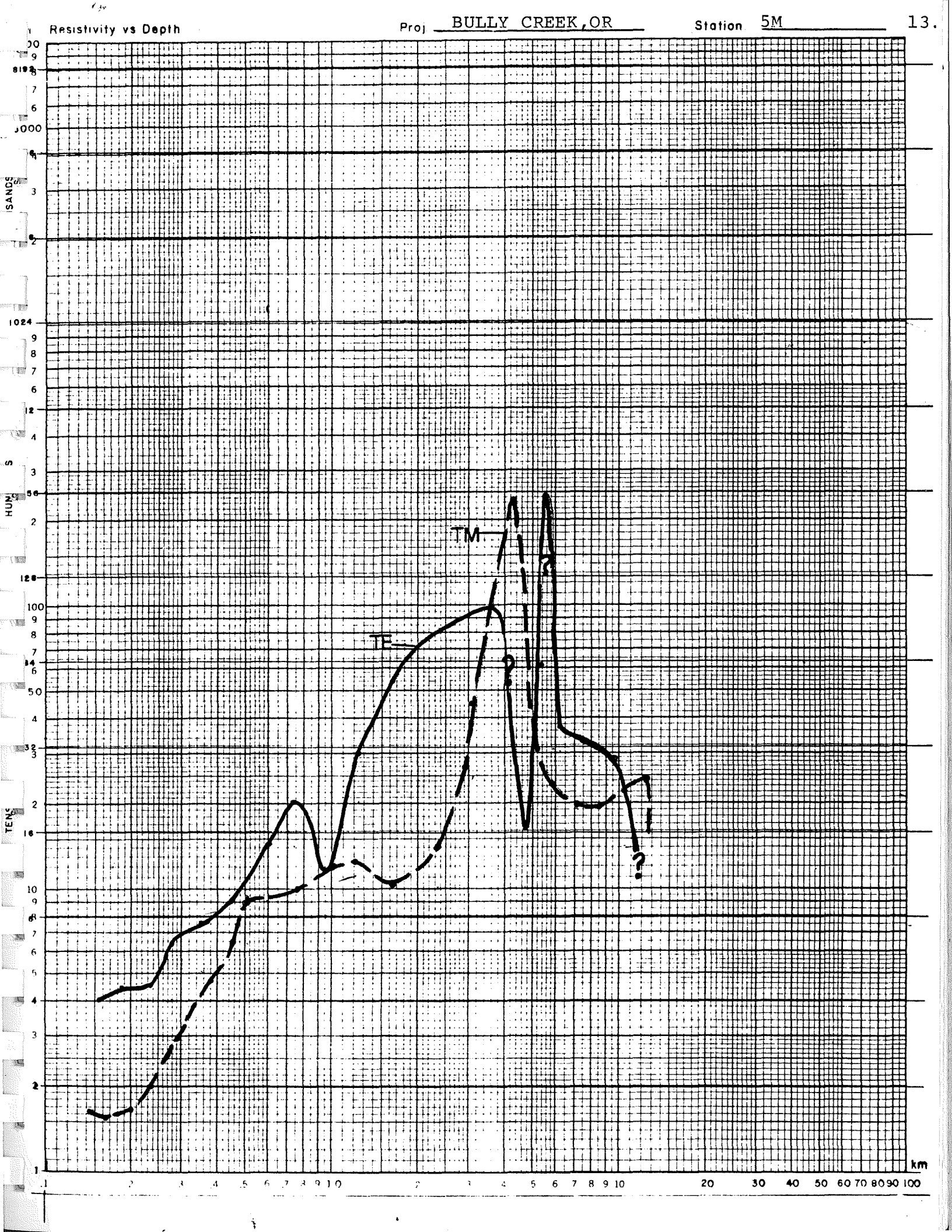
Resistivity vs Depth Proj BULLY CREEK,OR Station 4A



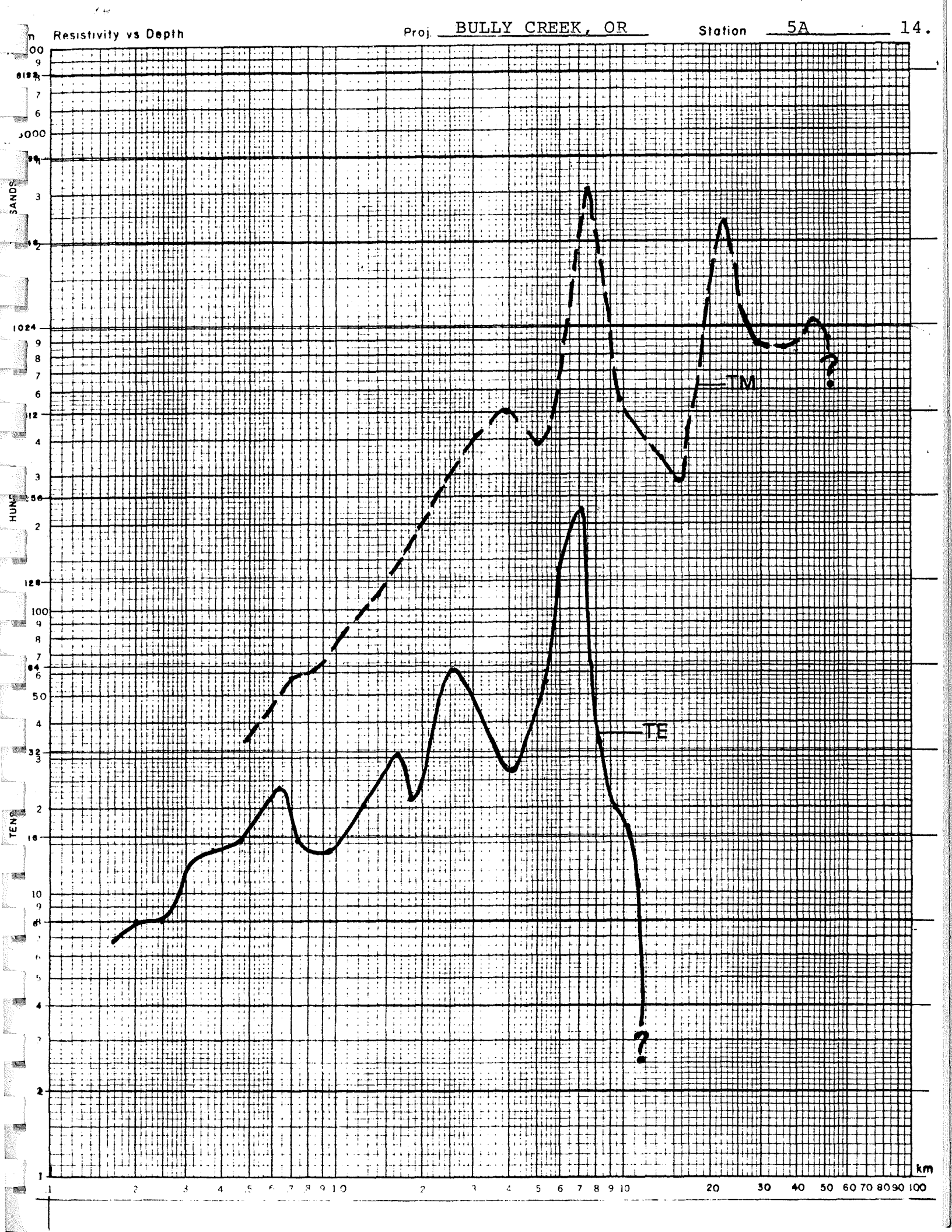
Resistivity vs Depth Proj BULLY CREEK, OR Station 4B



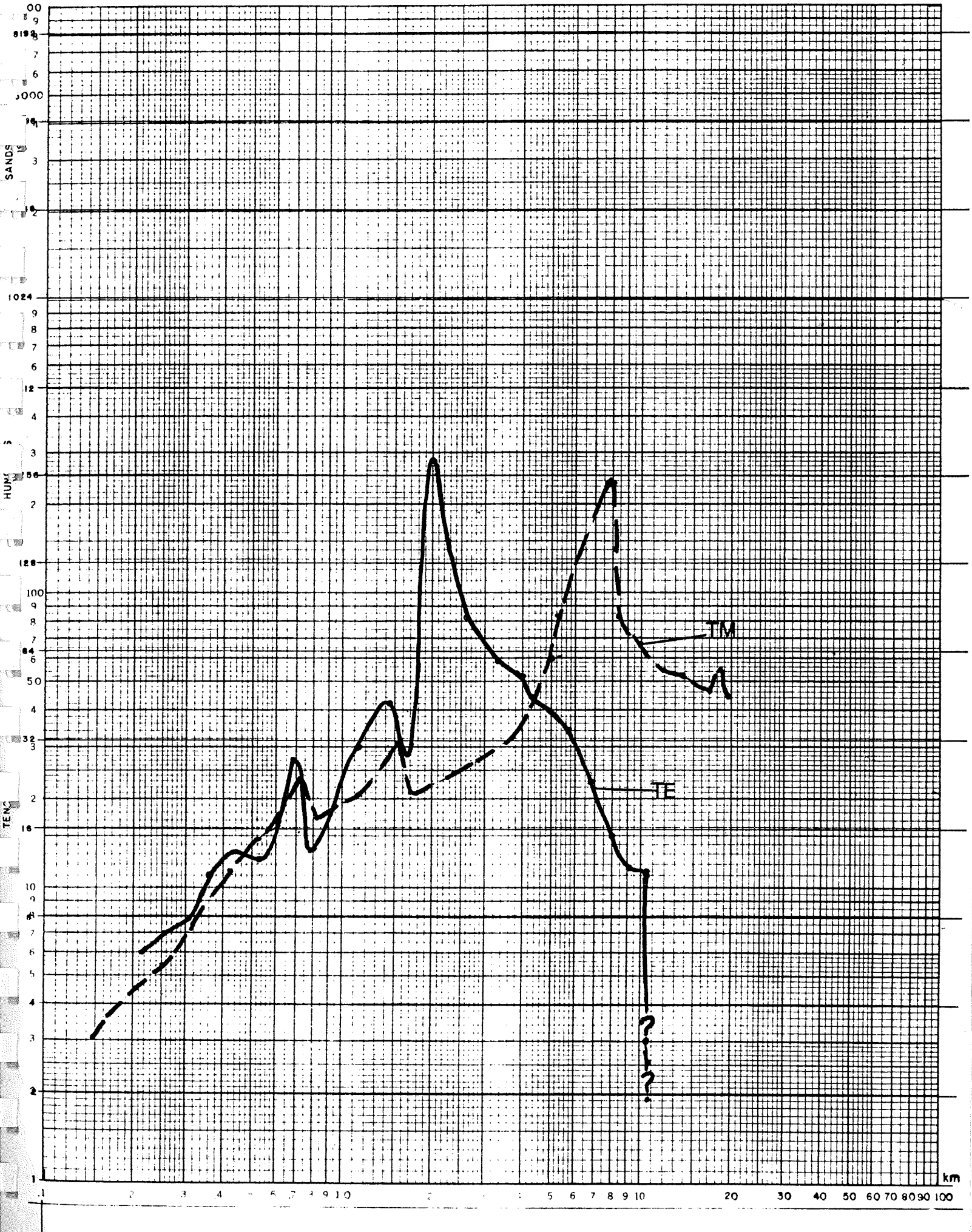
Resistivity vs Depth Proj BULLY CREEK,OR Station 5M



Resistivity vs Depth Proj. BULLY CREEK, OR Station 5A

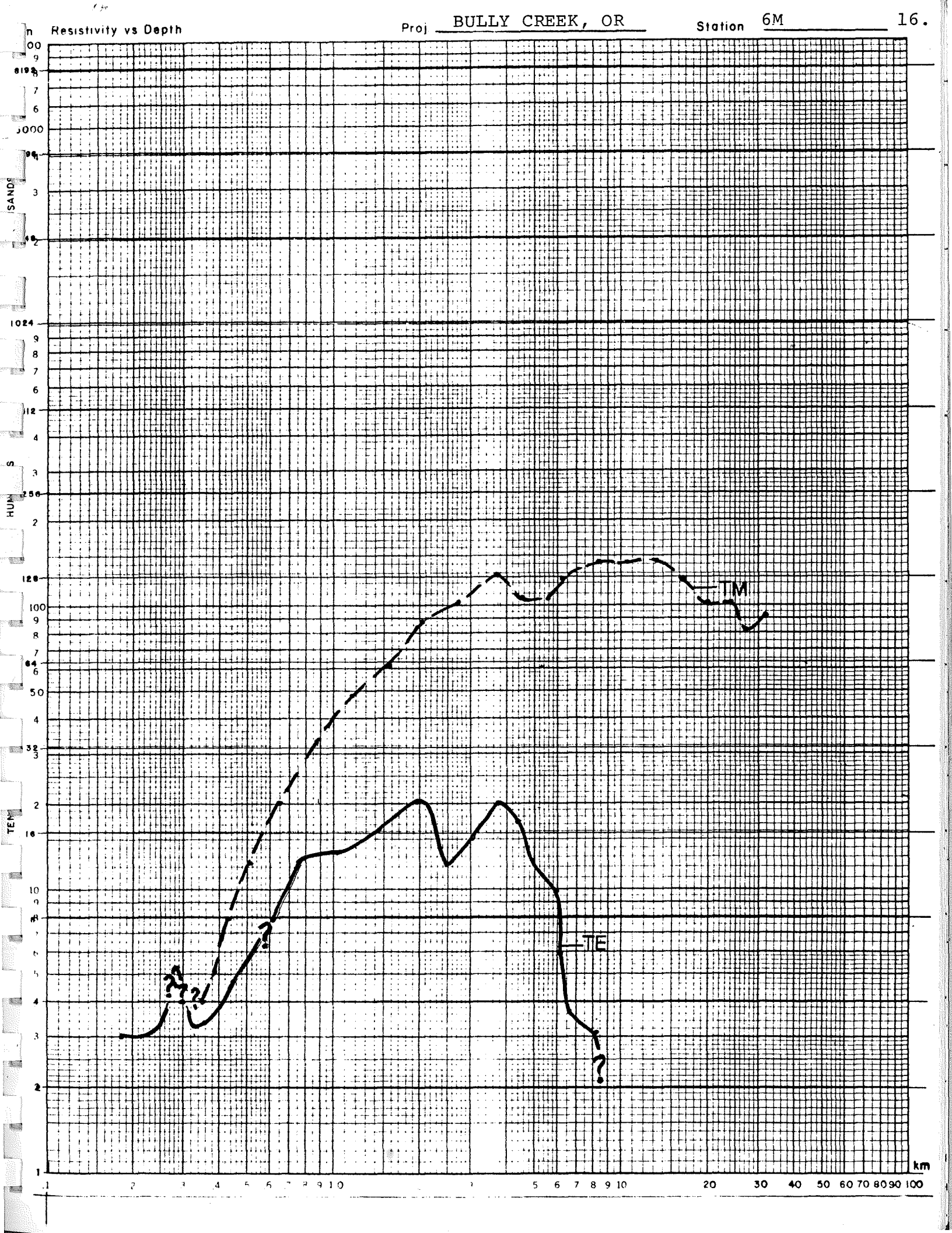


n Resistivity vs Depth Proj. BULLY CREEK, OR Station 5B



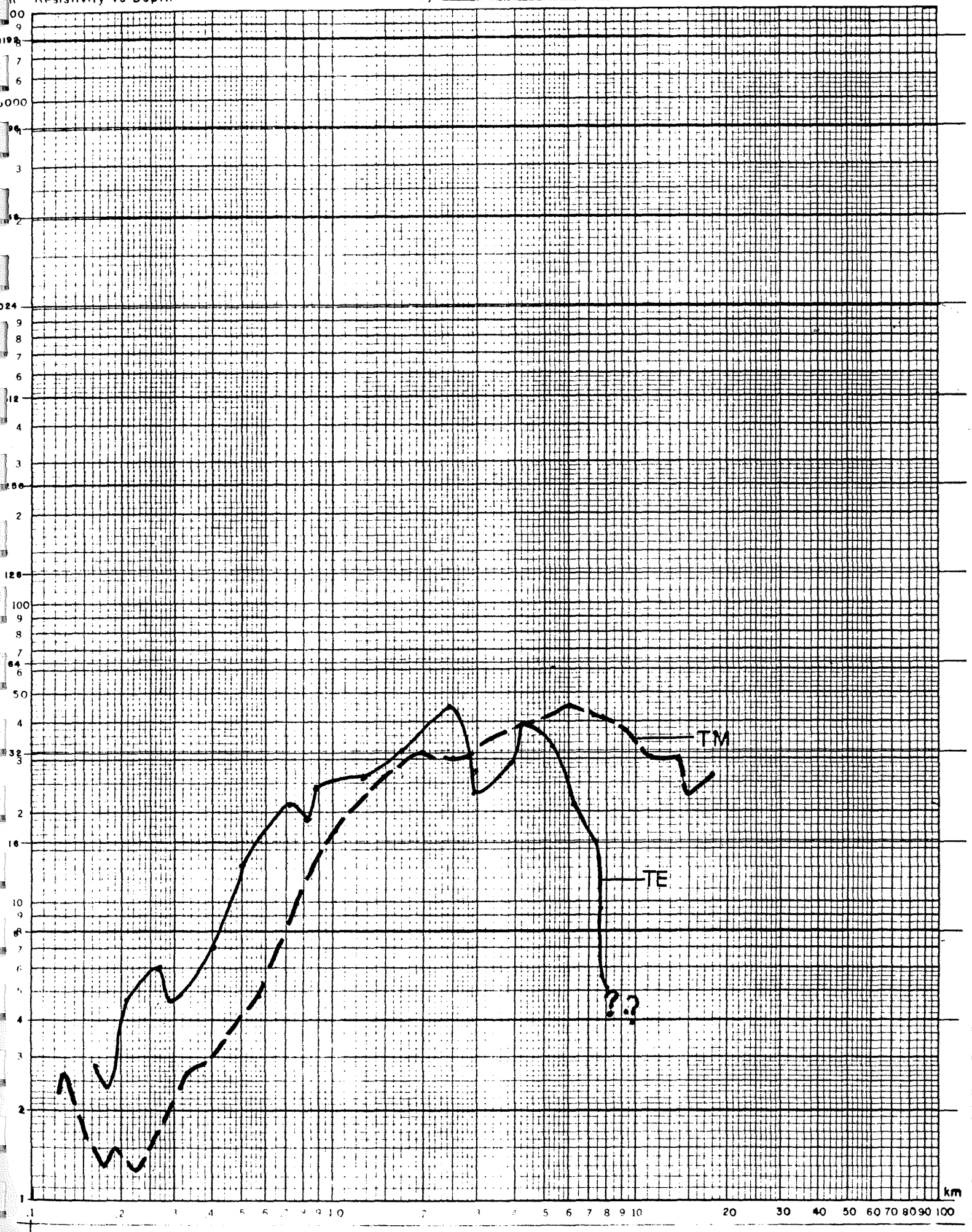
Resistivity vs Depth

Proj BULLY CREEK, OR Station 6M

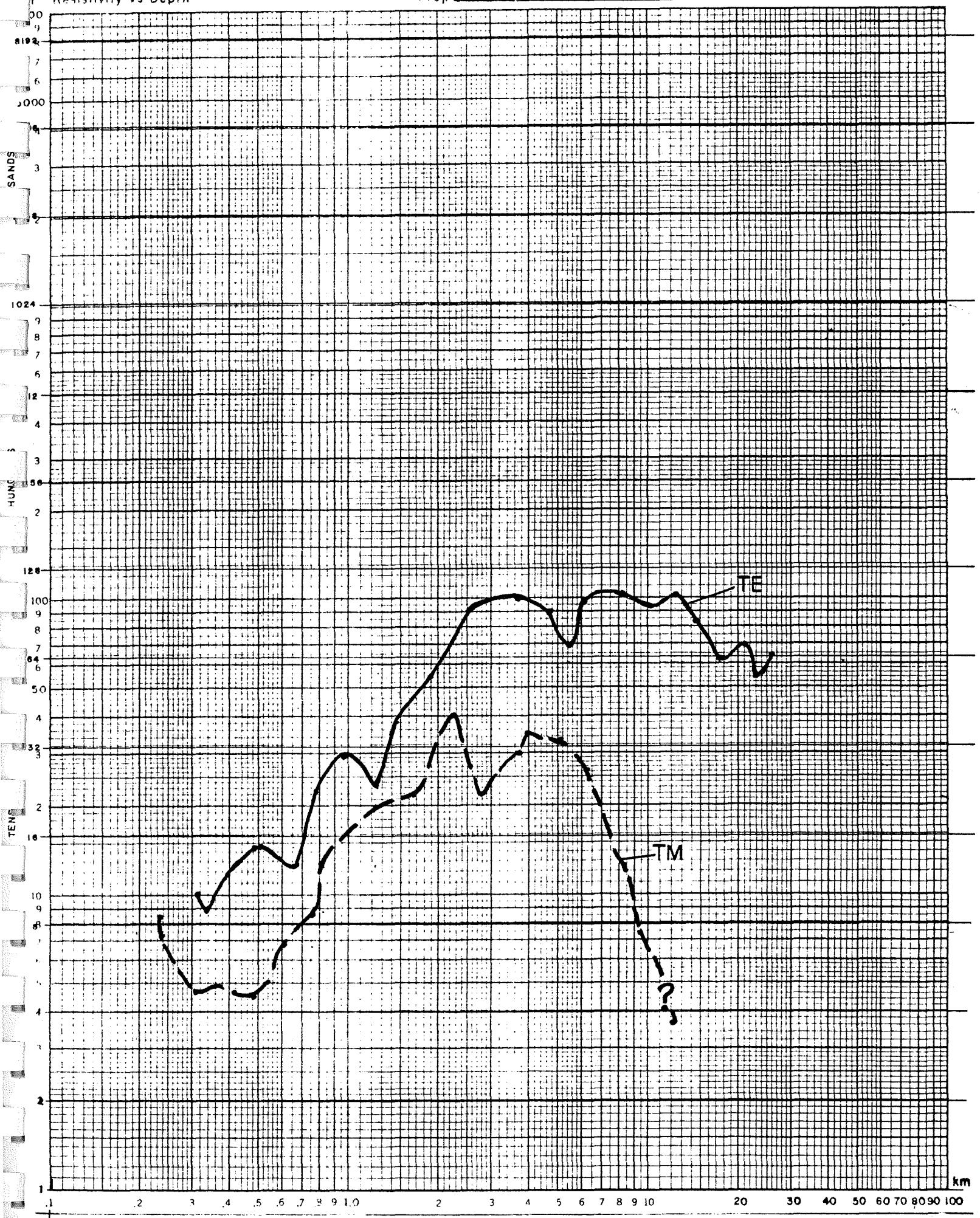


Resistivity vs Depth

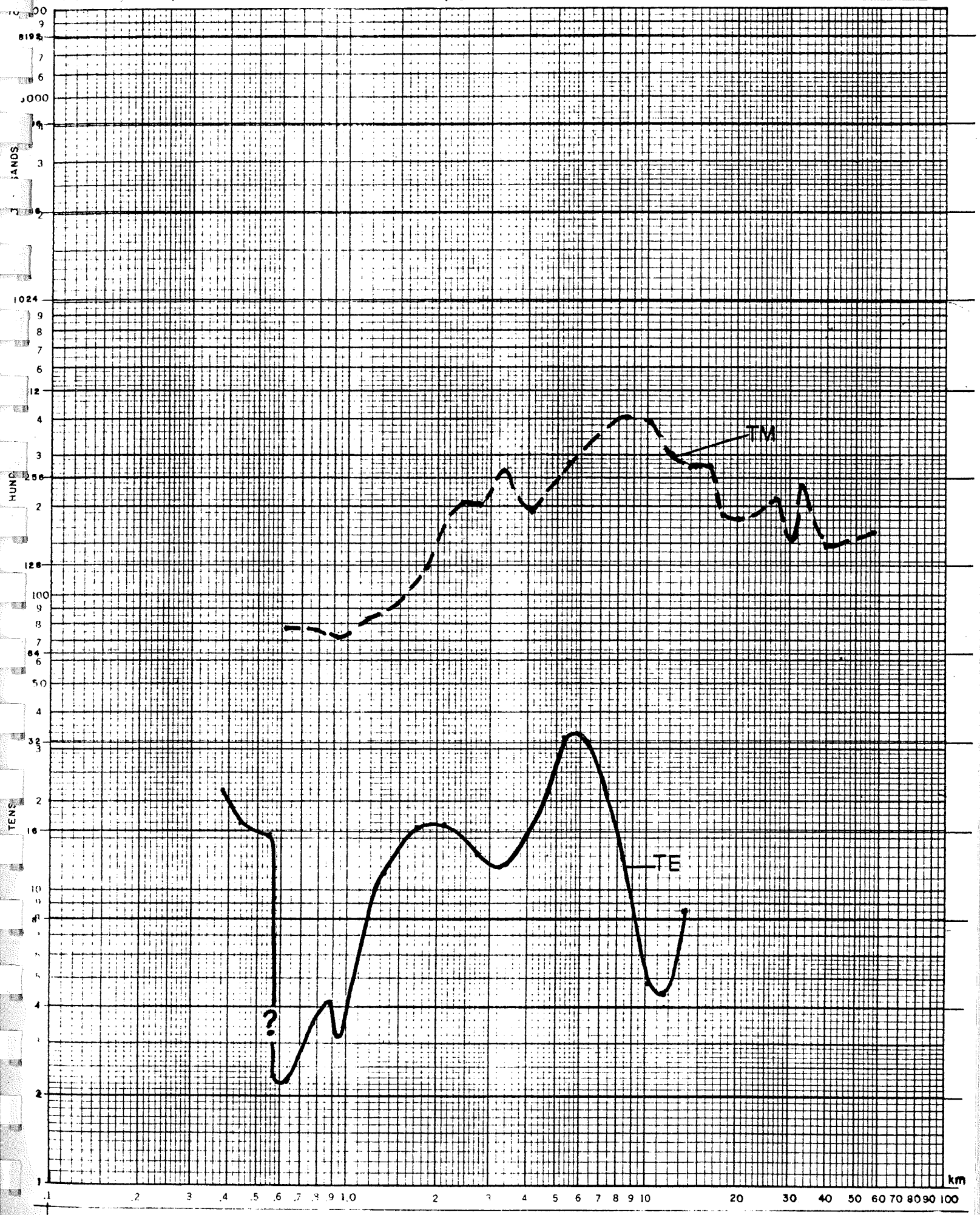
Proj BULLY CREEK, OR Station 6A



Resistivity vs Depth Proj. BULLY CREEK, OR Station 6B

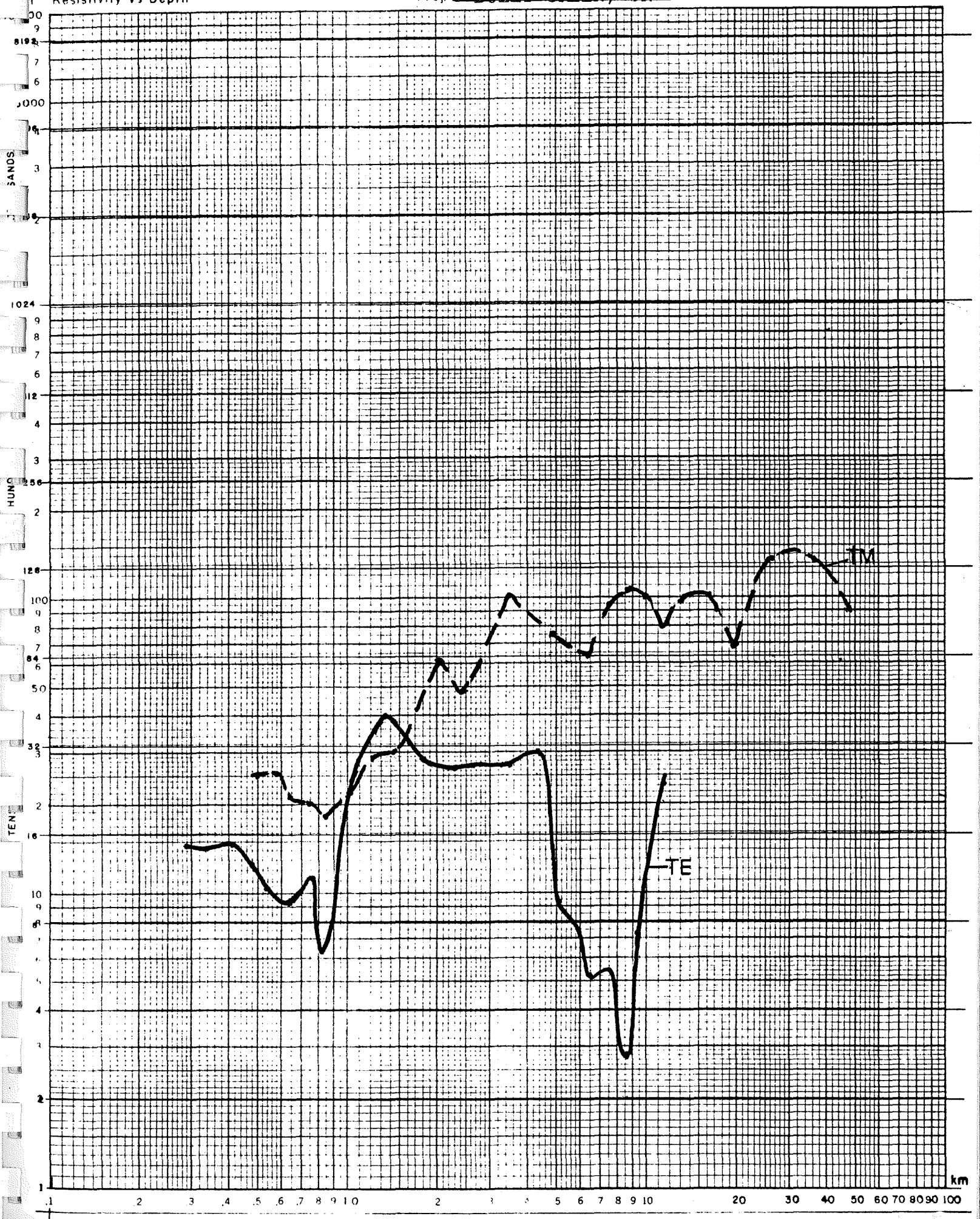


Resistivity vs Depth Proj. BULLY CREEK,OR Station 7M

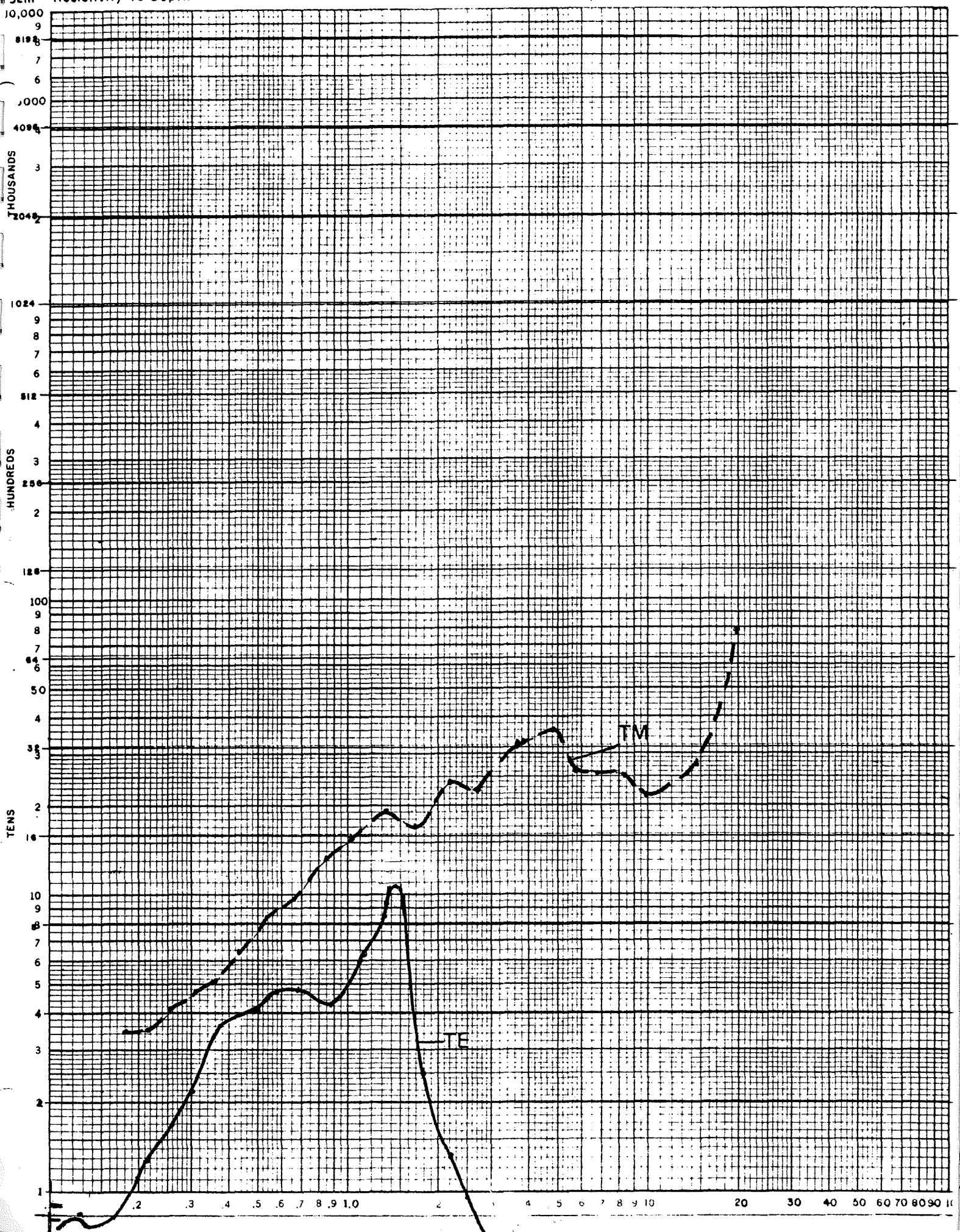


Resistivity vs Depth Proj. BULLY CREEK, OR Station 7A 20.

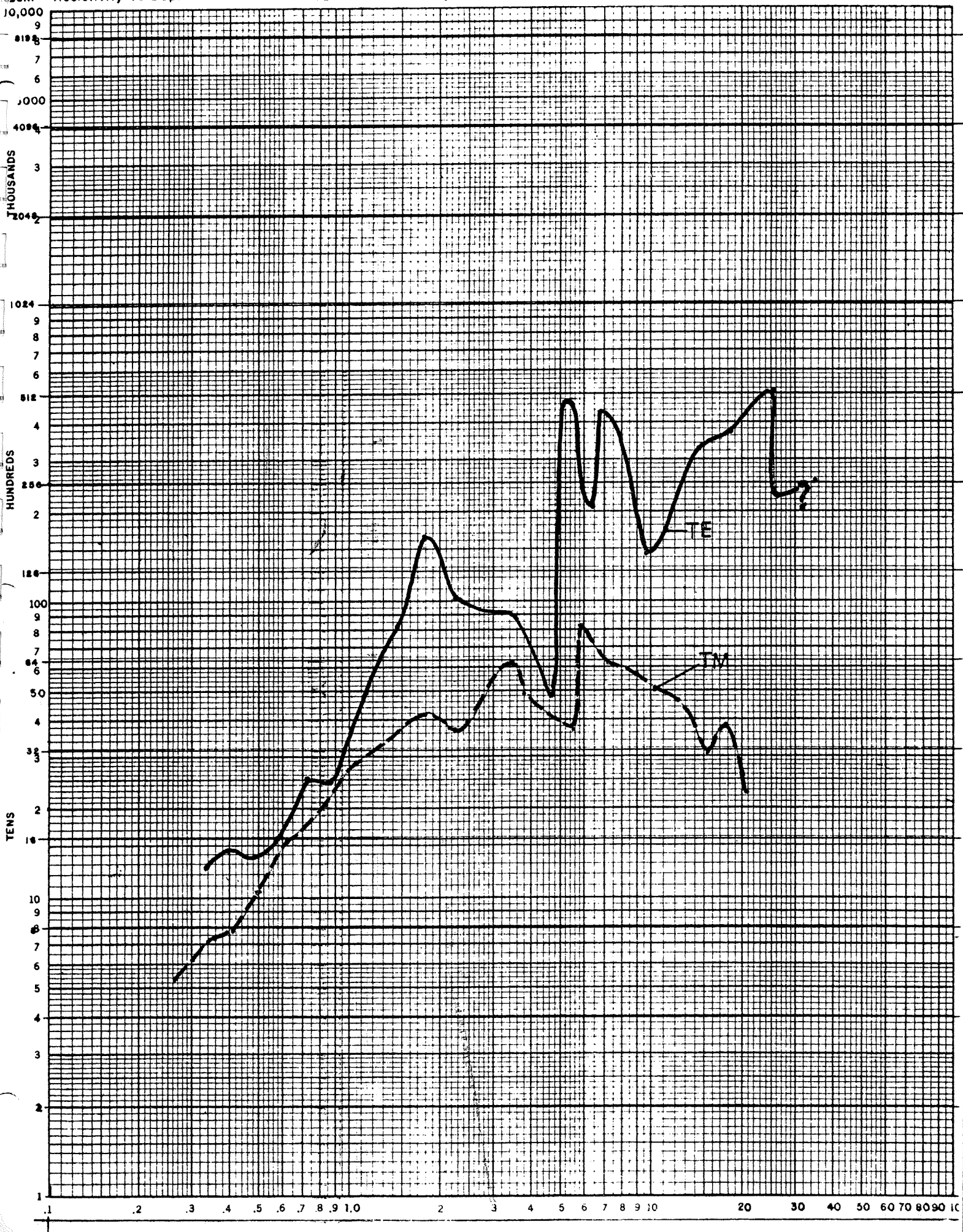
Resistivity vs Depth Proj. BULLY CREEK, OR Station 7B



Ωm Resistivity vs Depth — Pro BULLY CREEK, OR — Station 8M 22



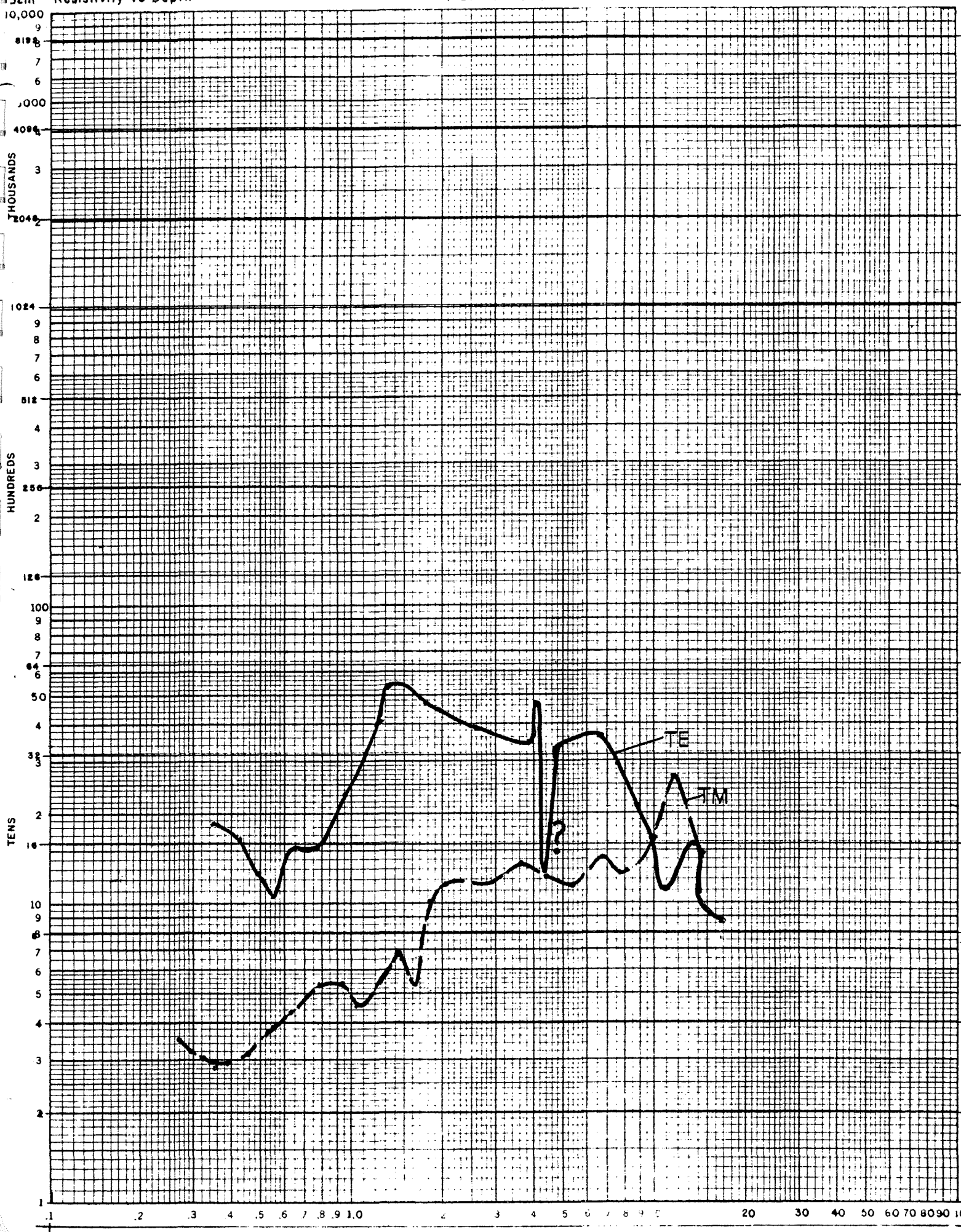
Ωm Resistivity vs Depth Proj. BULLY CREEK, OR Station 8A



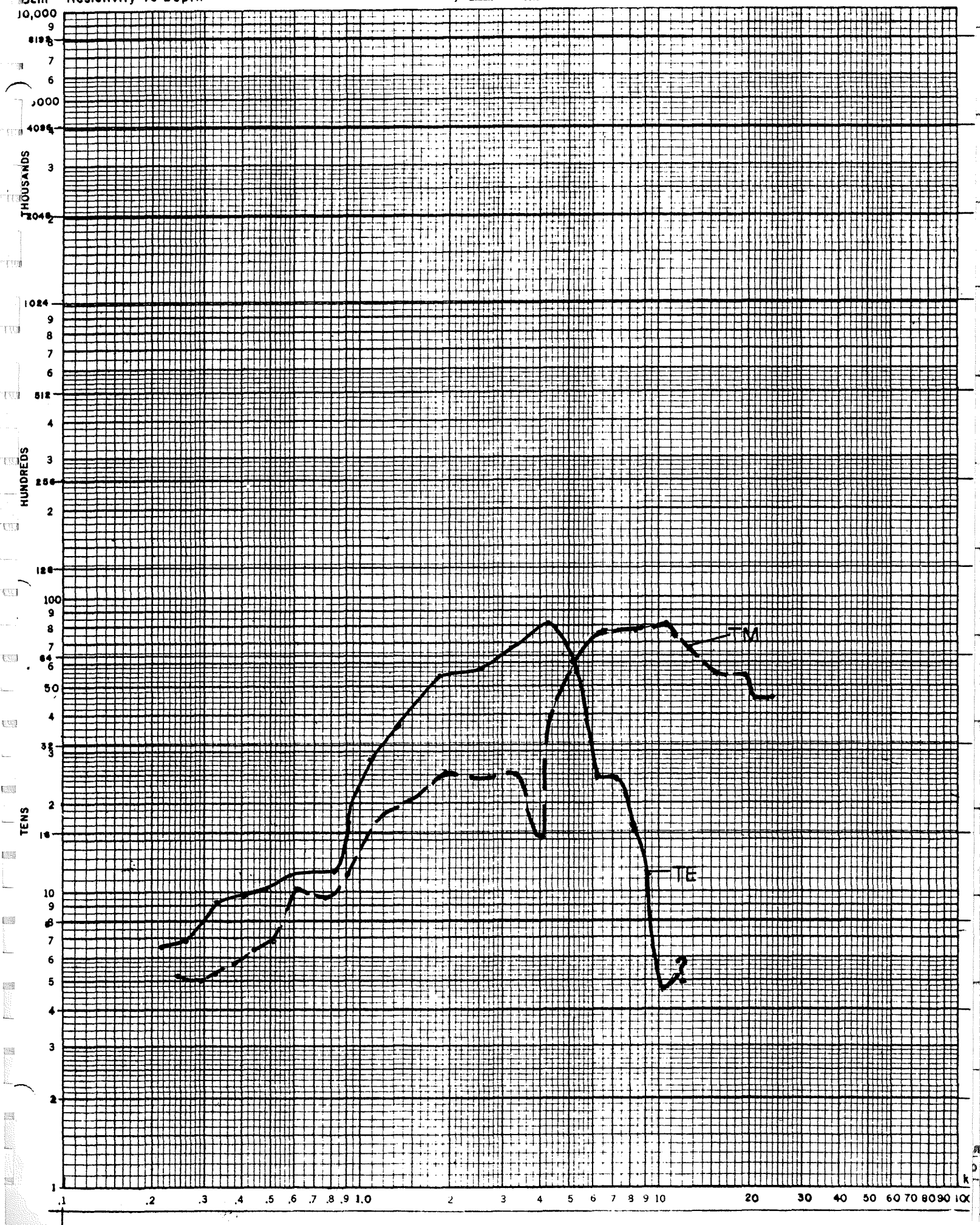
BULLY CREEK, OR

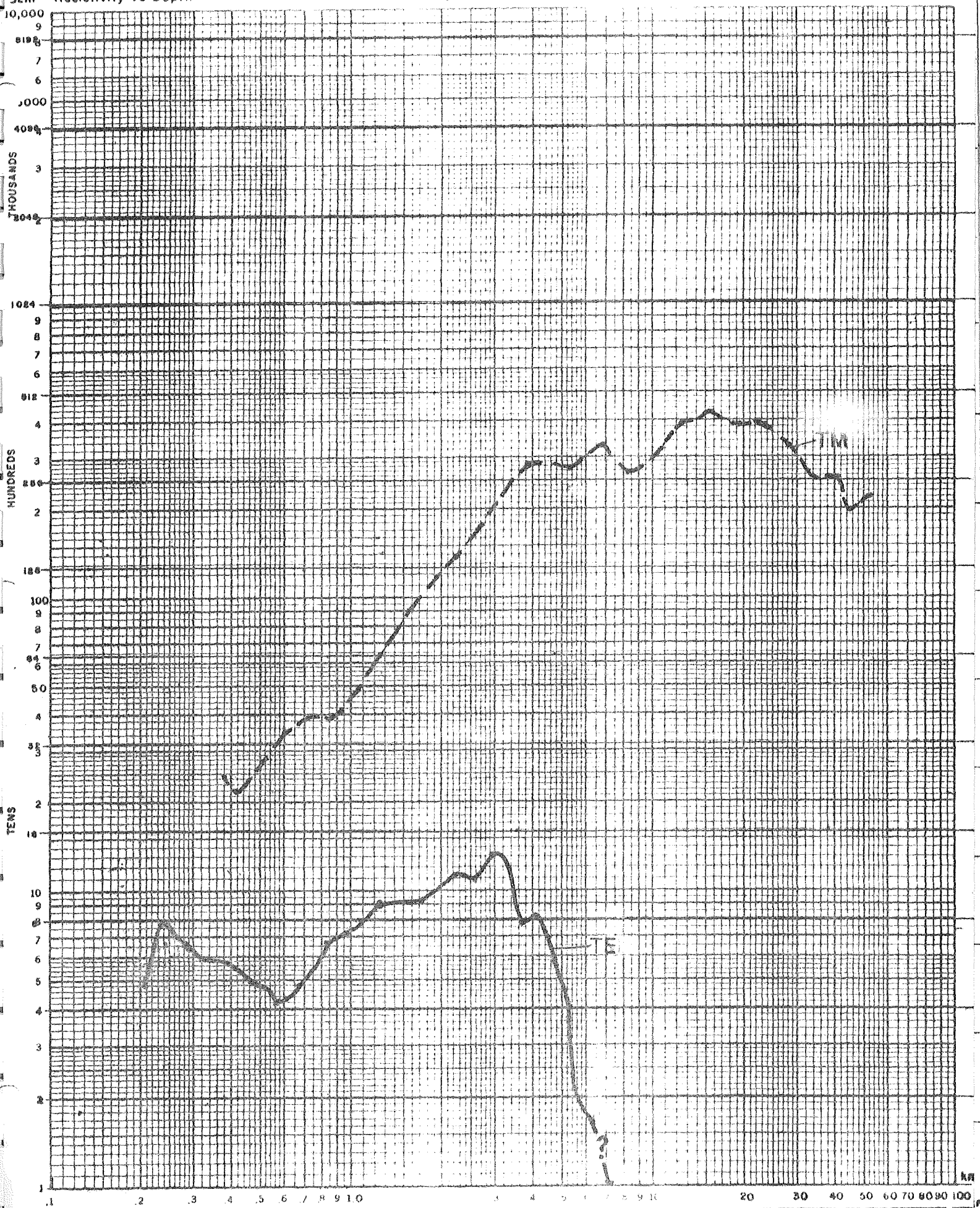
Prof. _____ Station 8B

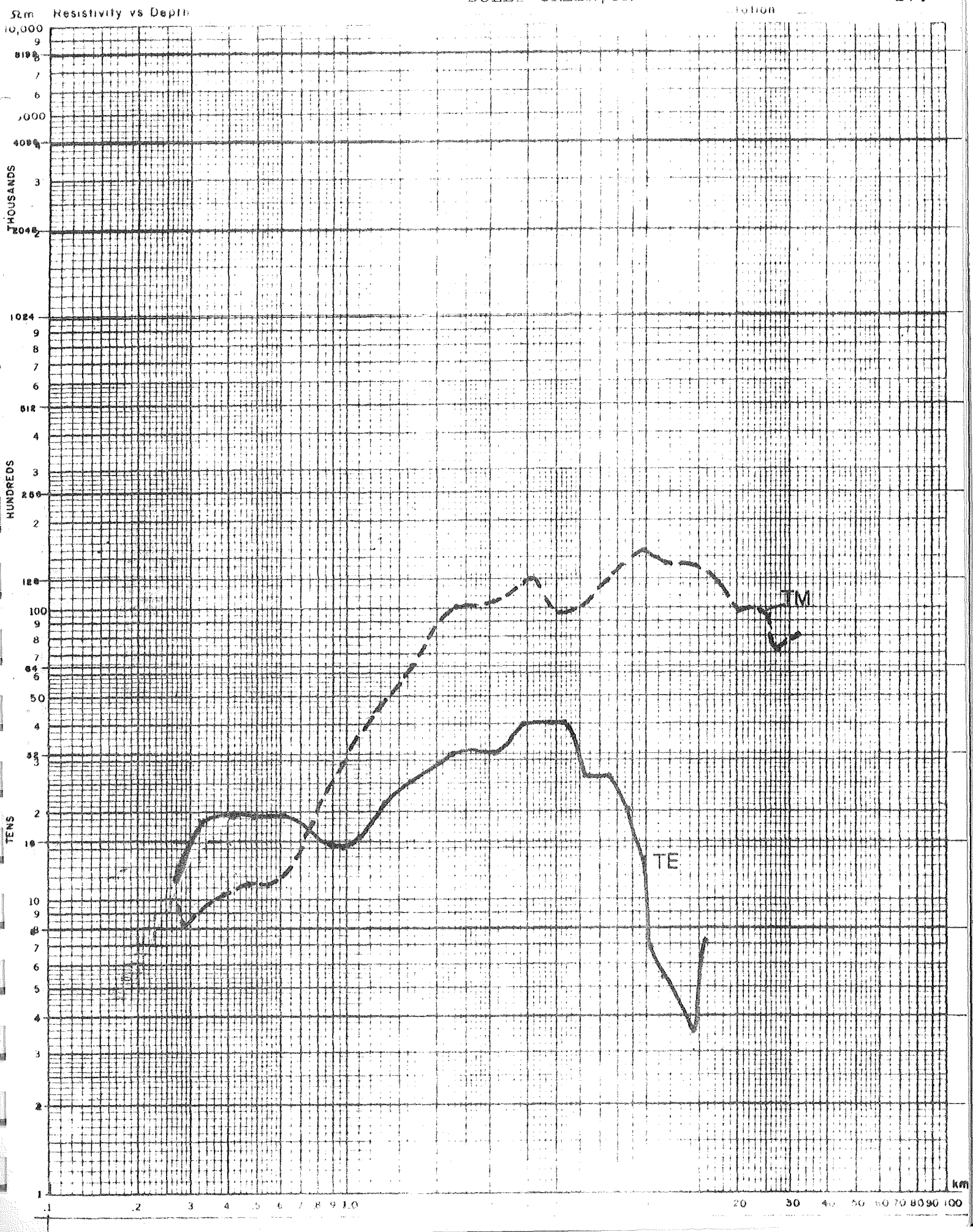
Ωm Resistivity vs Depth



Ωm Resistivity vs Depth Proj. BULLY CREEK, OR Station 9M



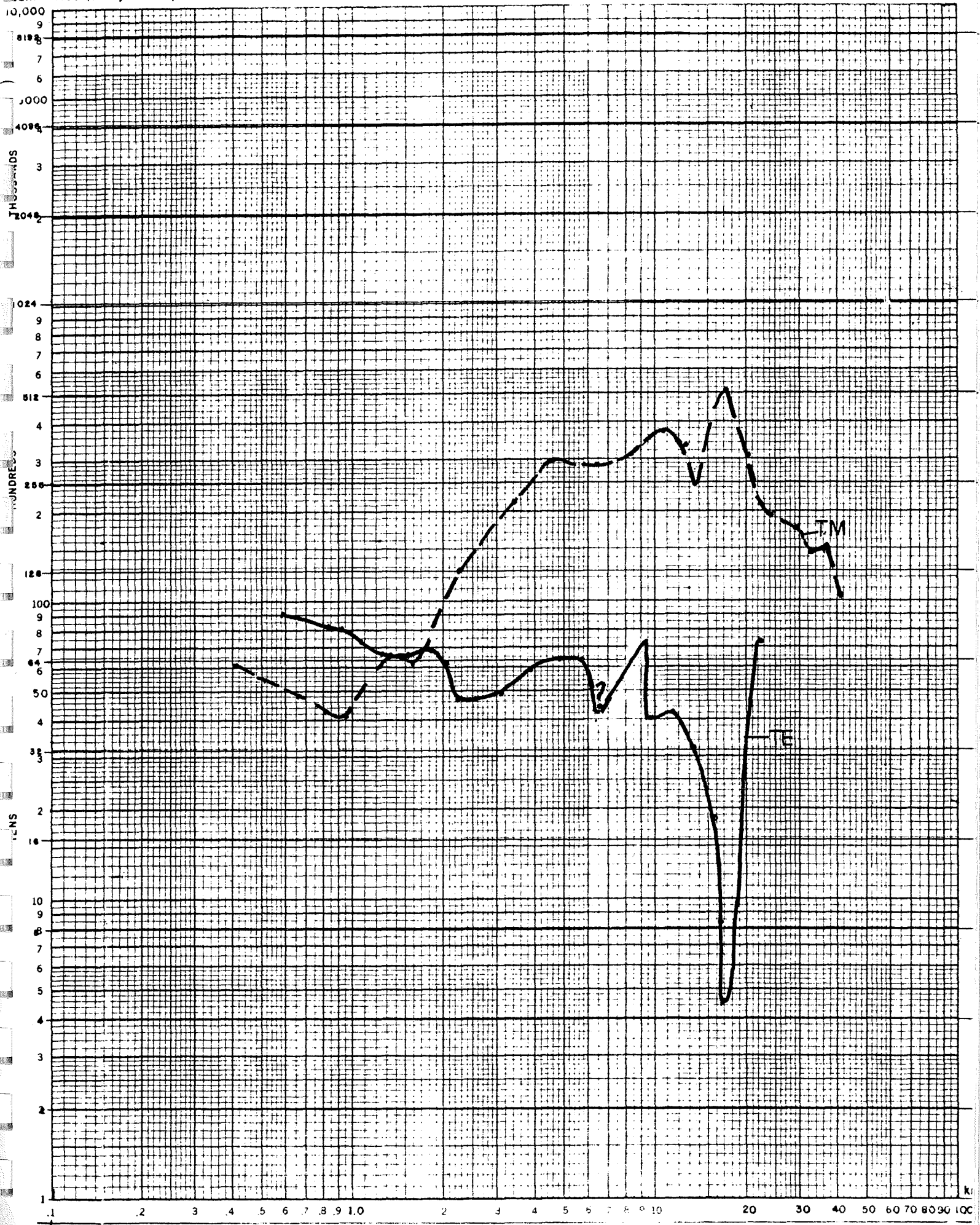

THOUSANDS
HUNDREDS
TENS
TM
TE
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
20
30
40
50
60
70
80
90
100


Ωm Resistivity vs Depth
THOUSANDS
HUNDREDS
TENS
TM
TE
km

BULLY CREEK, OR 10M

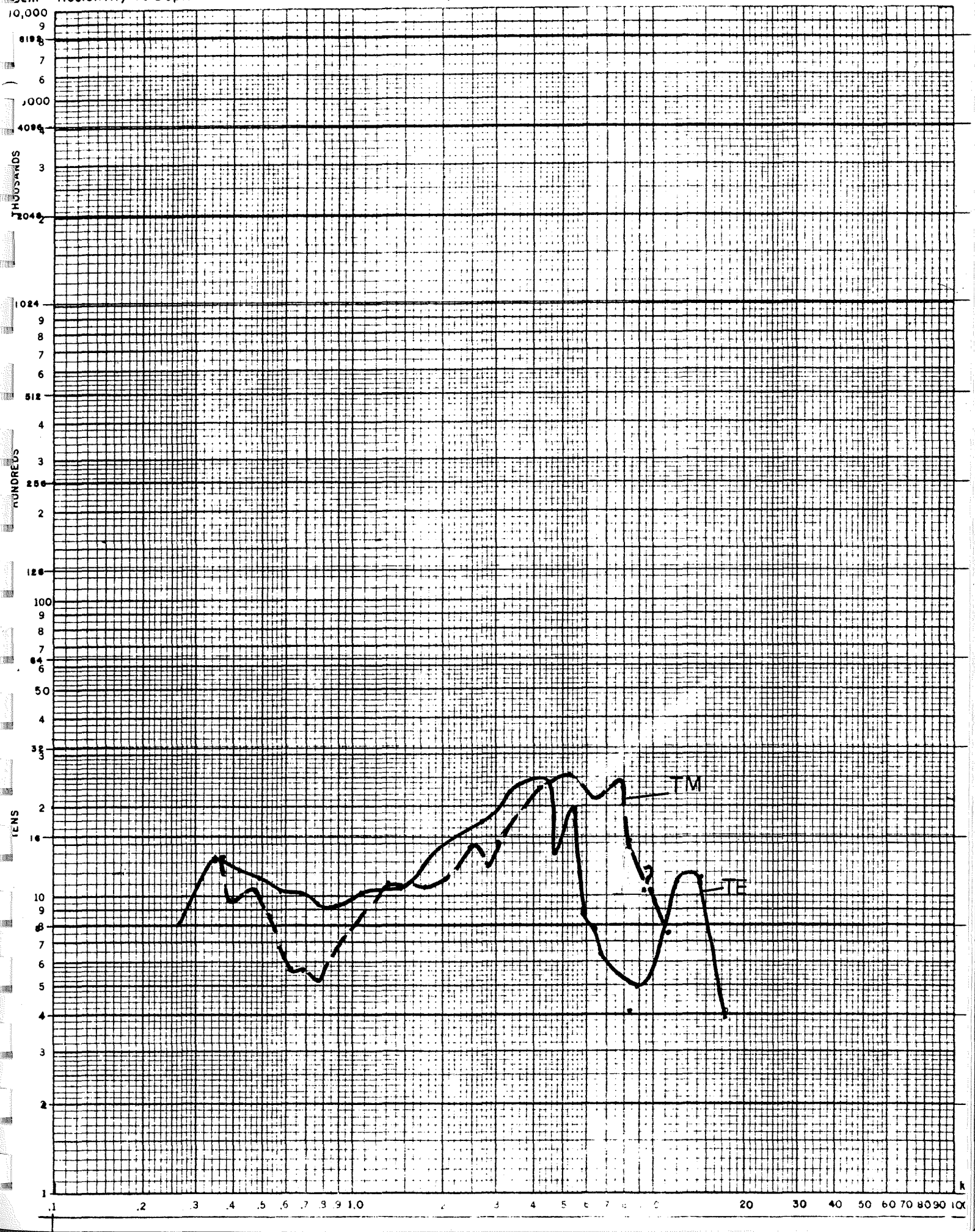
Station

Ωm Resistivity vs Depth



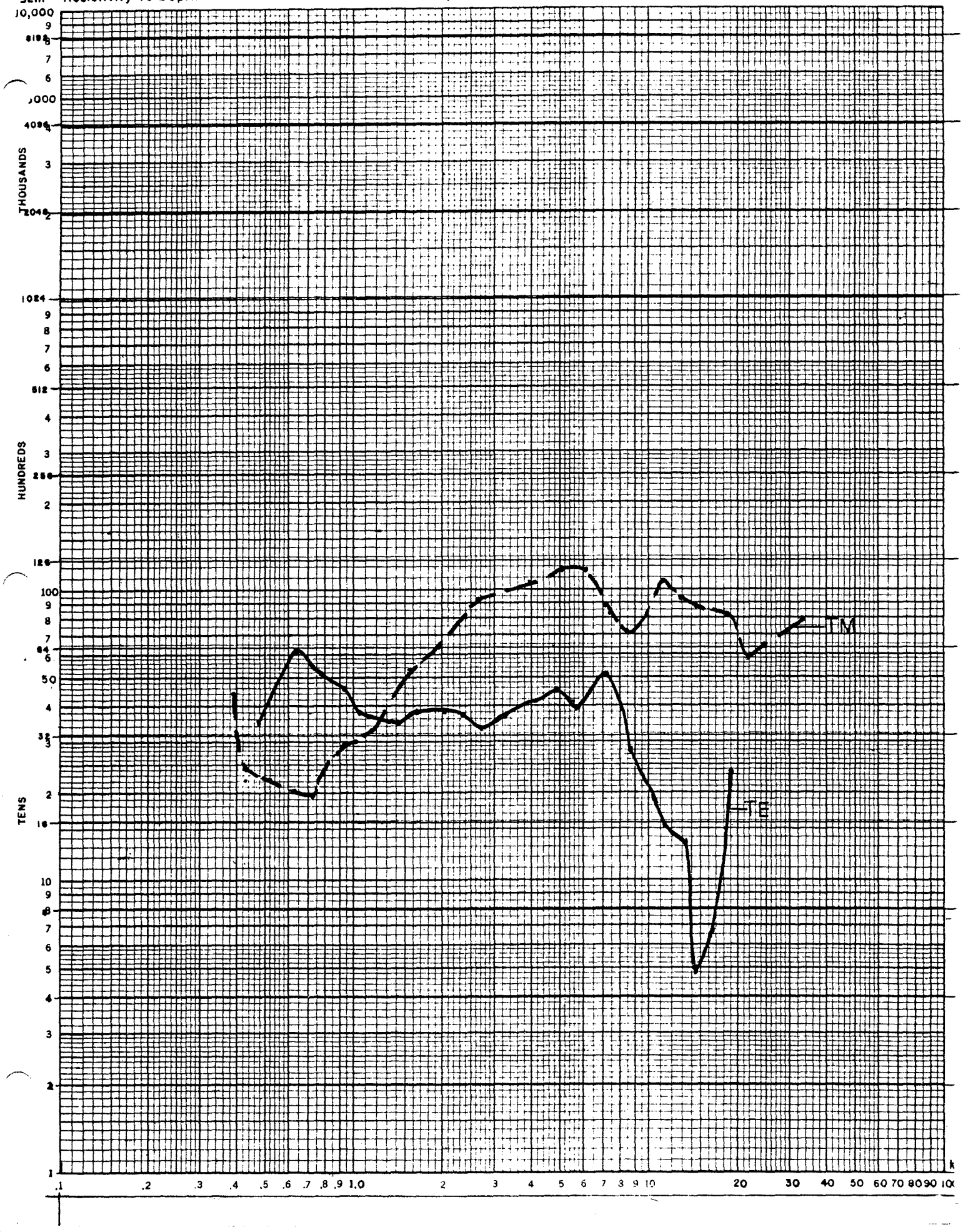
Ωm Resistivity vs Depth

Proj BULLY CREEK, OR Station 10A 29.

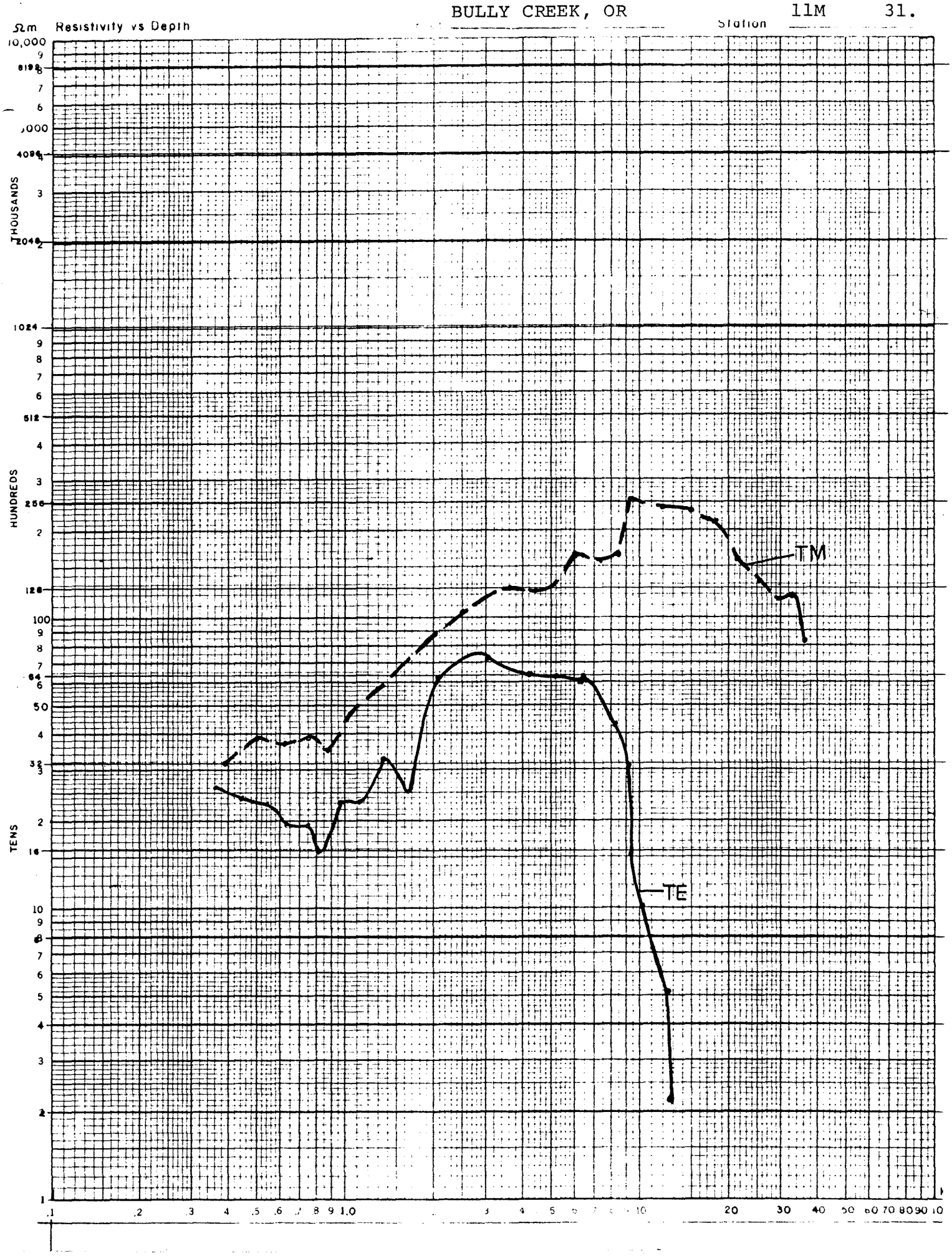


Ωm Resistivity vs Depth

Proj. BULLY CREEK, OR Station 10B 30.

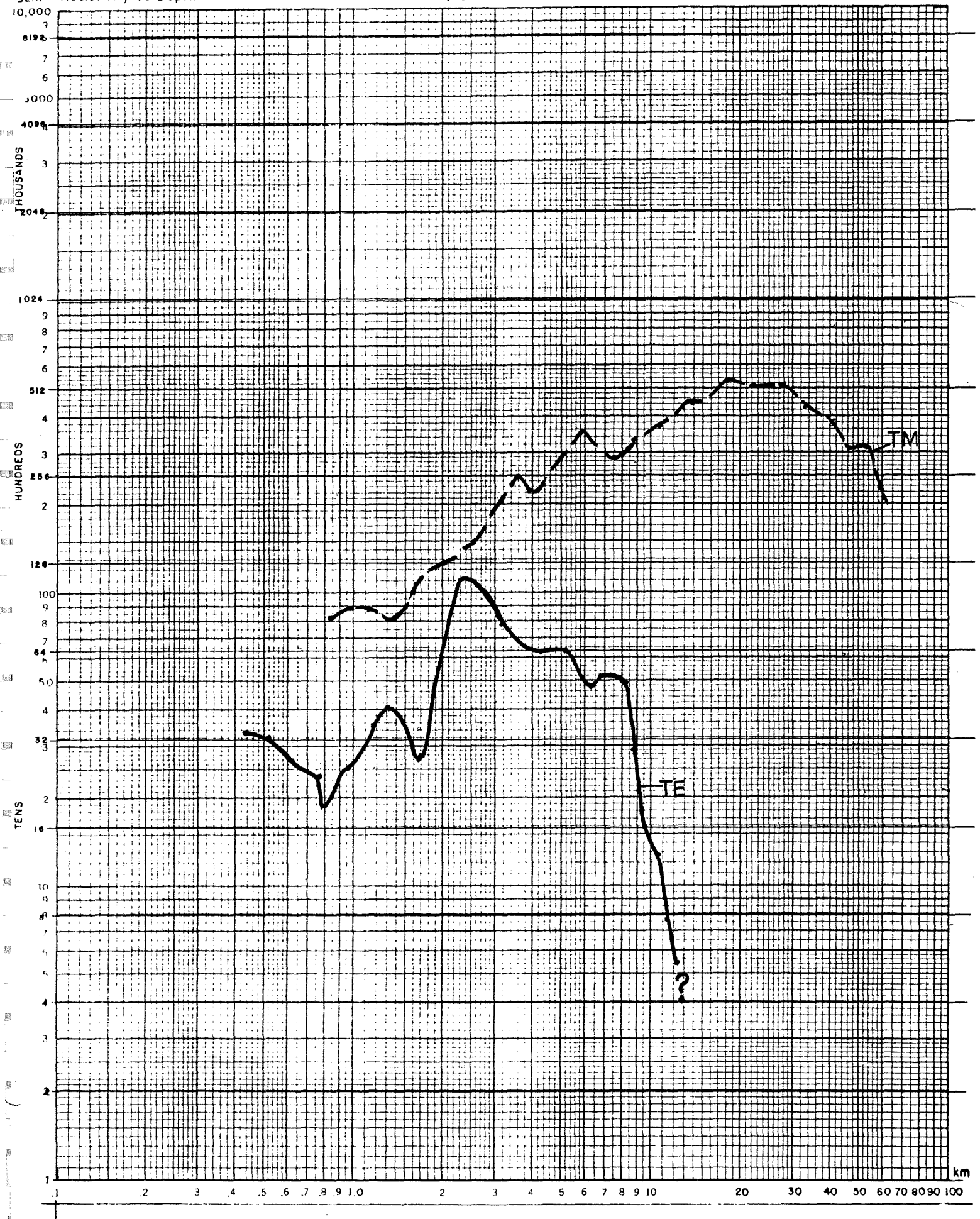


BULLY CREEK, OR Station 11M 31.

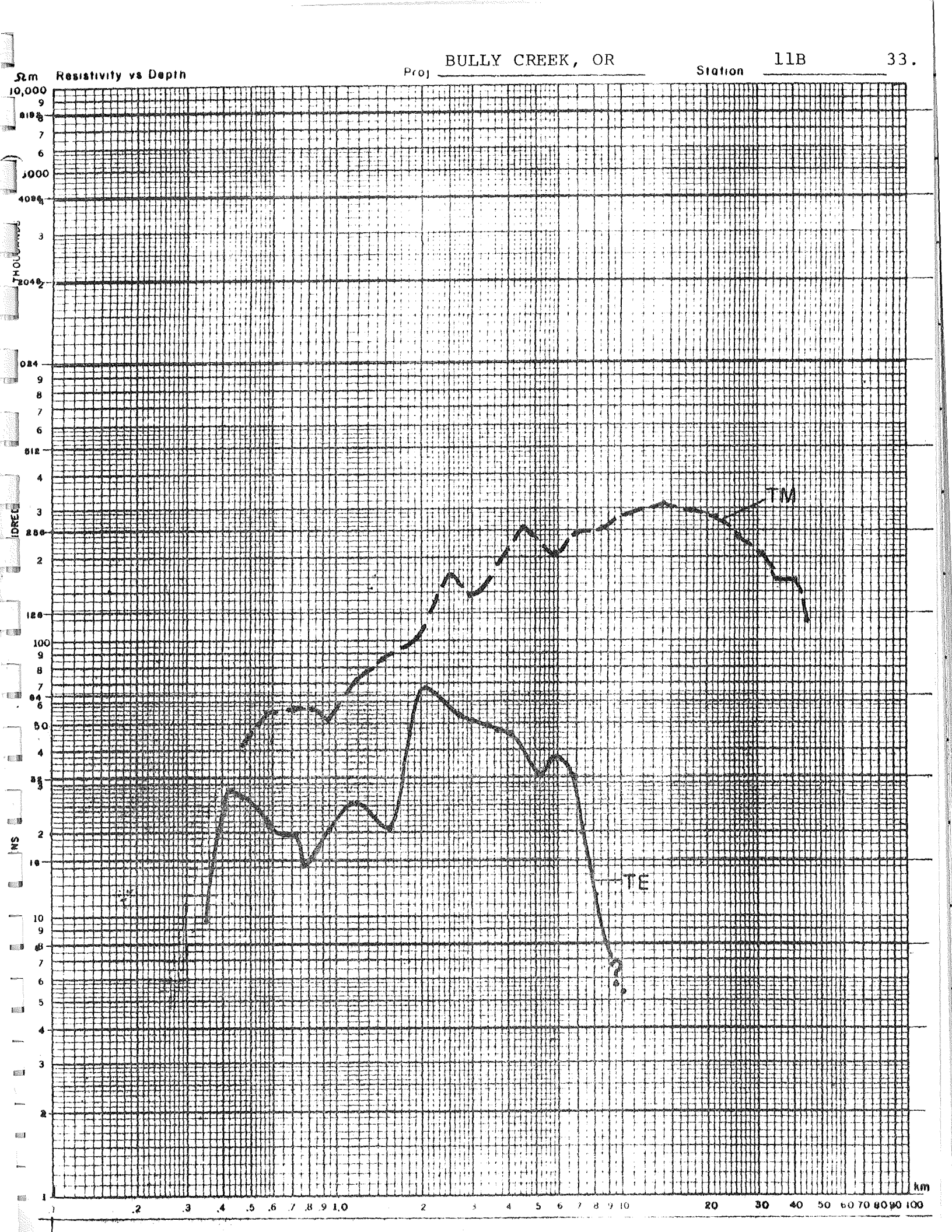


Ωm Resistivity vs Depth

Proj. BULLY CREEK, OR Station 11A

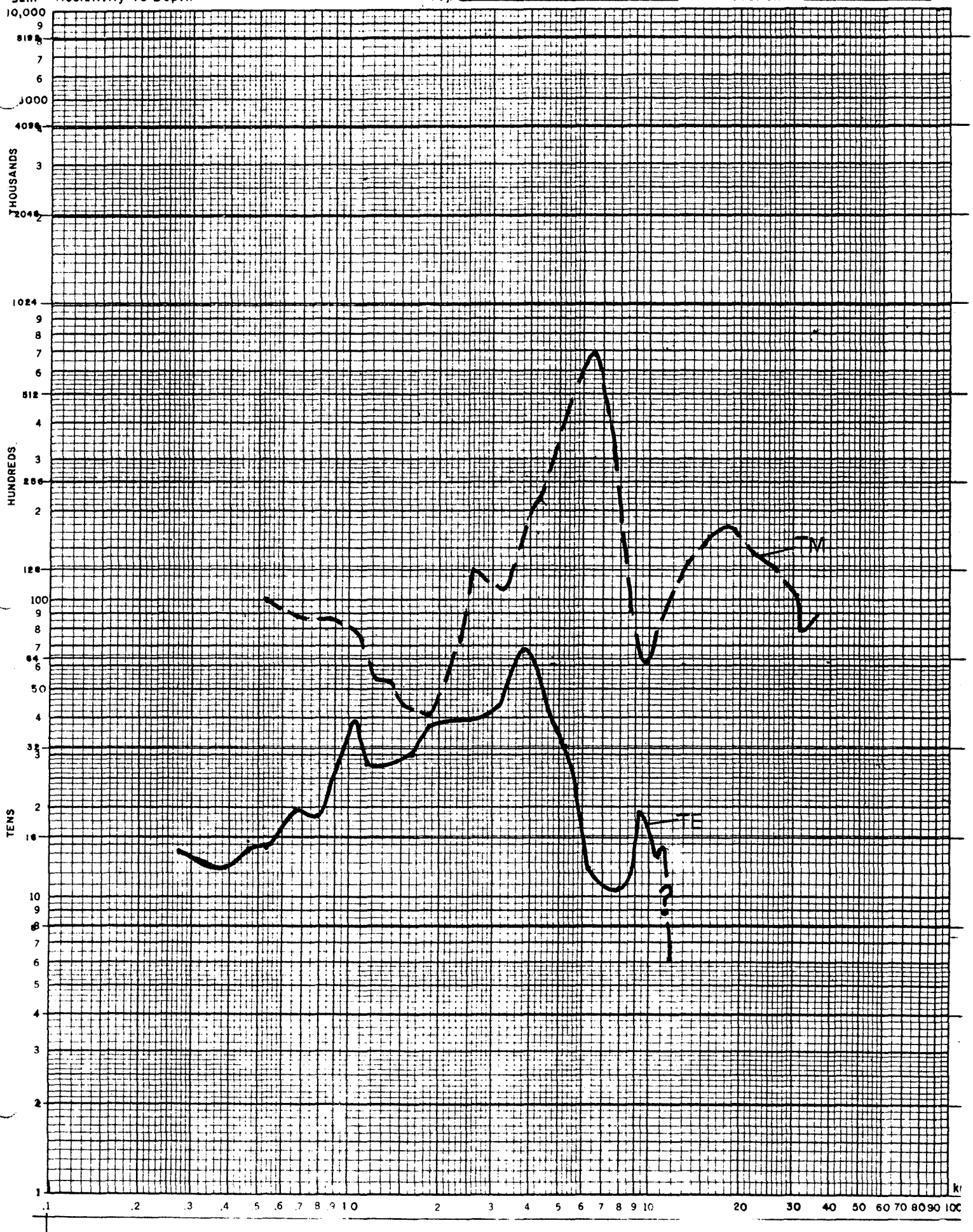


Ωm Resistivity vs Depth Proj BULLY CREEK, OR Station 11B

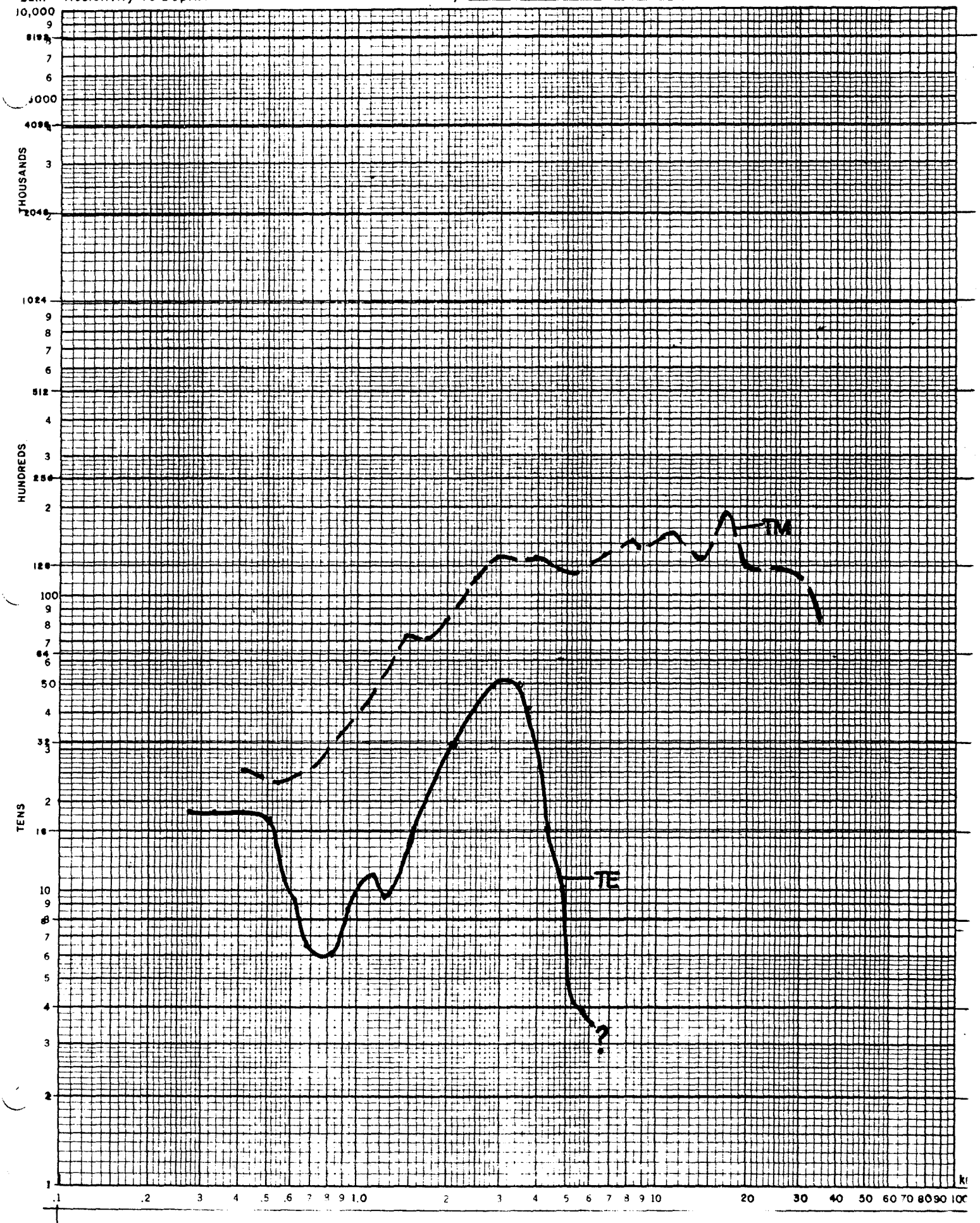


Ωm Resistivity vs Depth

Proj. BULLY CREEK, OR Station 12M



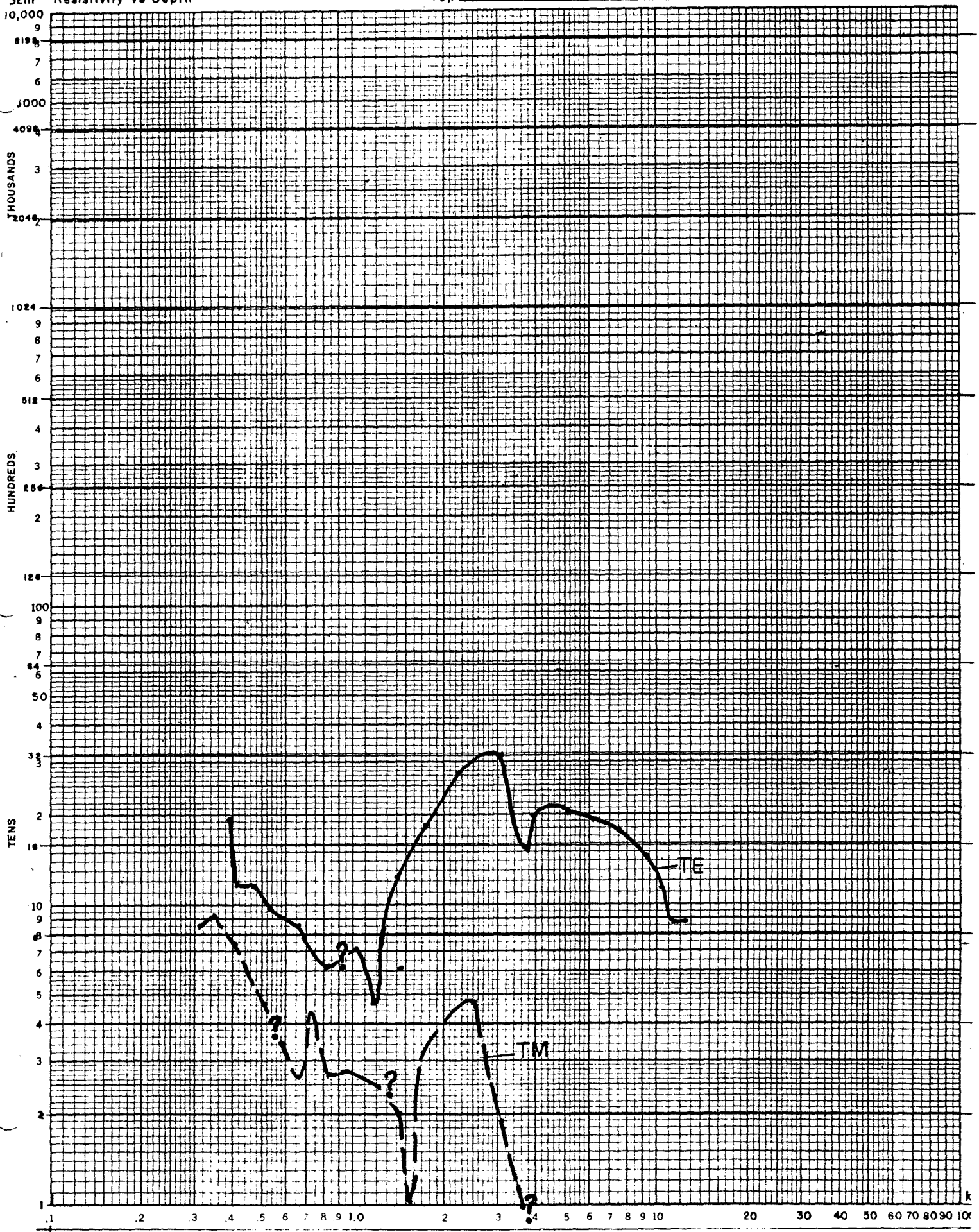
Ωm Resistivity vs Depth Proj. BULLY CREEK, OR Station 12B 35.



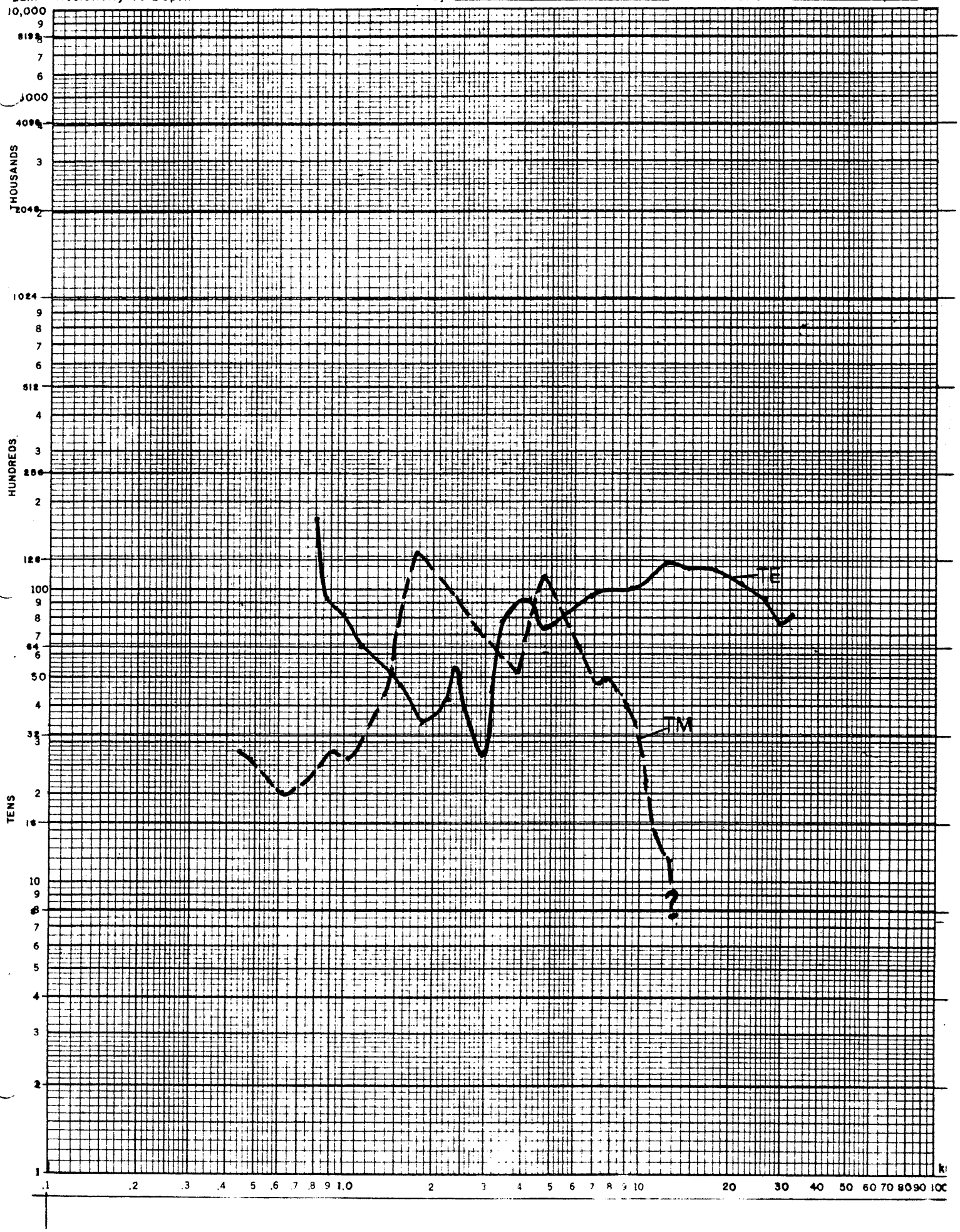
Ωm Resistivity vs Depth Proj. BULLY CREEK, OR Station 13M 36.

Ωm Resistivity vs Depth

Proj. BULLY CREEK, OR Station 13A 37.

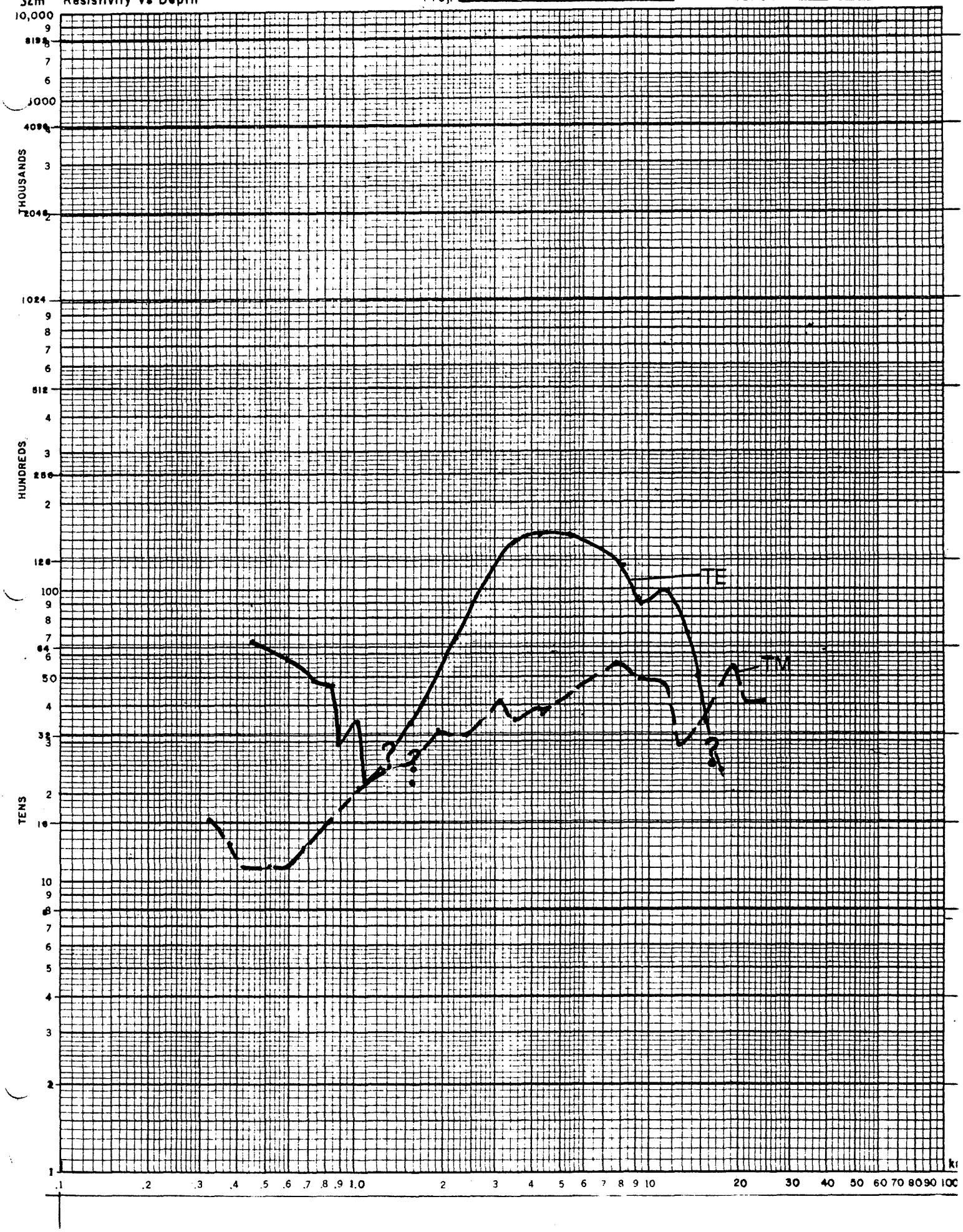


Ωm Resistivity vs Depth Proj. BULLY CREEK, OR Station 13B

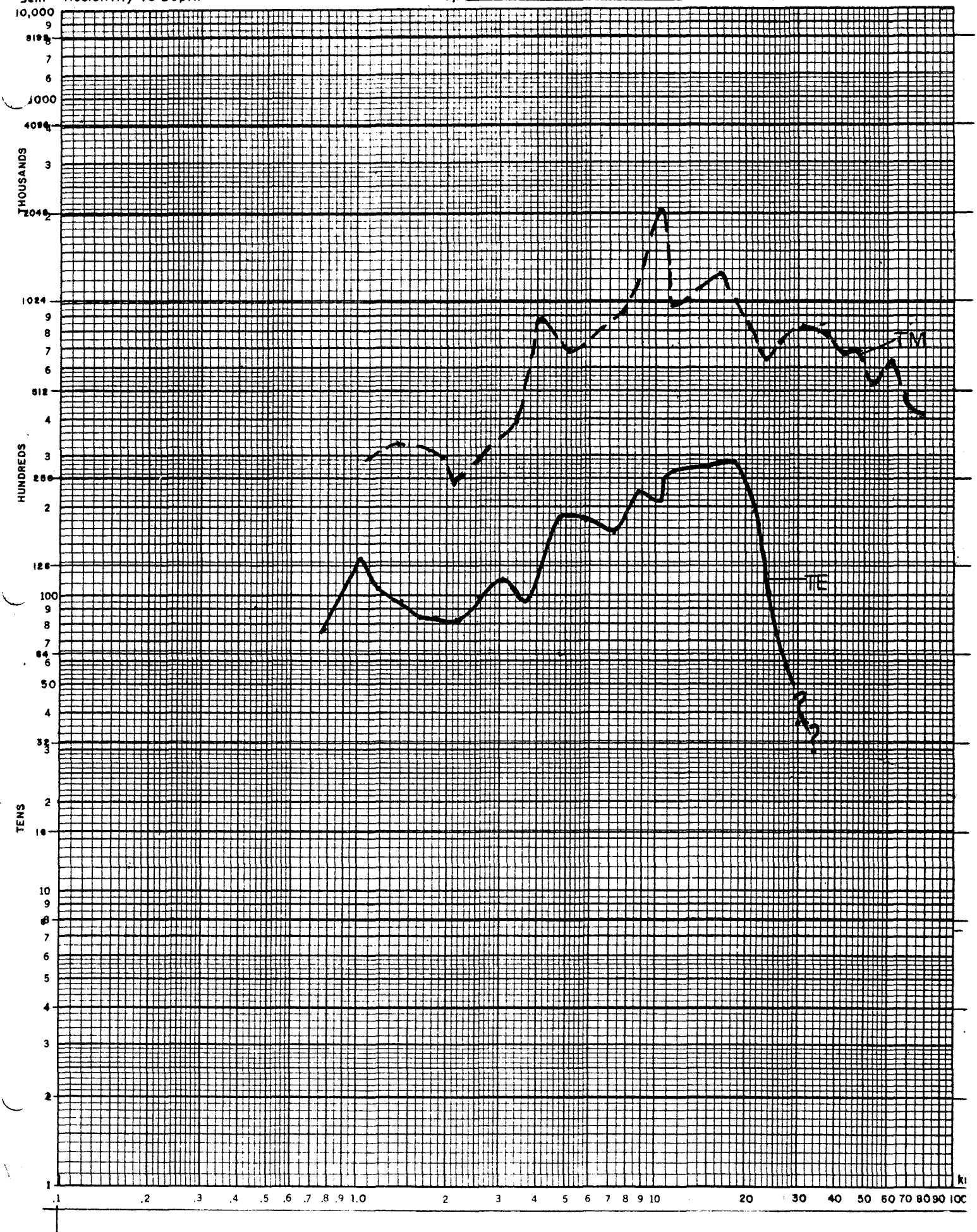


Ωm Resistivity vs Depth

Proj. BULLY CREEK, OR Station 14M

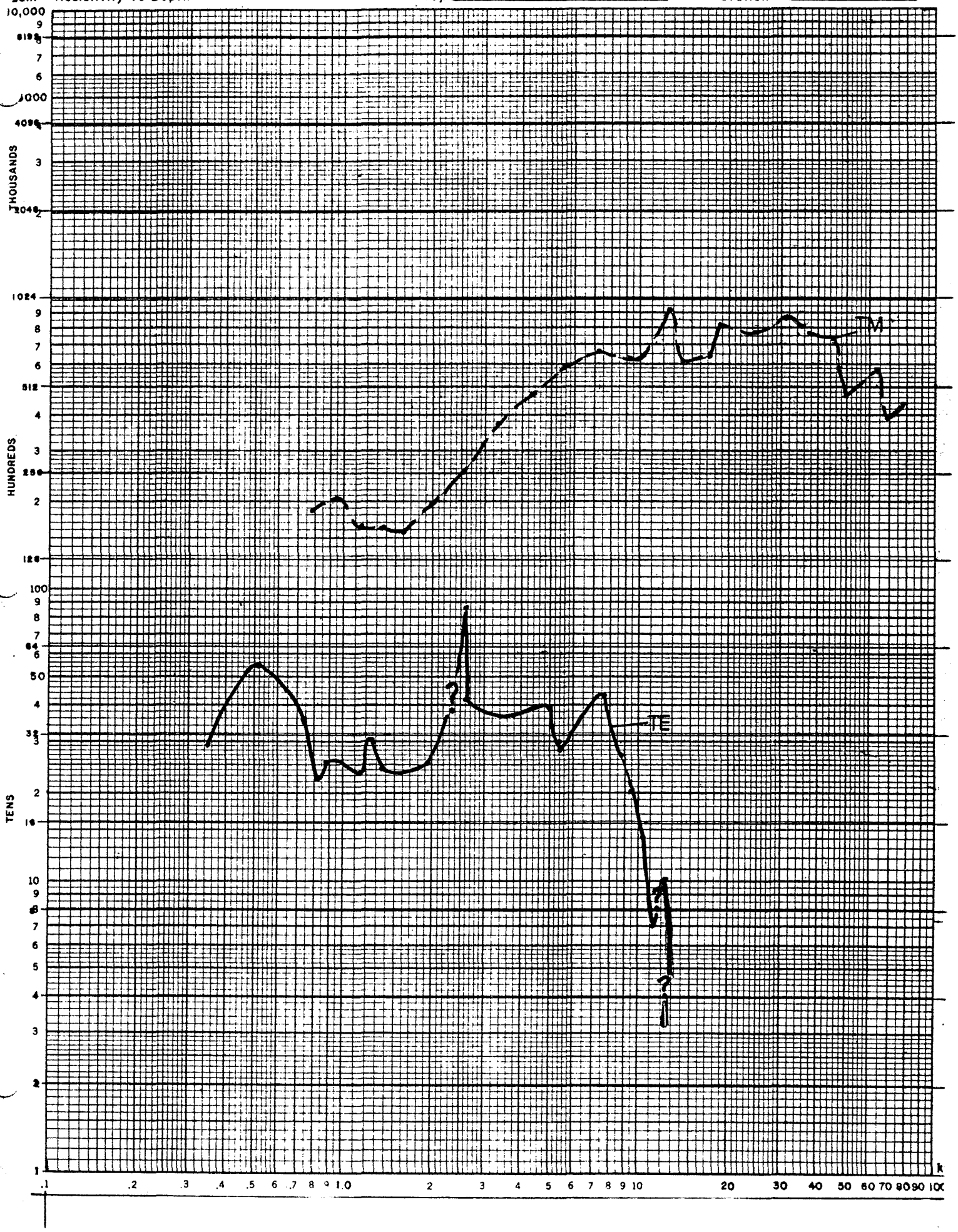


Ωm Resistivity vs Depth Proj. BULLY CREEK, OR Station 14A



Ωm Resistivity vs Depth

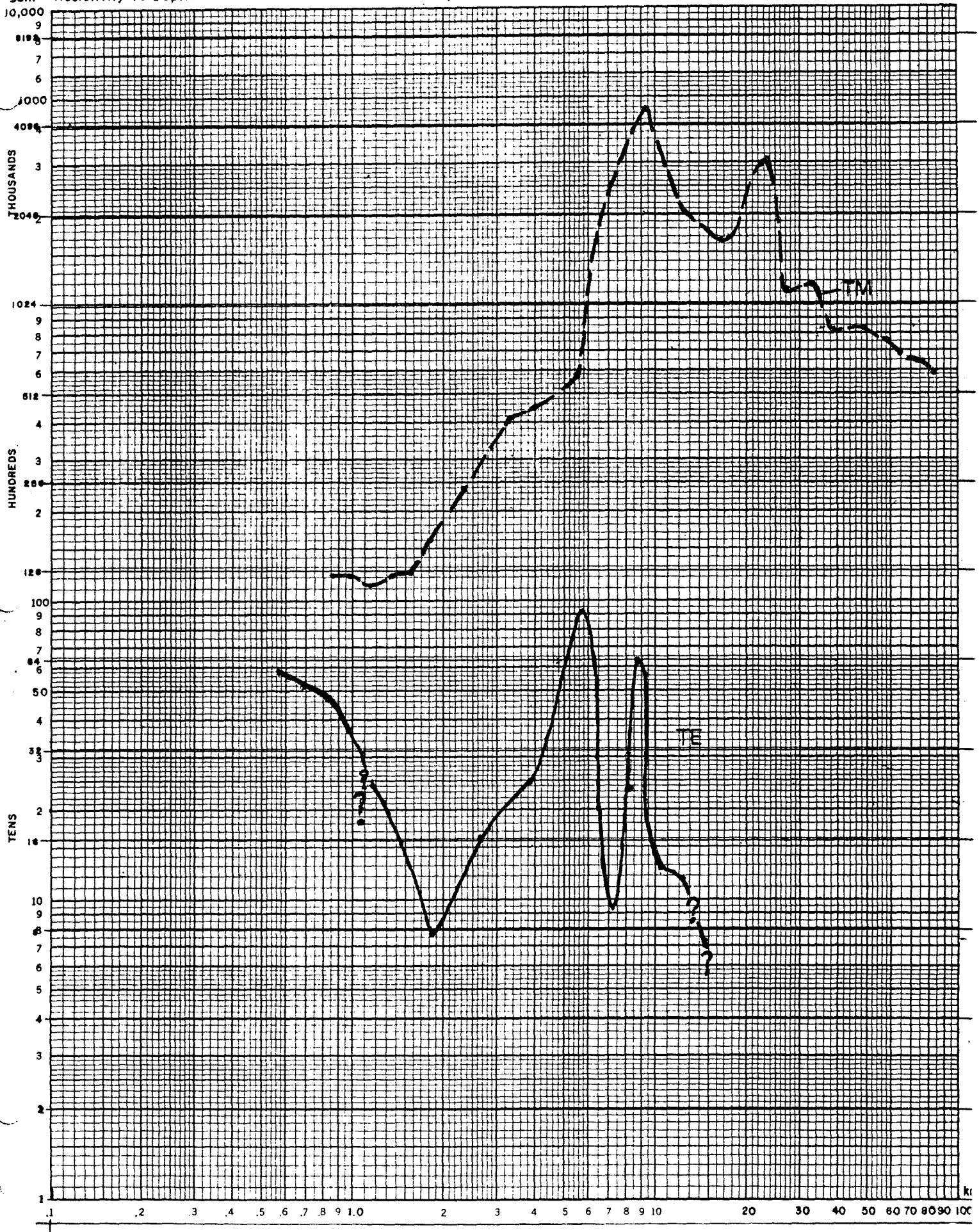
Proj. BULLY CREEK, OR Station 14B



Ωm Resistivity vs Depth

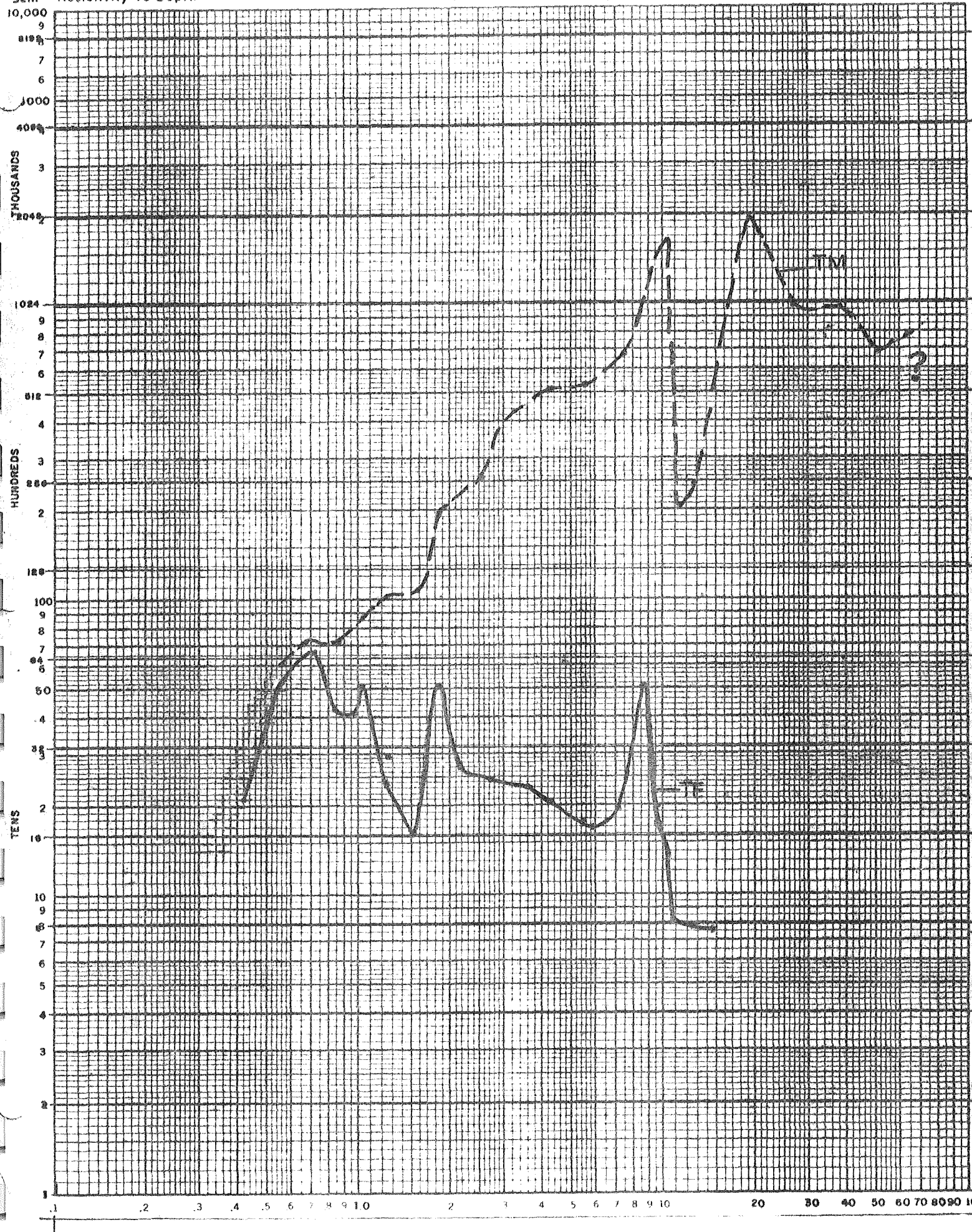
Proj. BULLY CREEK, OR Station 15M

Ωm Resistivity vs Depth Proj. BULLY CREEK, OR Station 15B



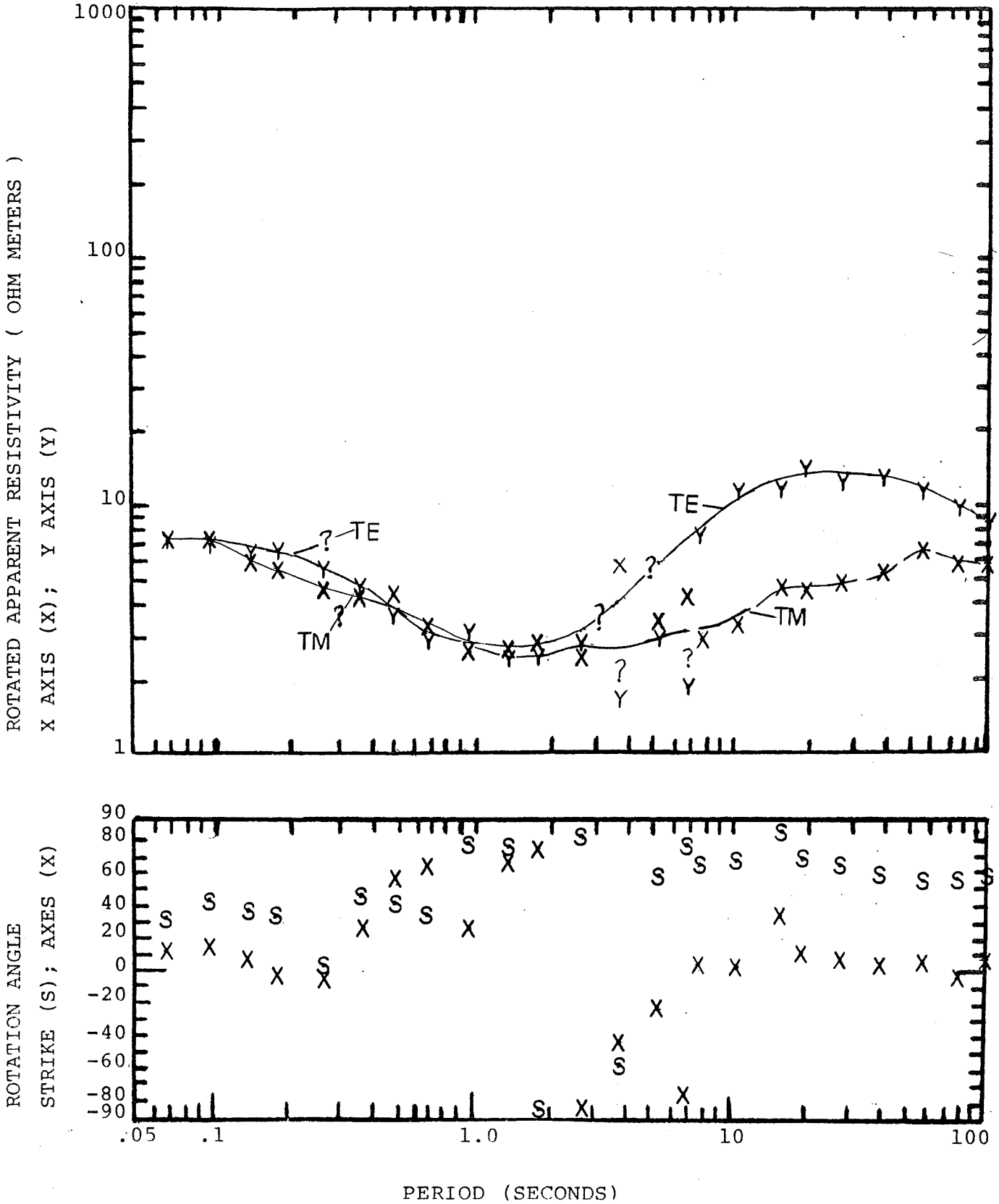
Ωm Resistivity vs Depth

Proj BULLY CREEK, OR Station 17A



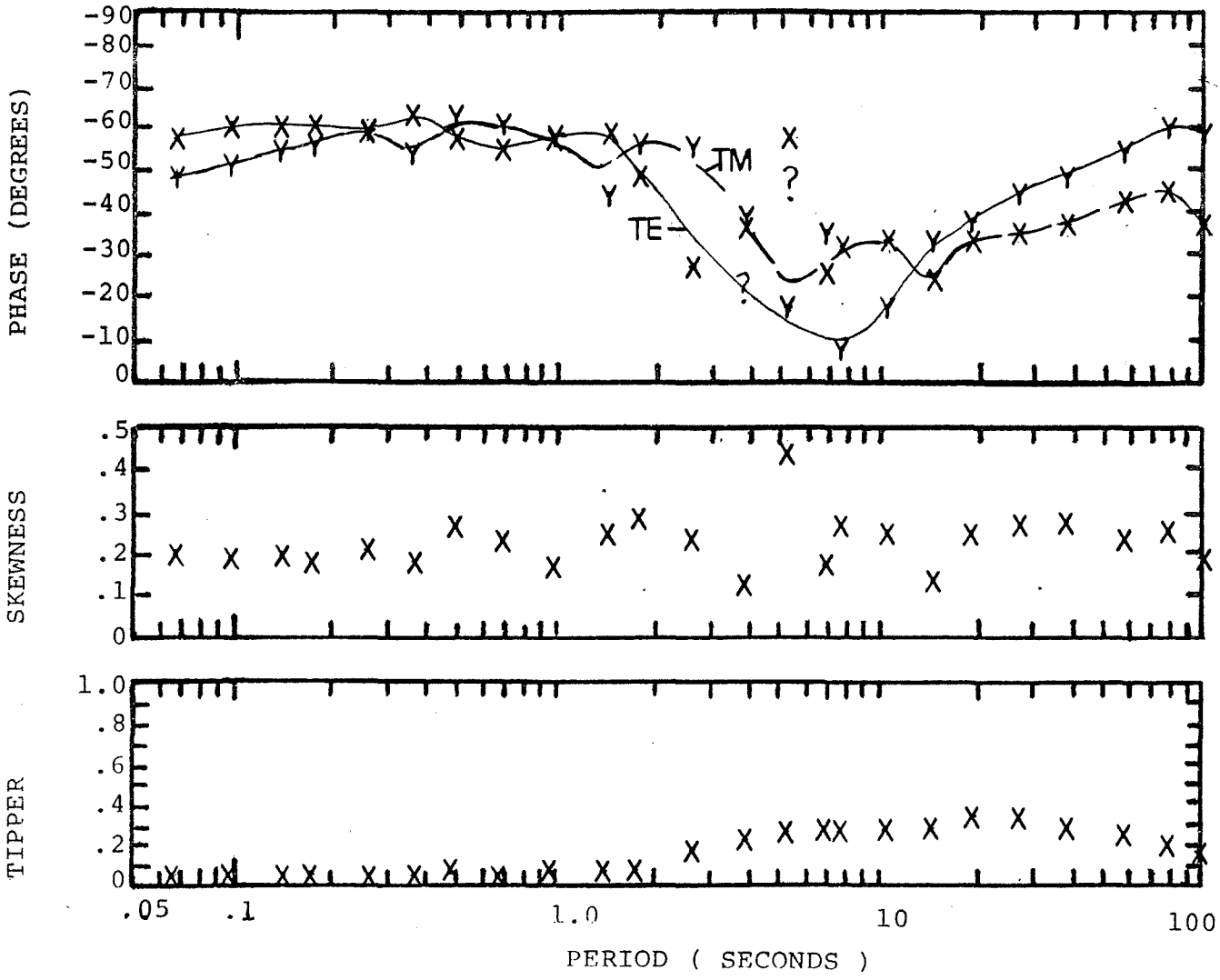
PROSPECT BULLY CREEK, OREGON

STATION 1M



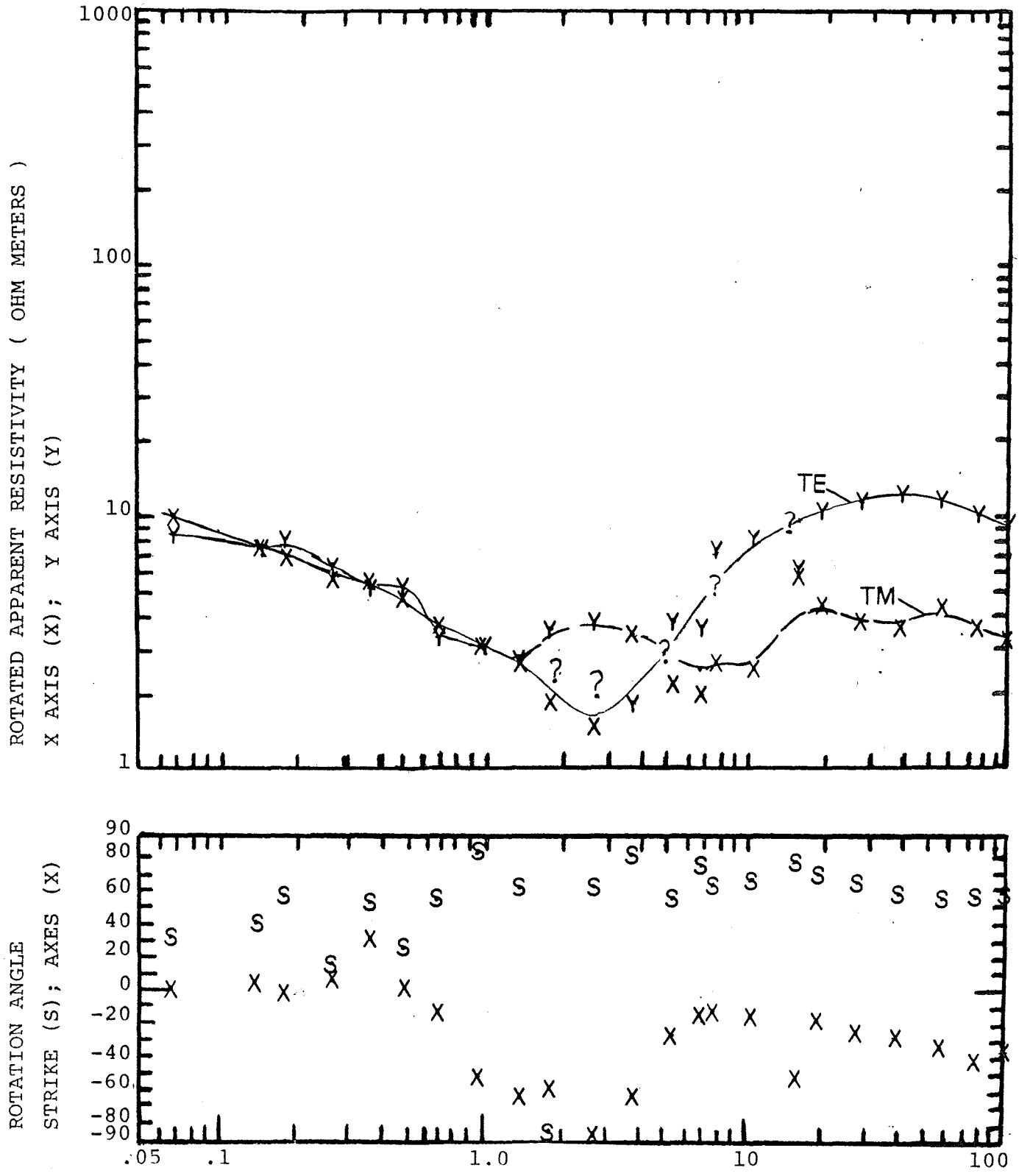
PROSPECT BULLY CREEK, OREGON

STATION 1M



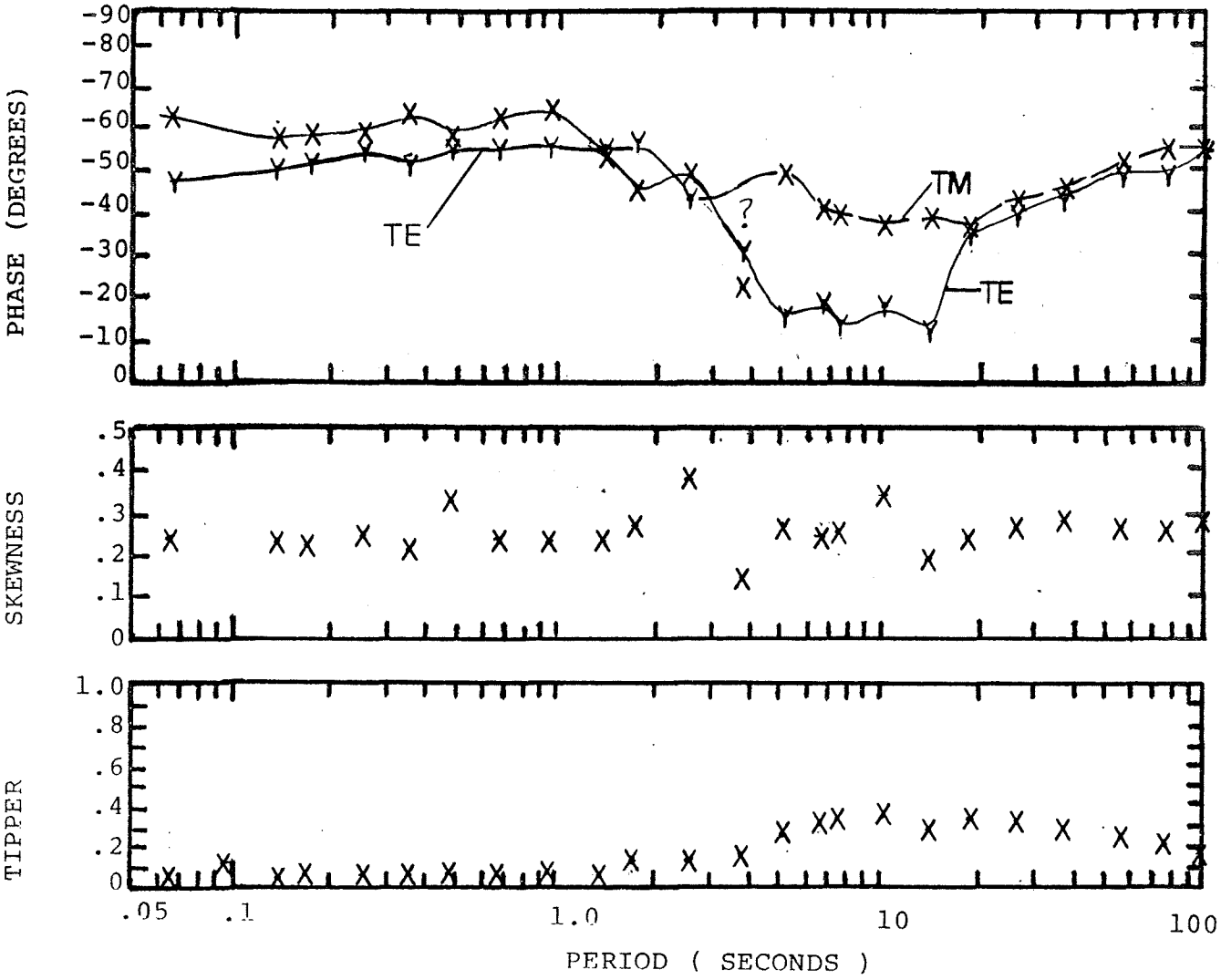
PROSPECT BULLY CREEK, OREGON

STATION 1A



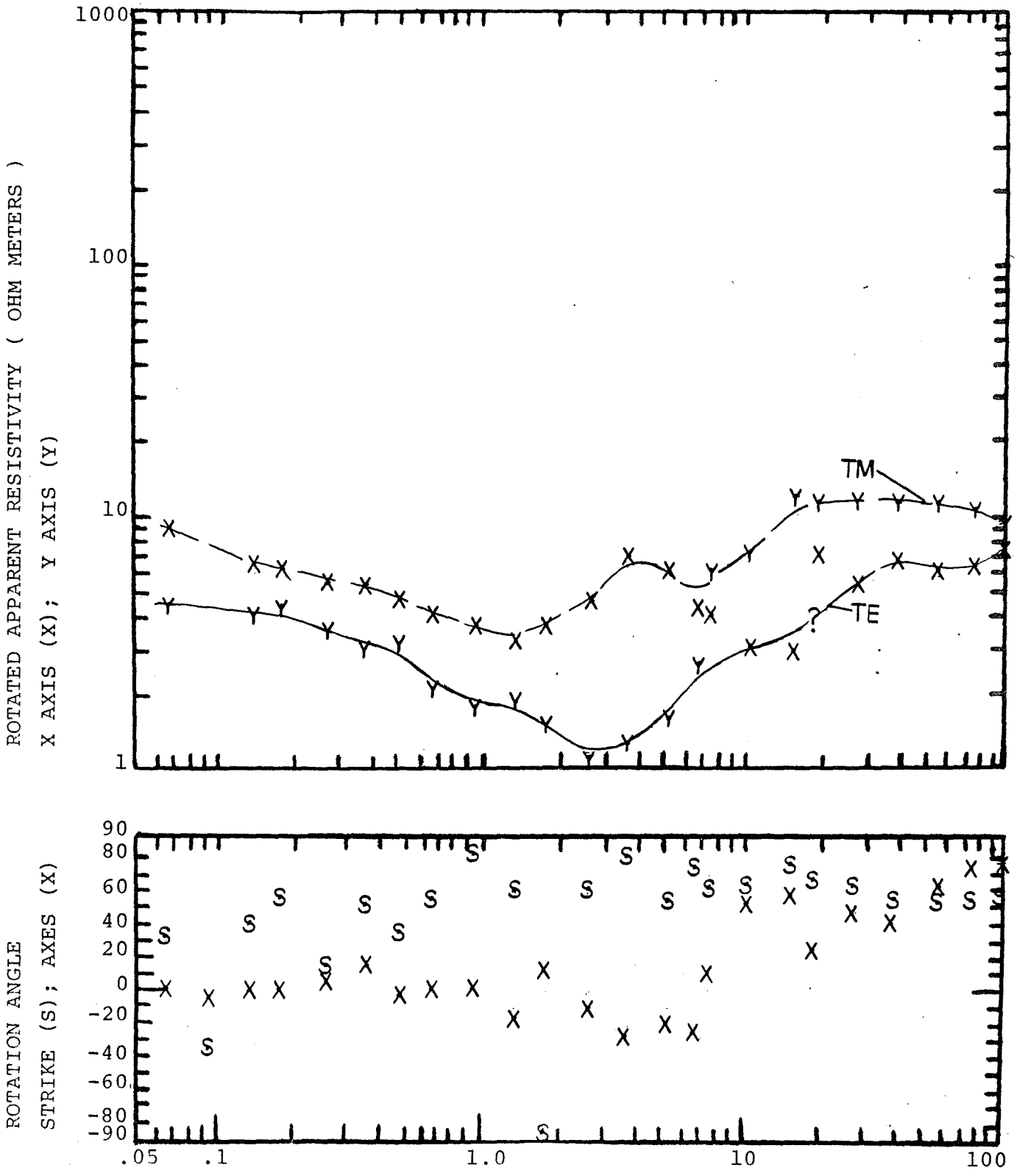
PROSPECT BULLY CREEK, OREGON

STATION 1A



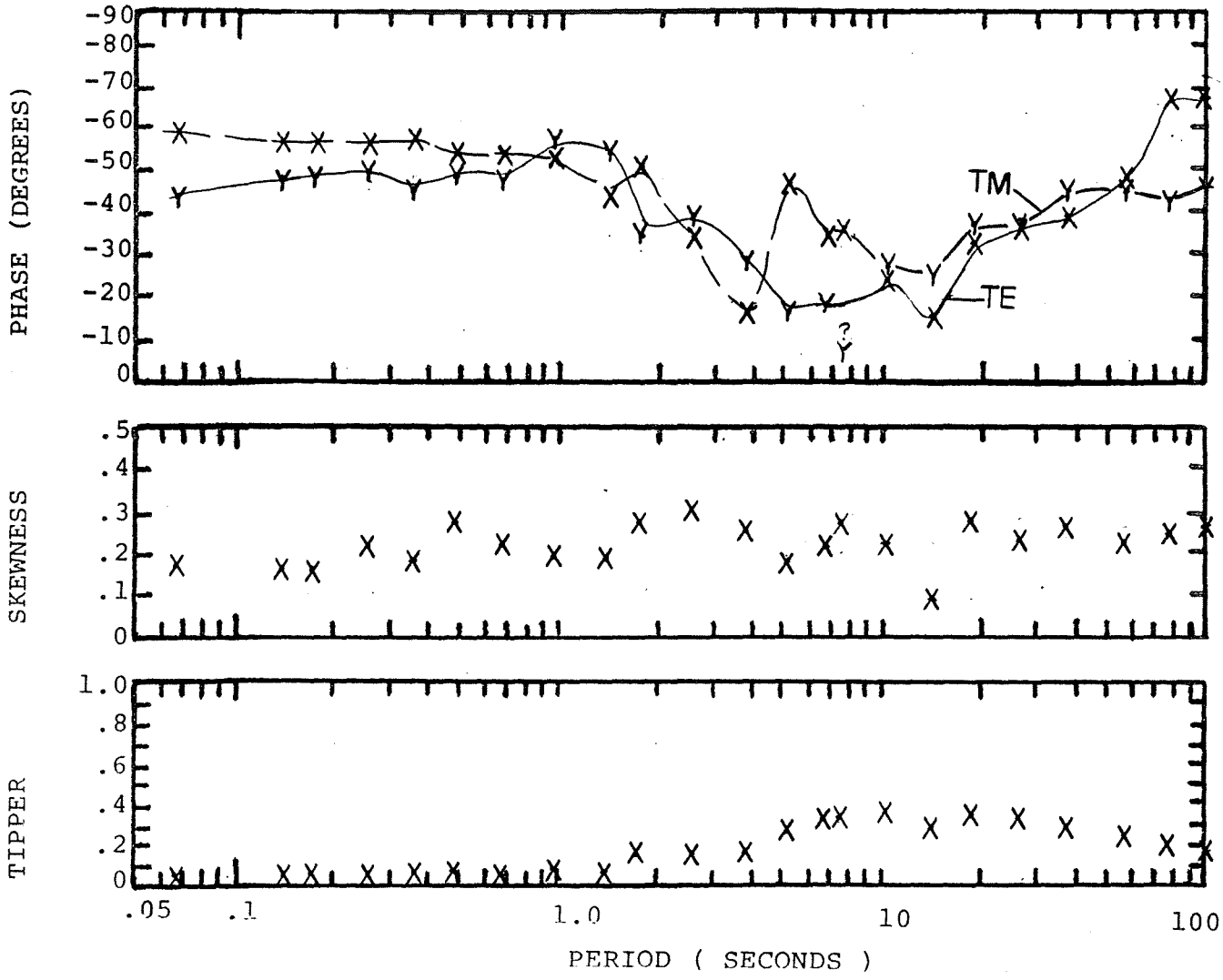
PROSPECT BULLY CREEK, OREGON

STATION 1B



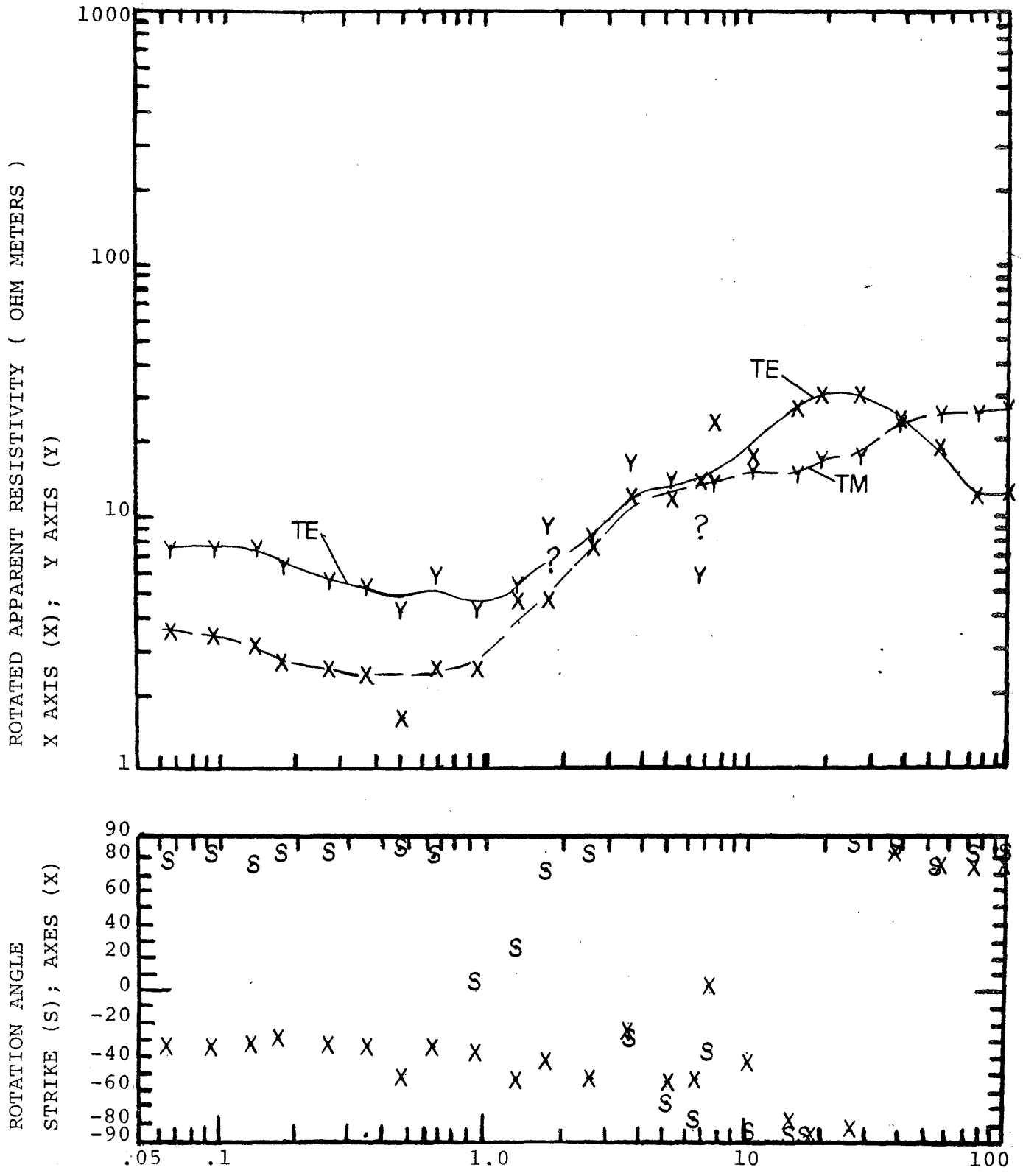
PROSPECT BULLY CREEK, OREGON

STATION 1B



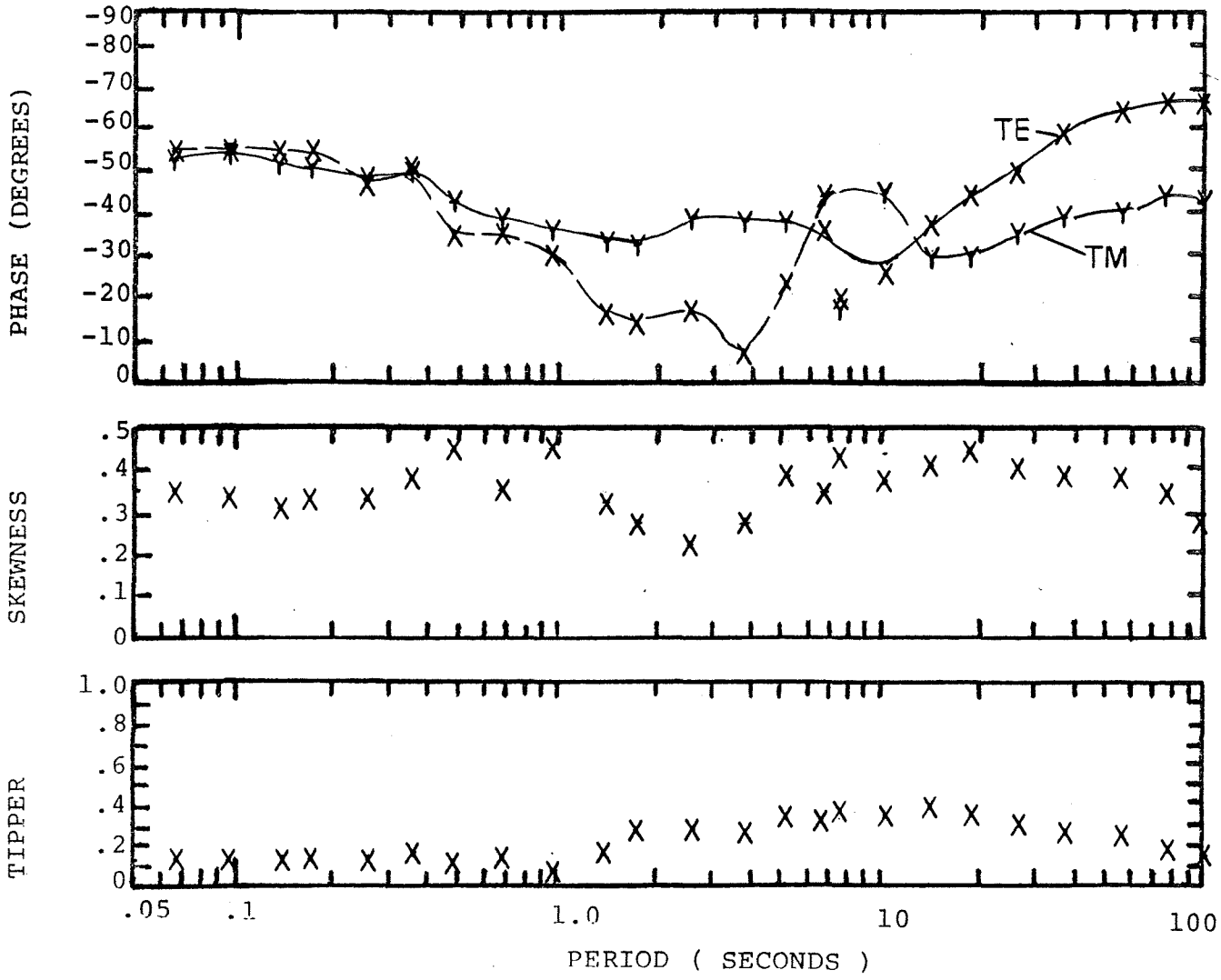
PROSPECT BULLY CREEK, OREGON

STATION 2M



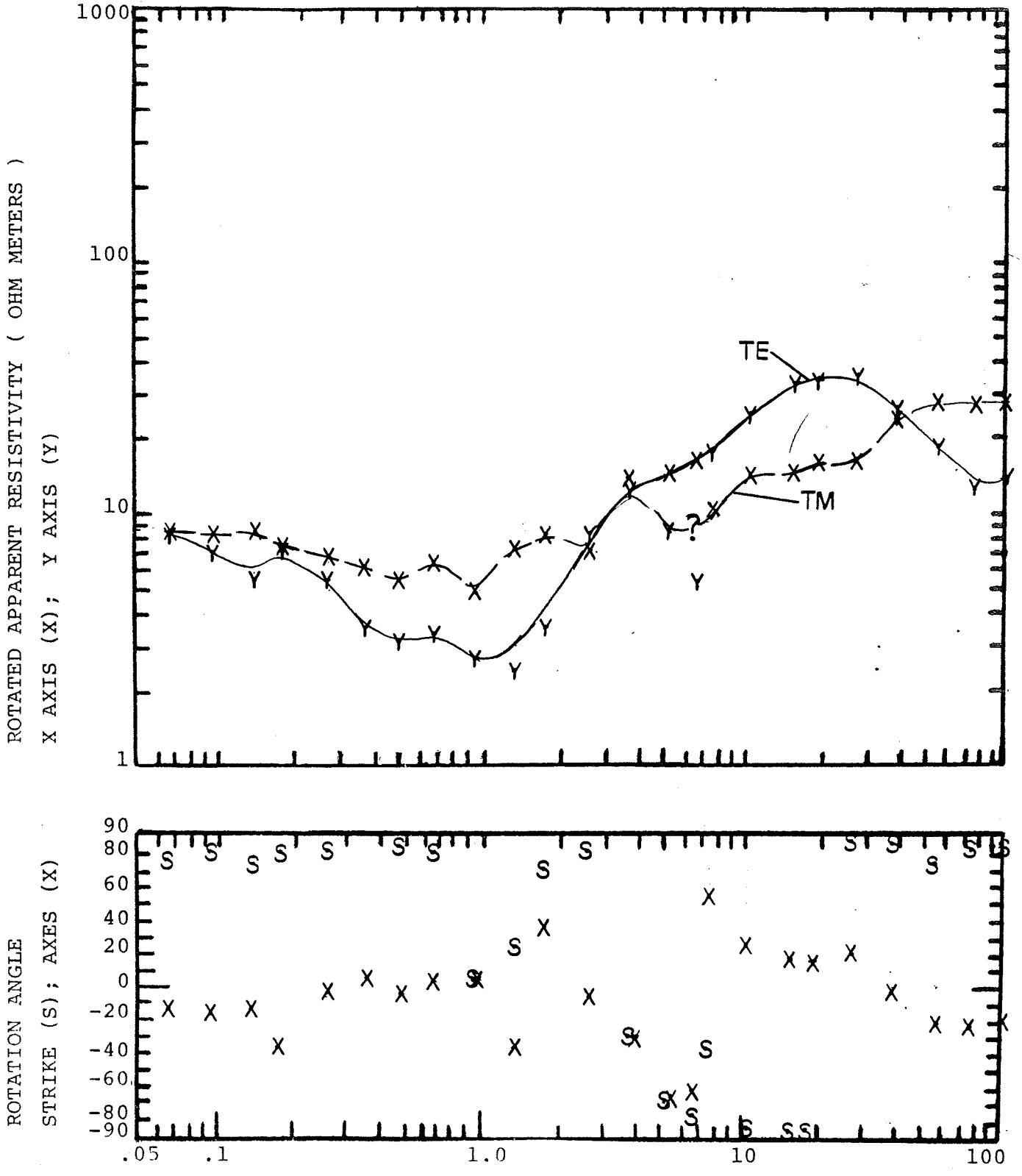
PROSPECT BULLY CREEK, OREGON

STATION 2M



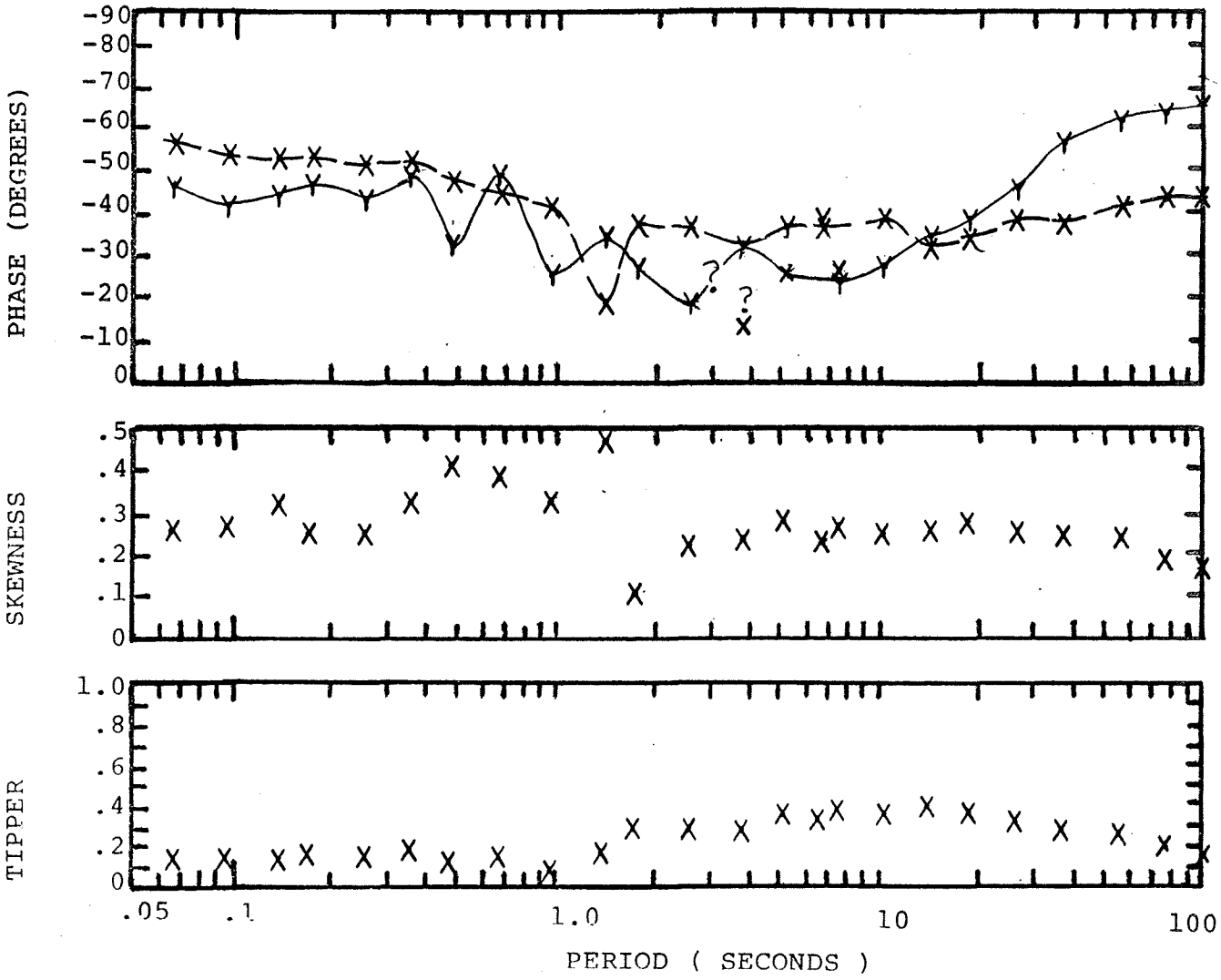
PROSPECT BULLY CREEK, OREGON

STATION 2A



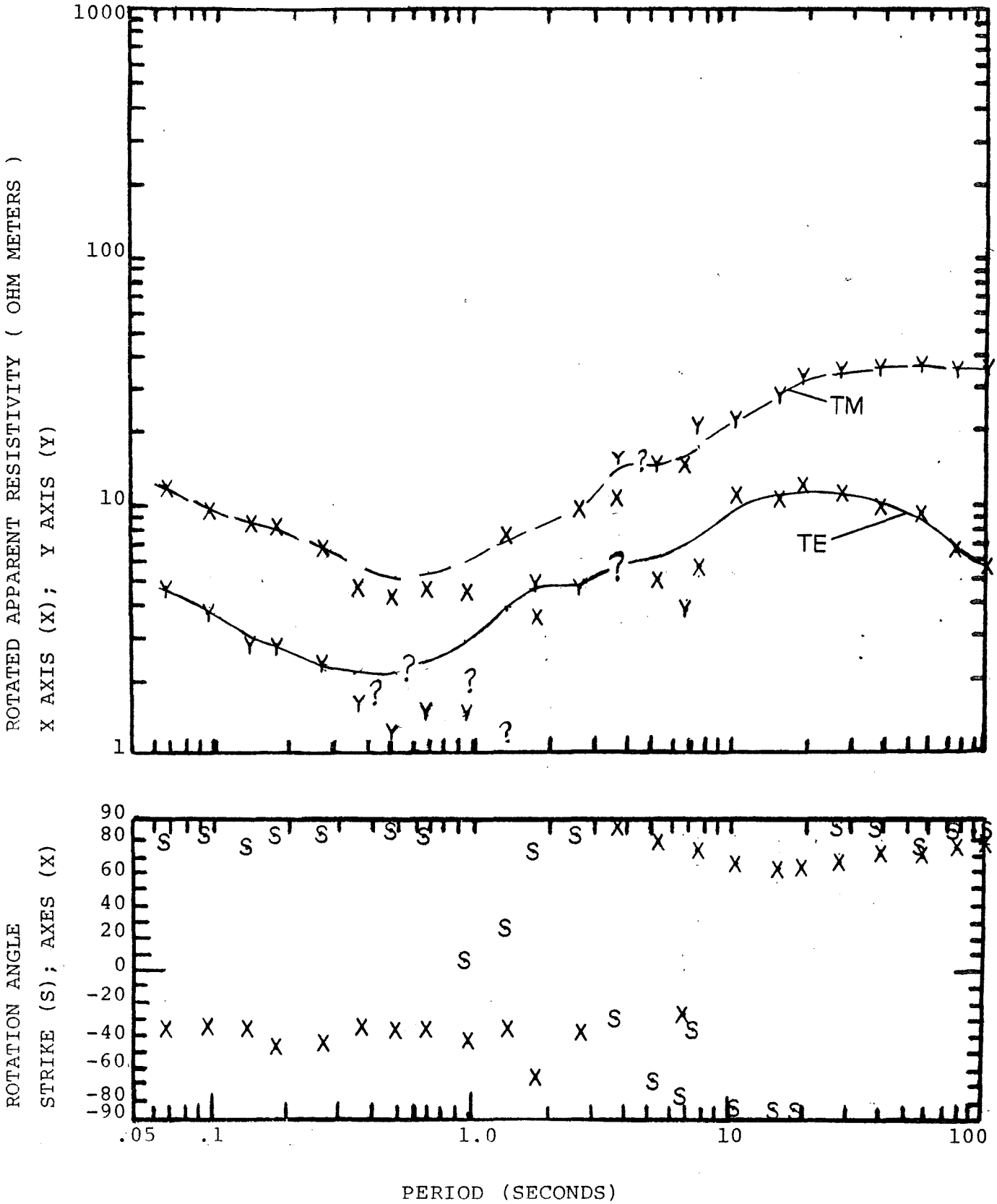
PROSPECT BULLY CREEK, OREGON

STATION 2A



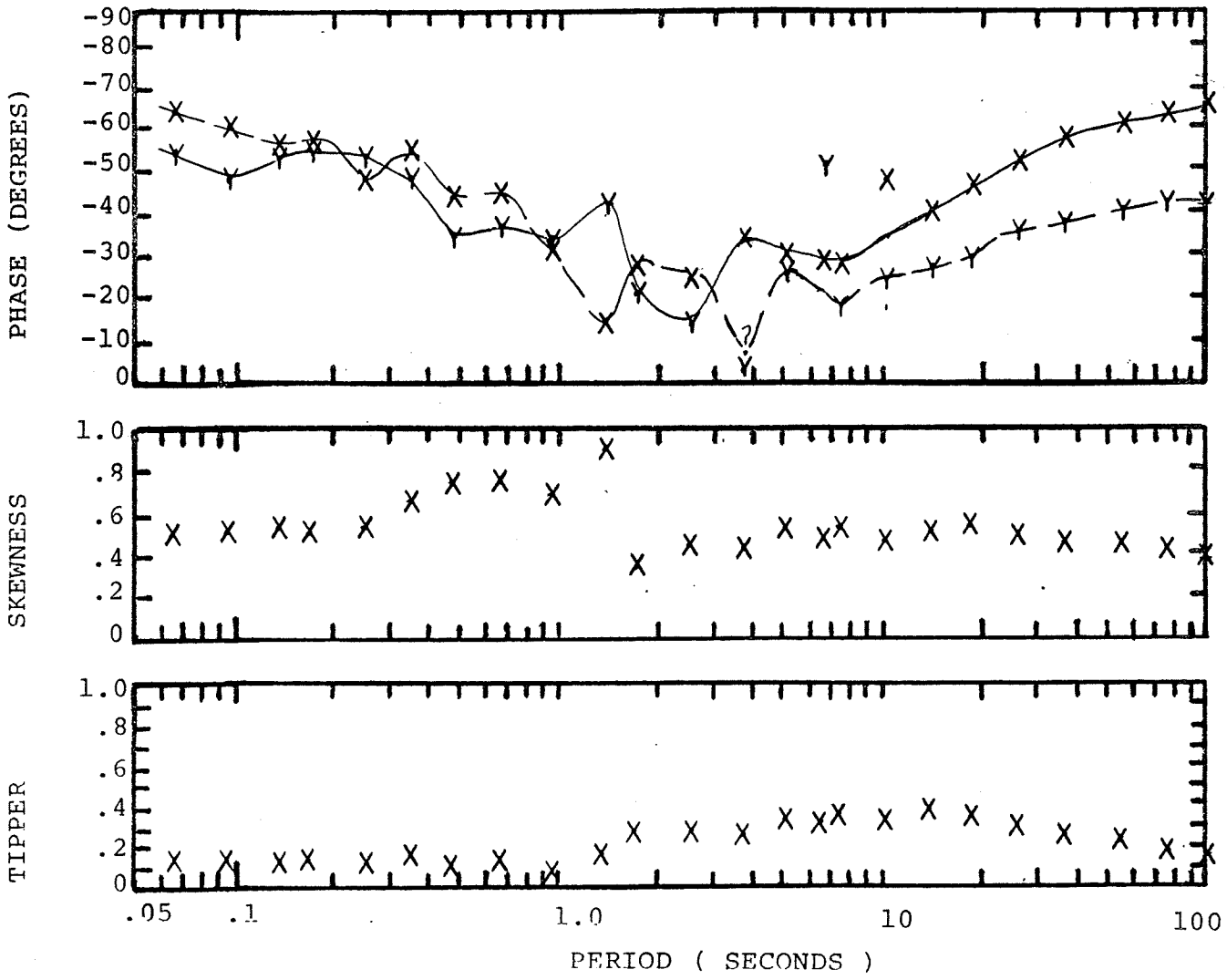
PROSPECT BULLY CREEK, OREGON

STATION 2B



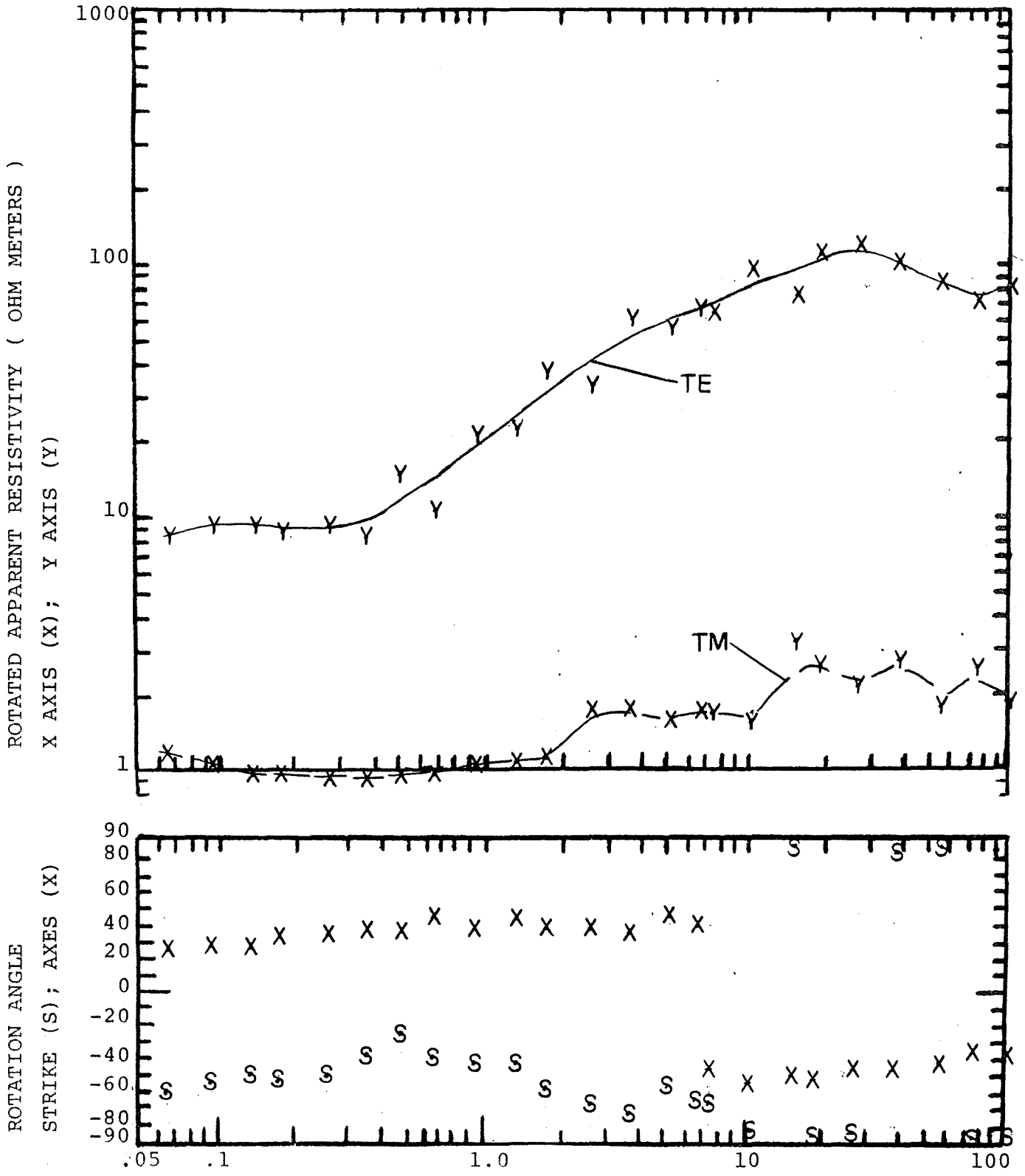
PROSPECT BULLY CREEK, OREGON

STATION 2B



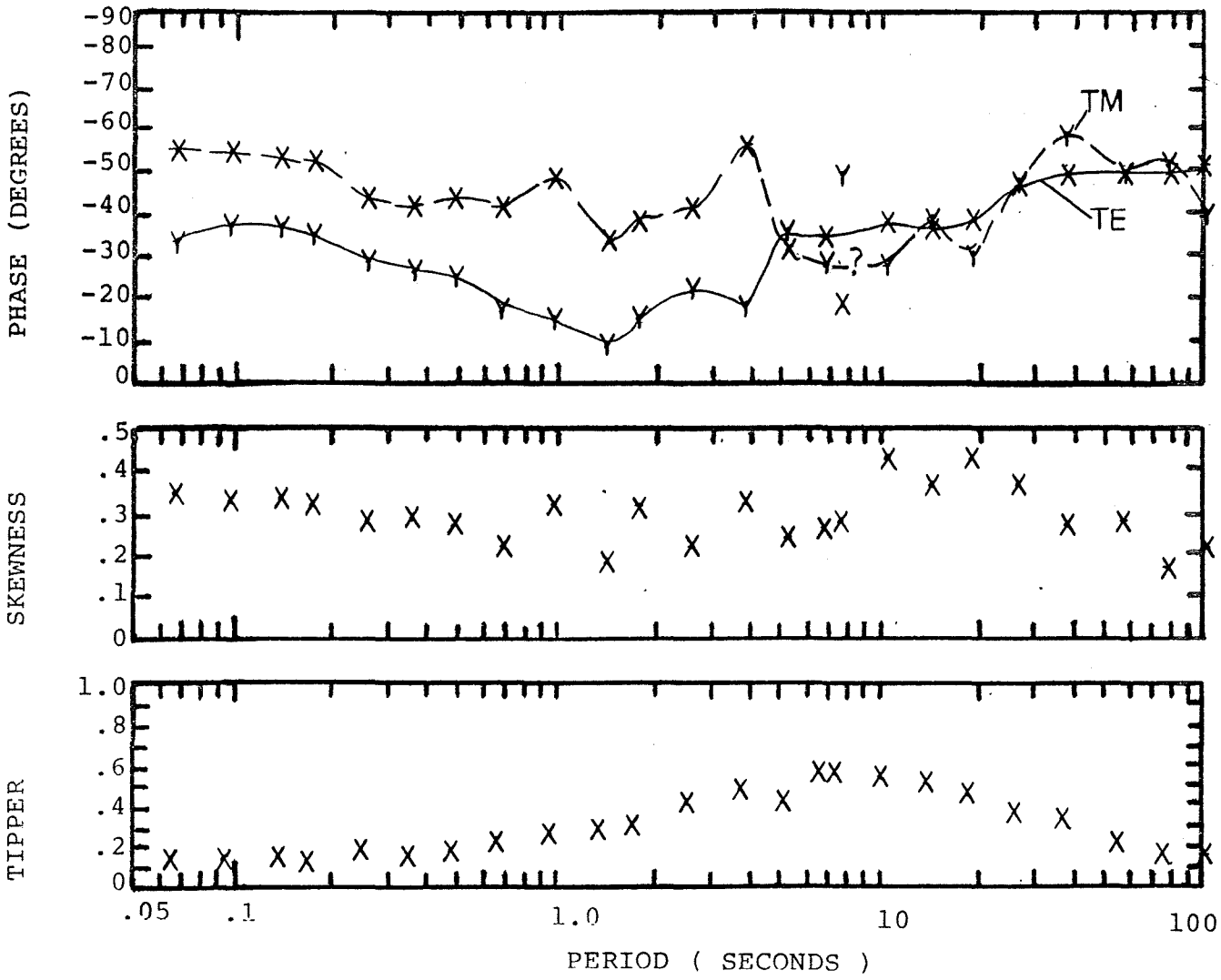
PROSPECT BULLY CREEK, OREGON

STATION 3M



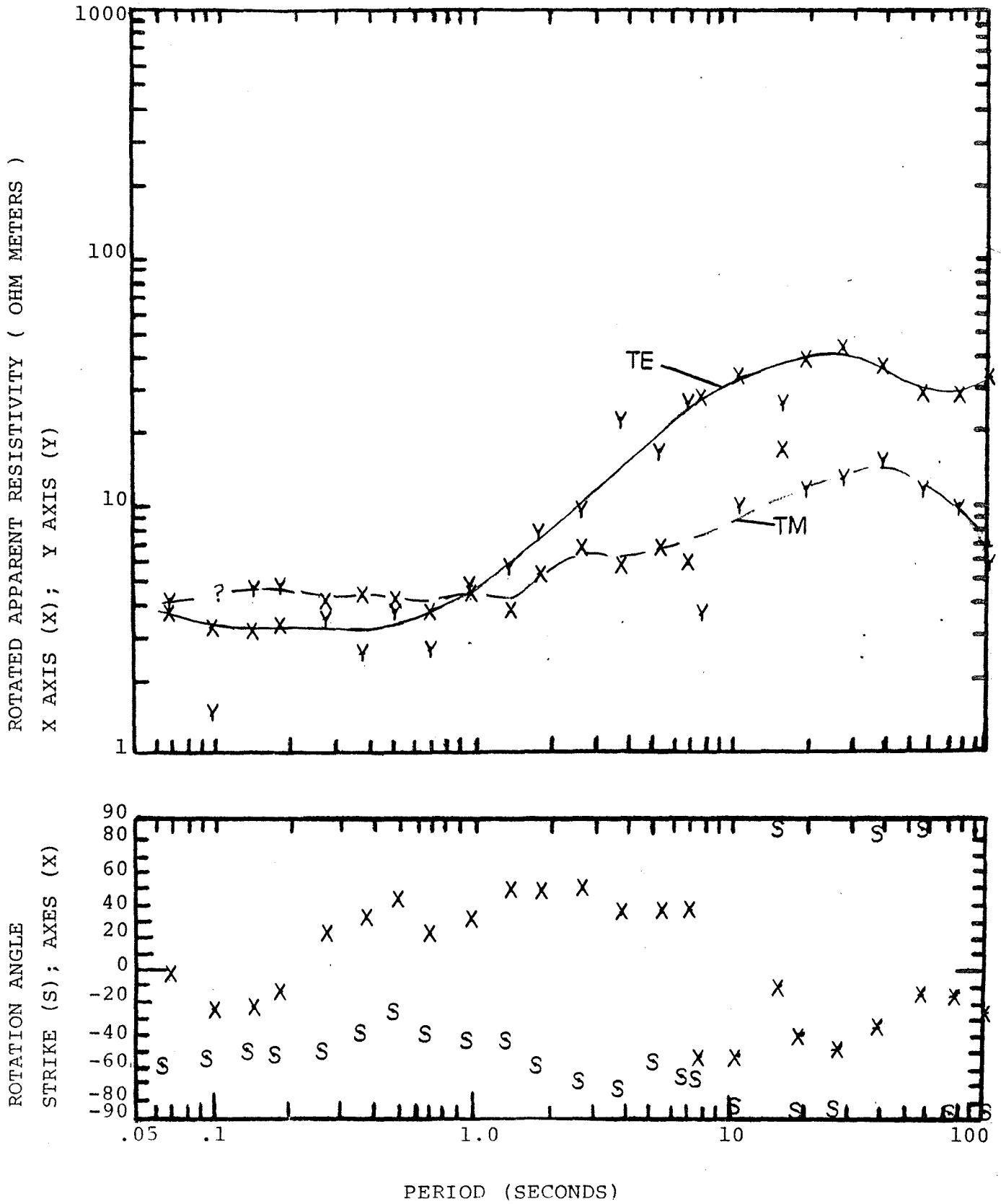
PROSPECT BULLY CREEK, OREGON

STATION 3M



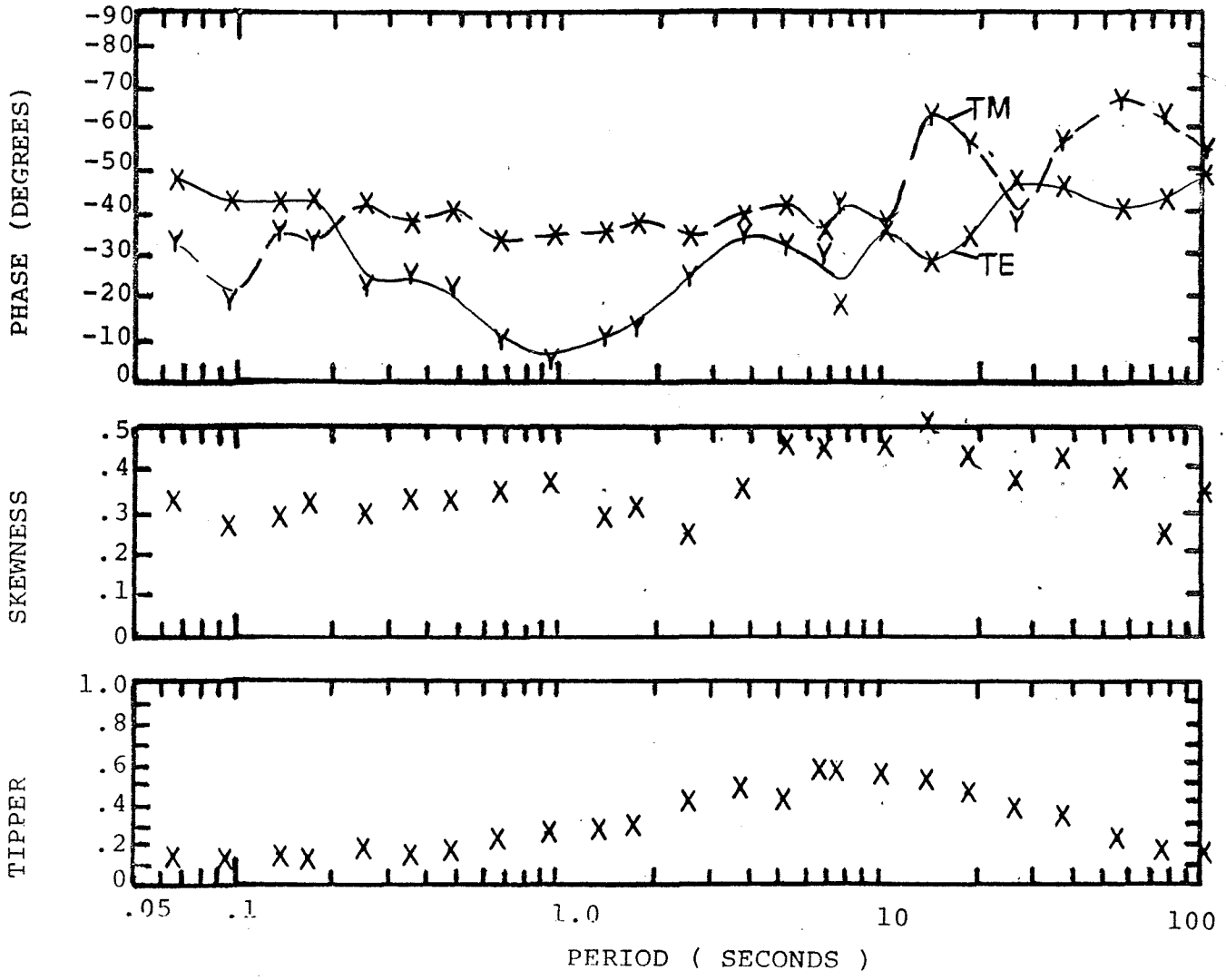
PROSPECT BULLY CREEK, OREGON

STATION 3A



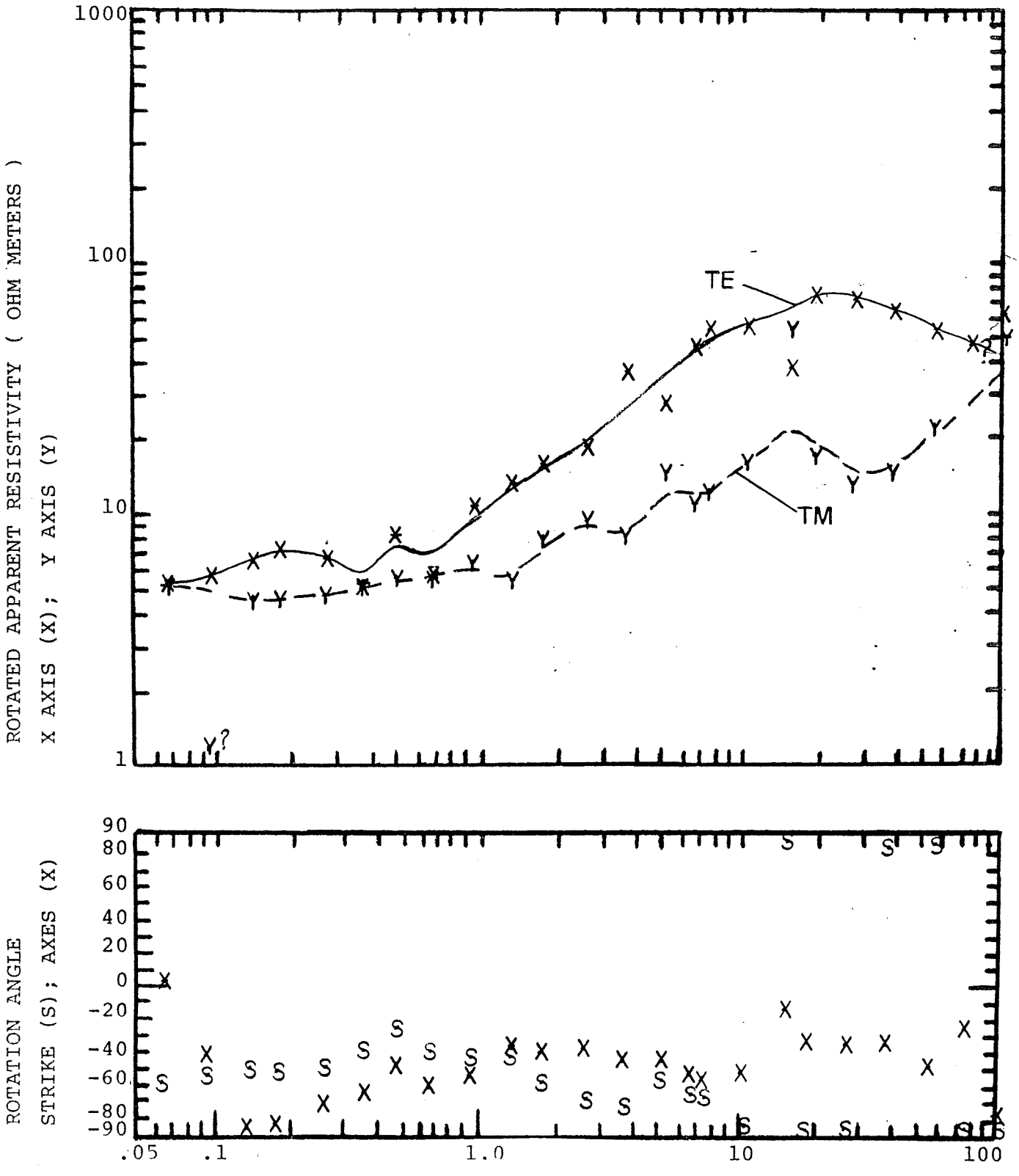
PROSPECT BULLY CREEK, OREGON

STATION 3A



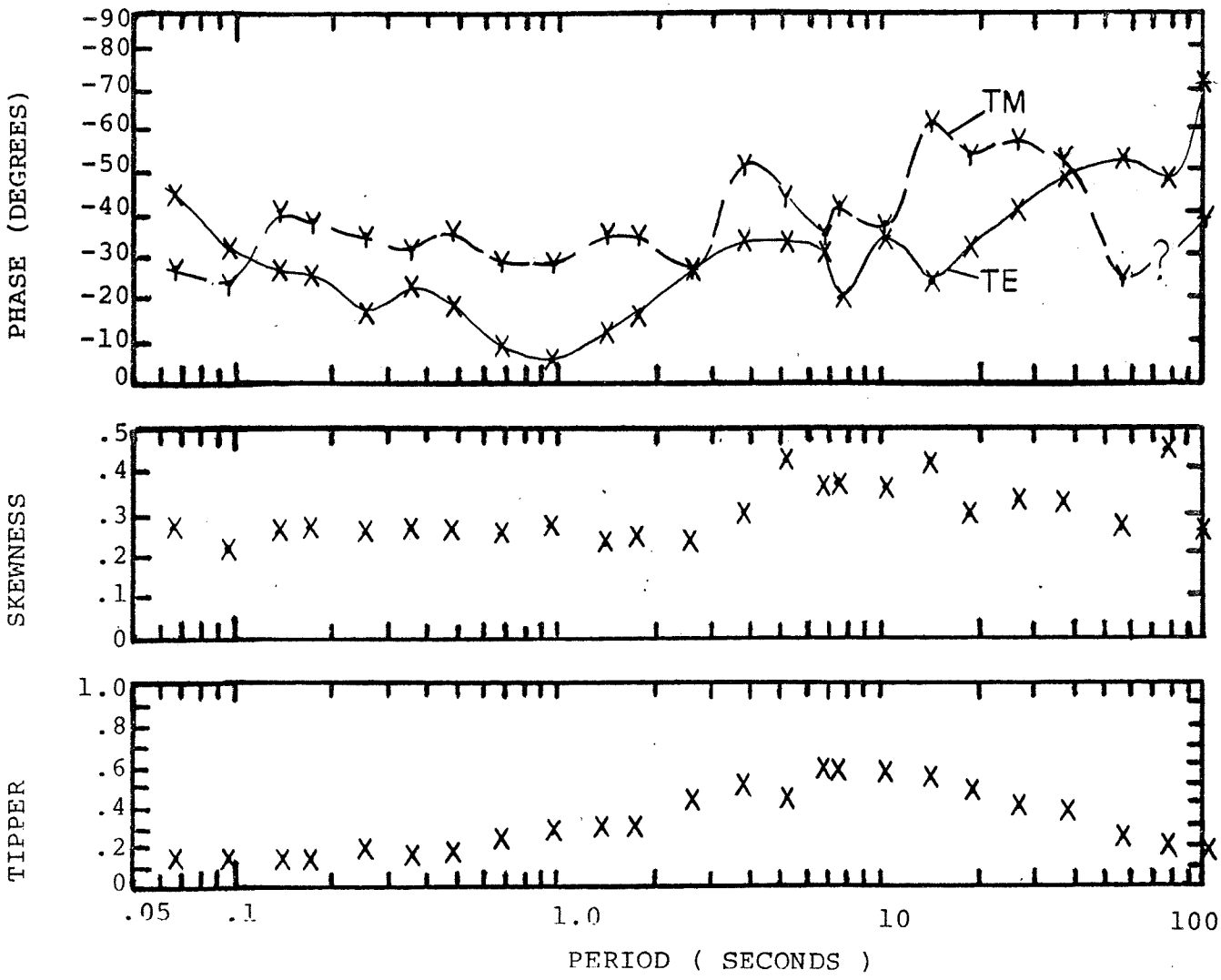
PROSPECT BULLY CREEK, OREGON

STATION 3B



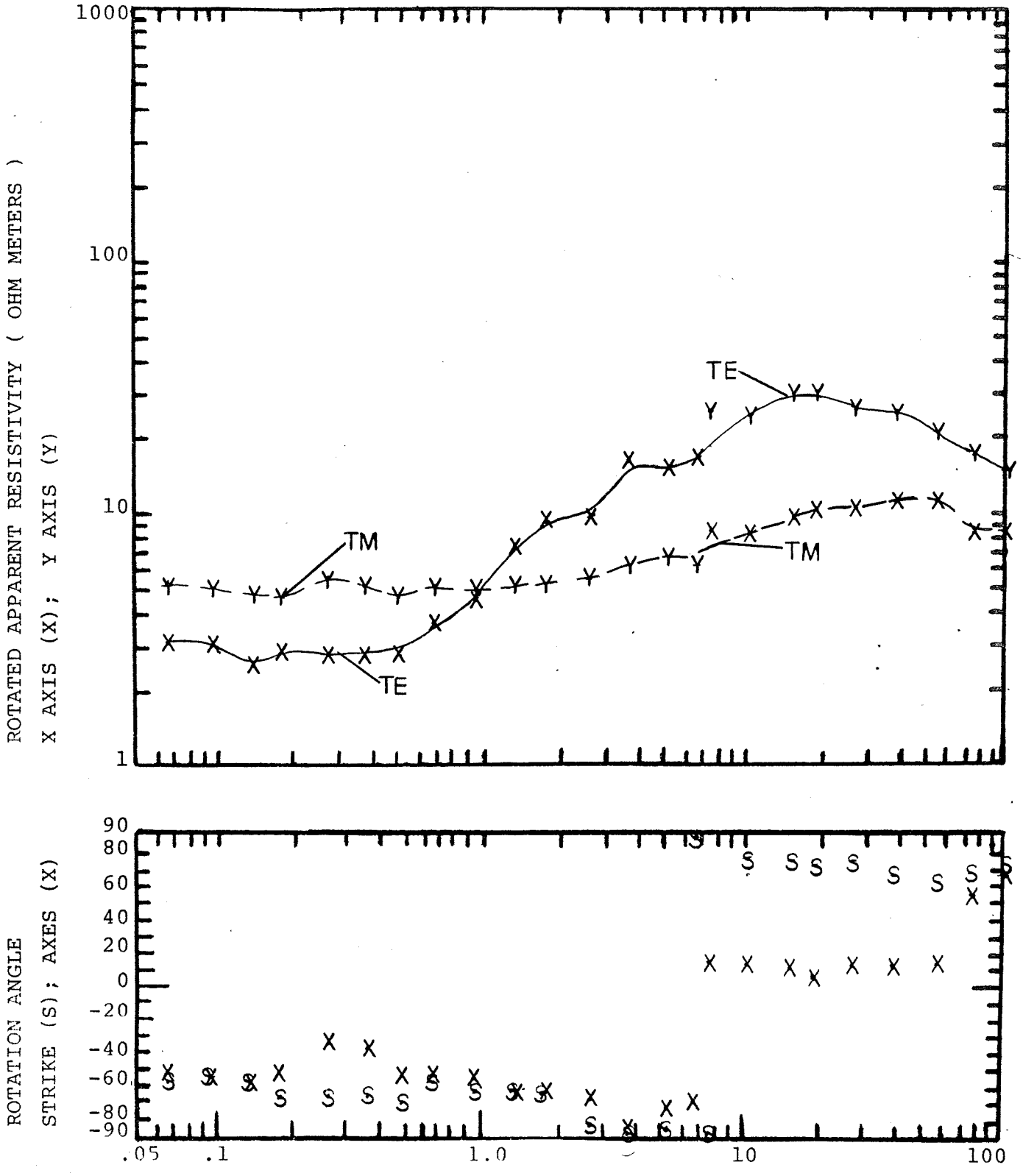
PROSPECT BULLY CREEK, OREGON

STATION 3B



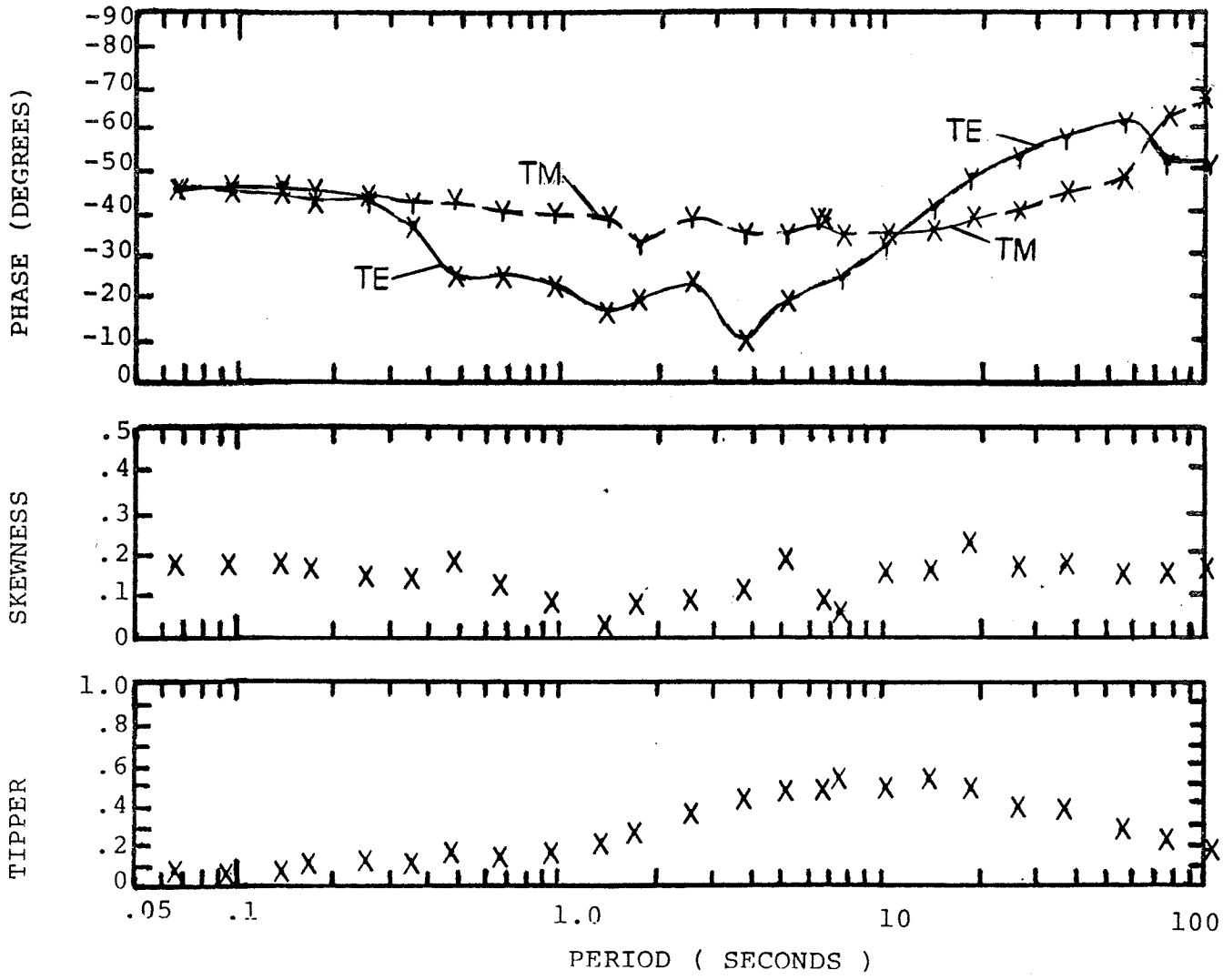
PROSPECT BULLY CREEK, OREGON

STATION 4M



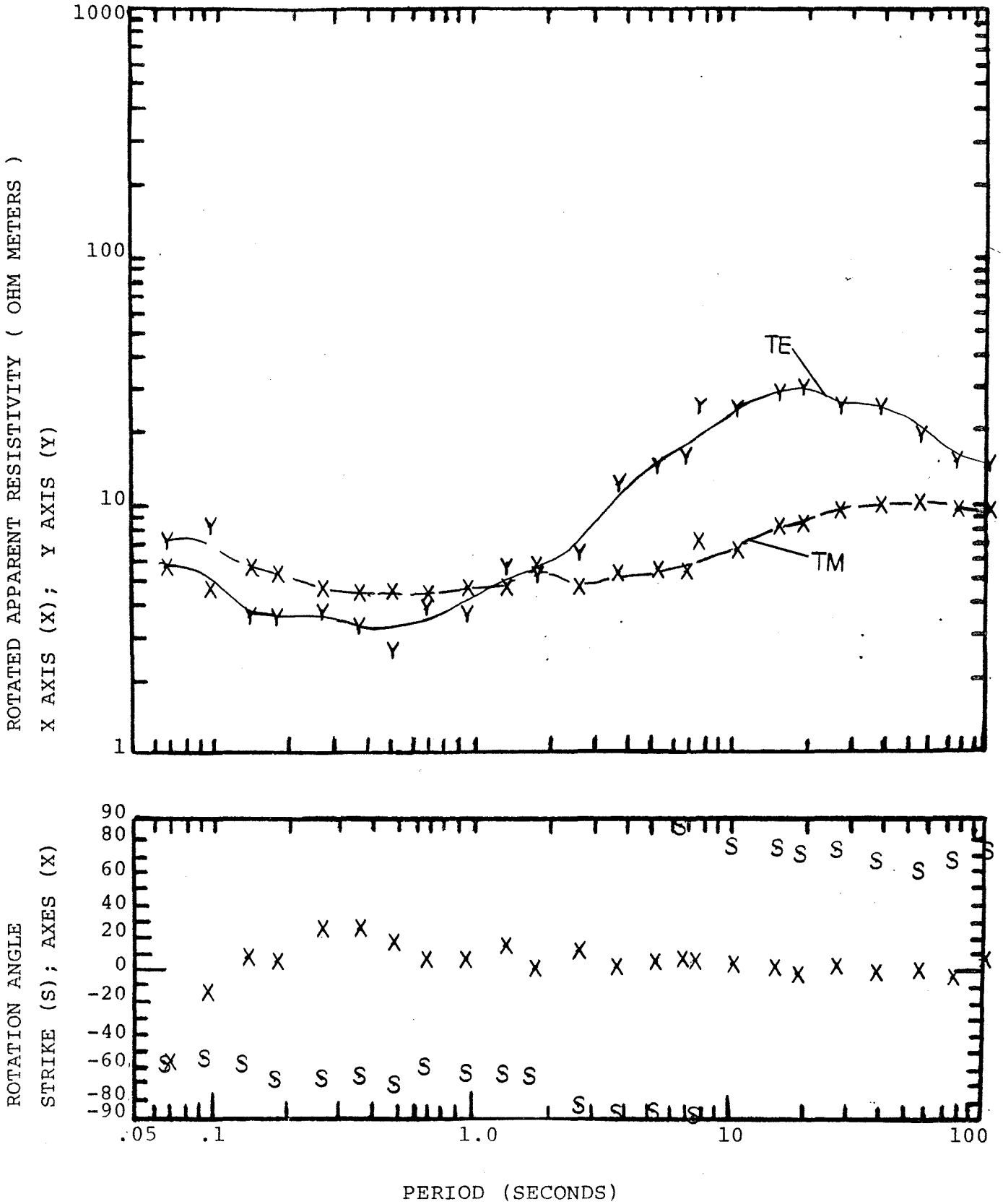
PROSPECT BULLY CREEK, OREGON

STATION 4M



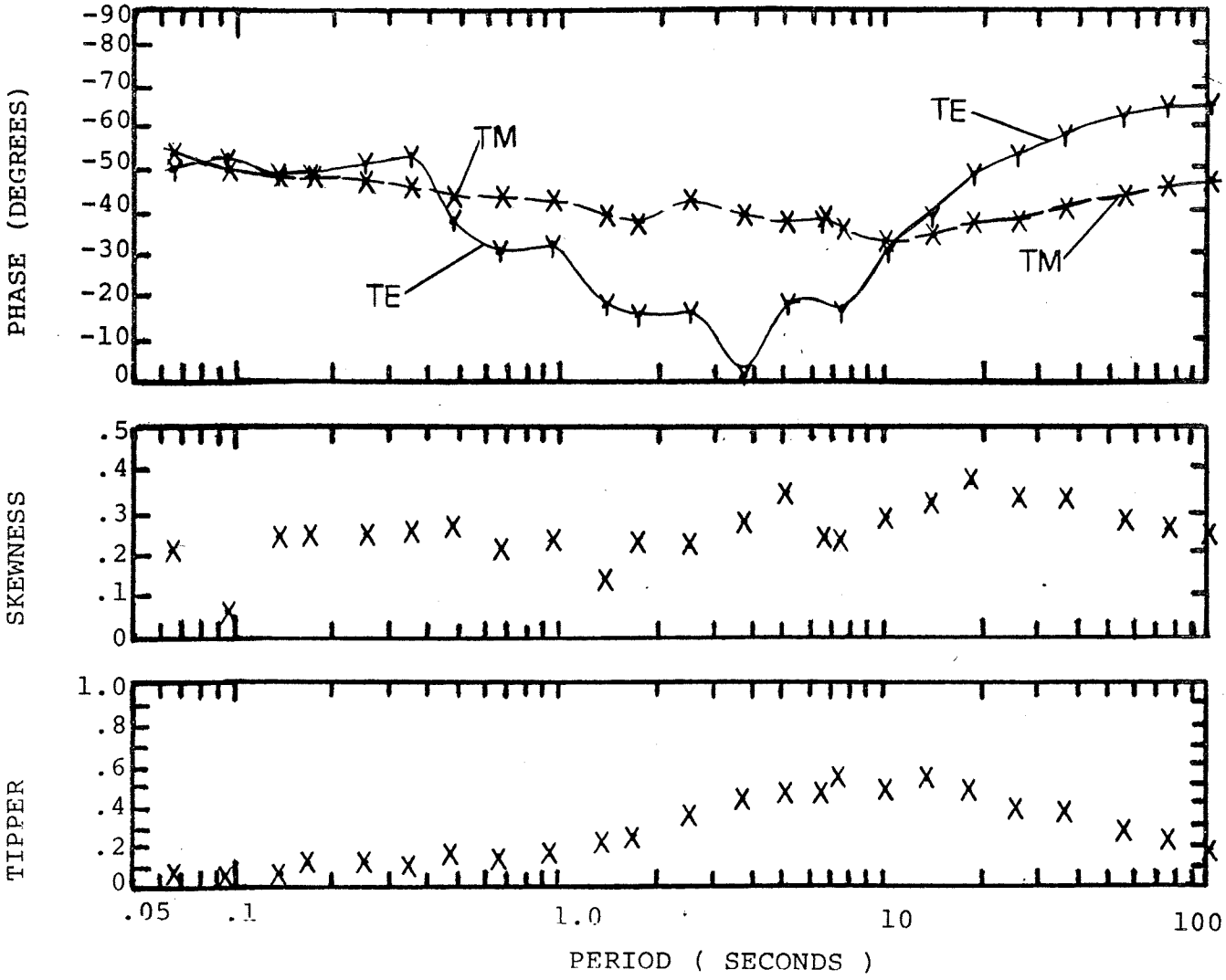
PROSPECT BULLY CREEK, OREGON

STATION 4A



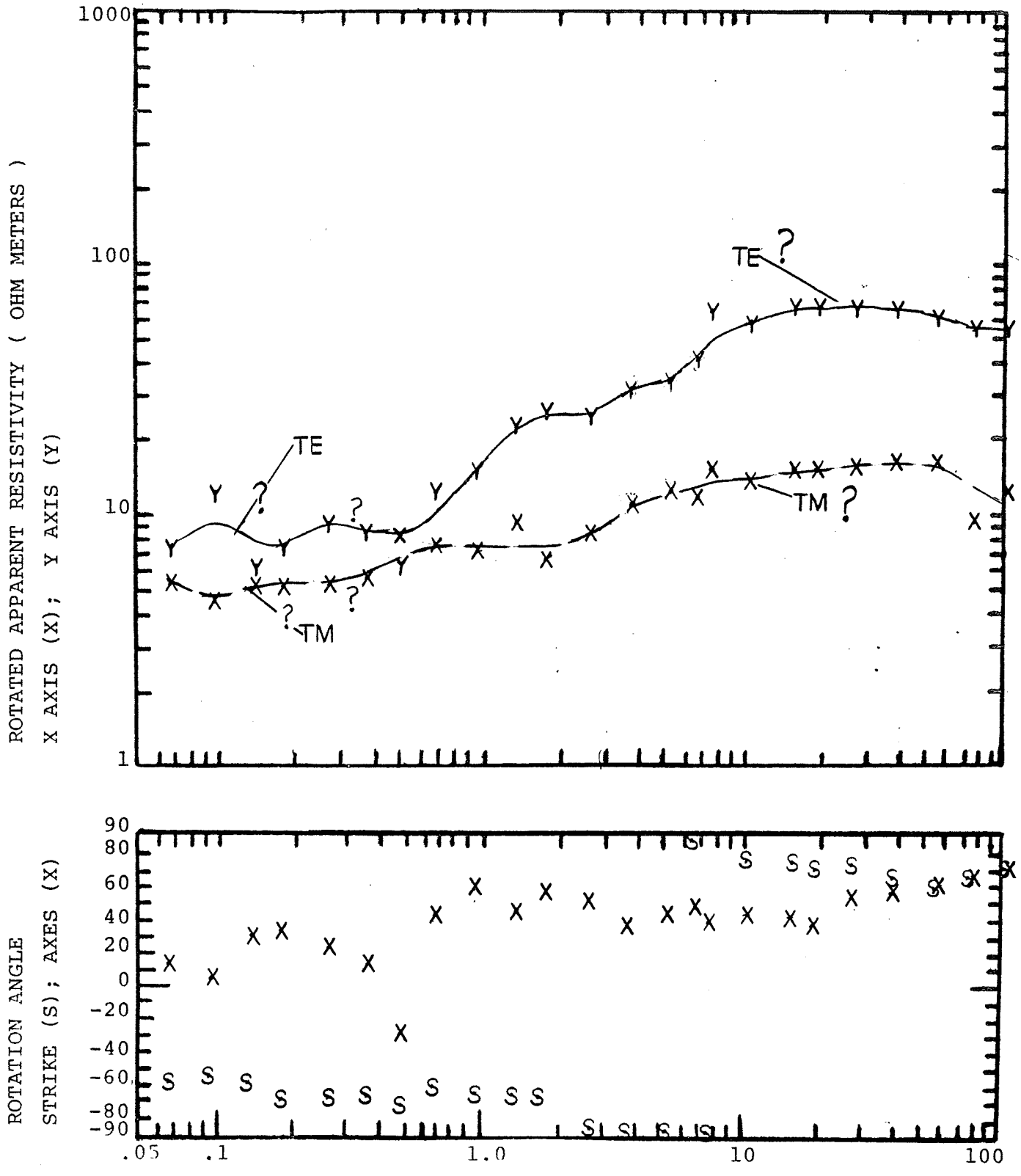
PROSPECT BULLY CREEK, OREGON

STATION 4A



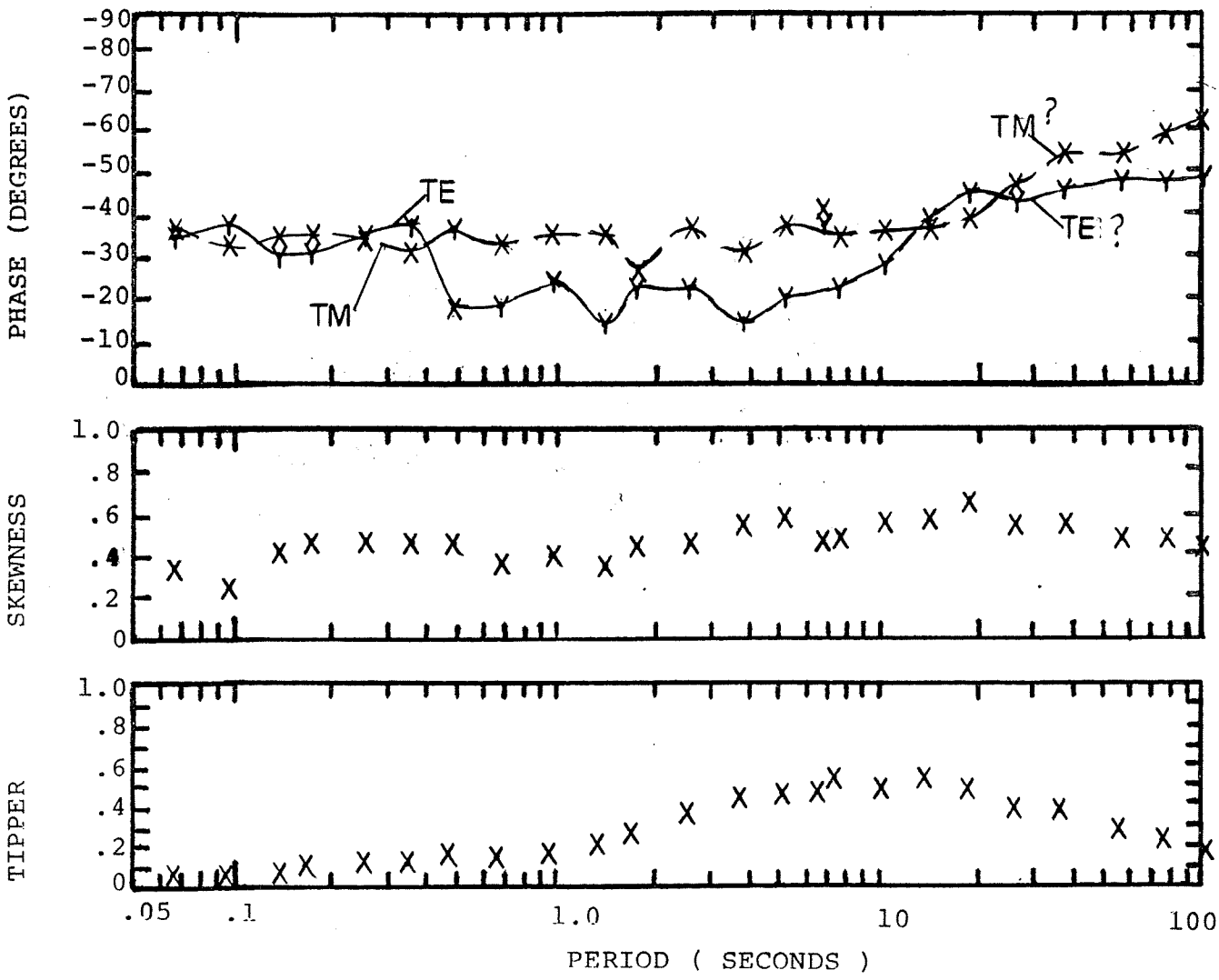
PROSPECT BULLY CREEK, OREGON

STATION 4B



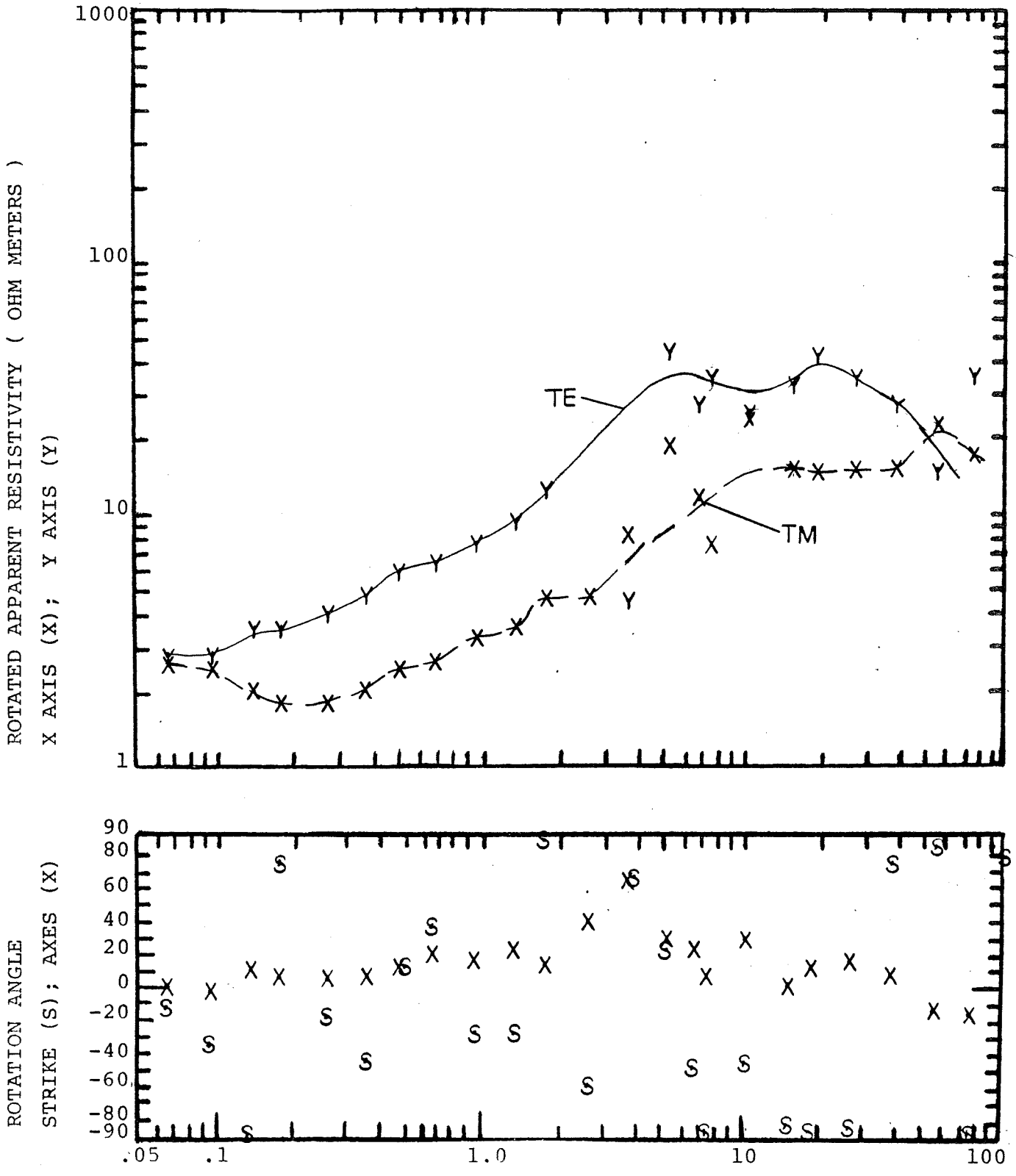
PROSPECT BULLY CREEK, OREGON

STATION 4B



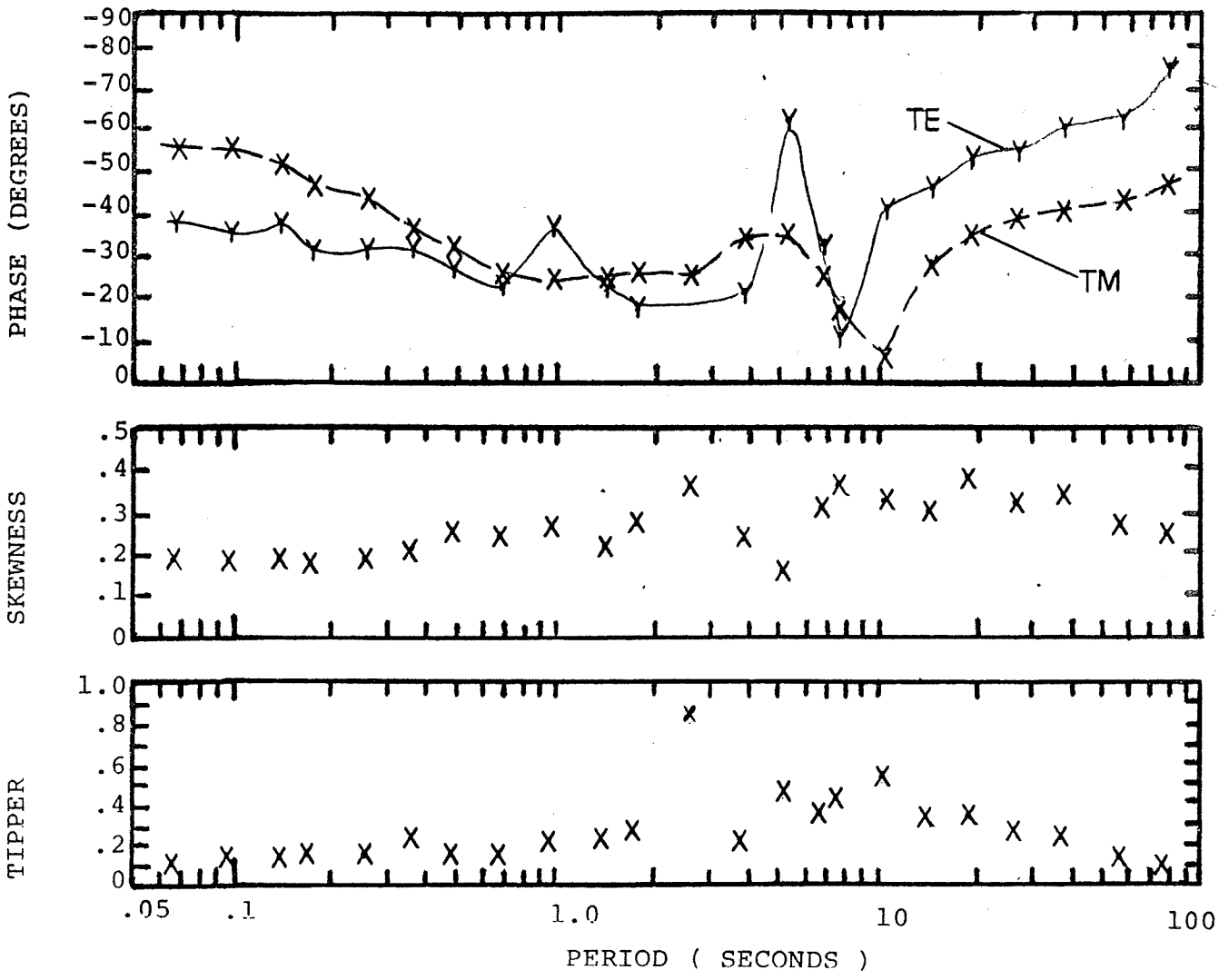
PROSPECT BULLY CREEK, OREGON

STATION 5M



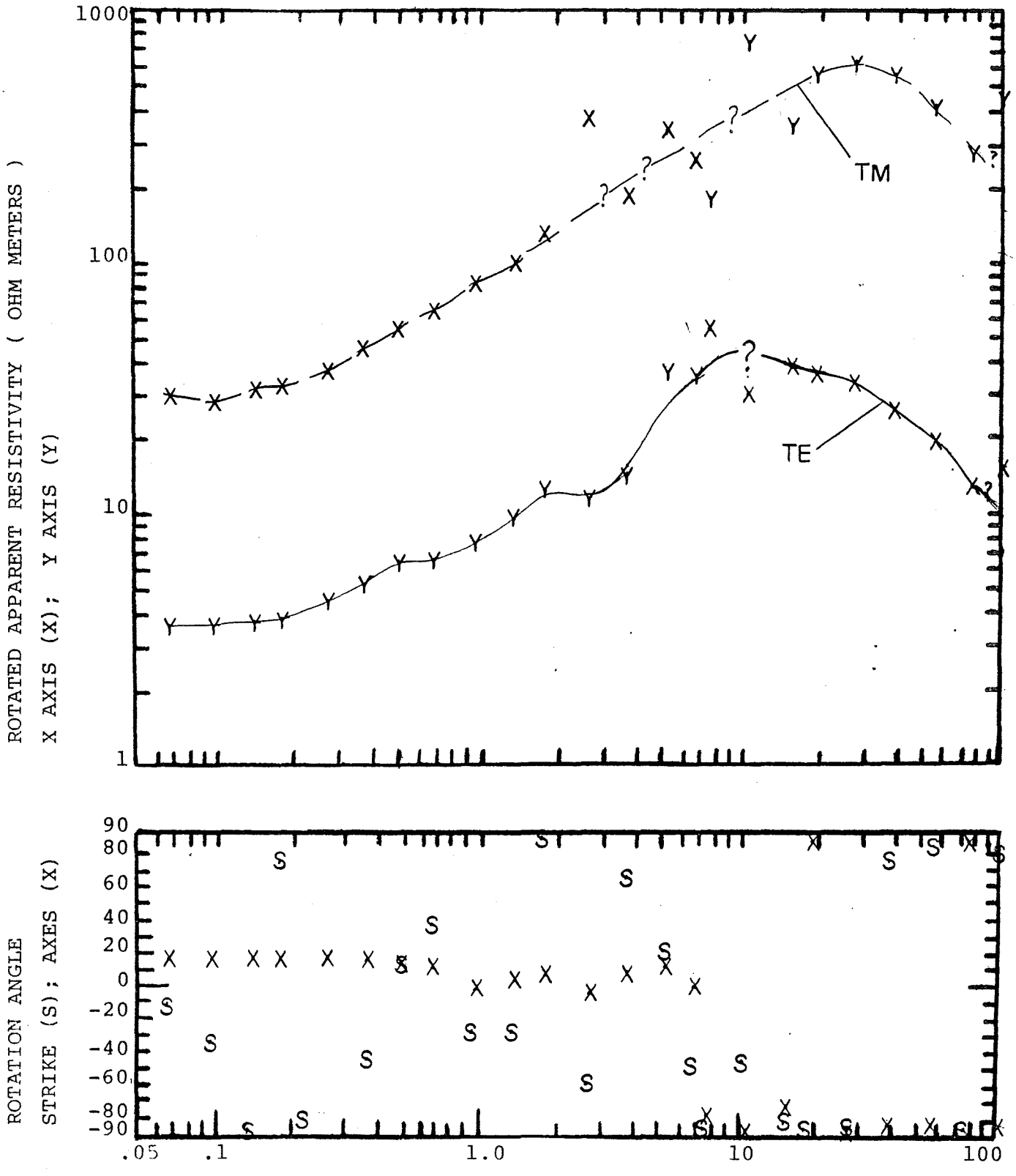
PROSPECT BULLY CREEK, OREGON

STATION 5M



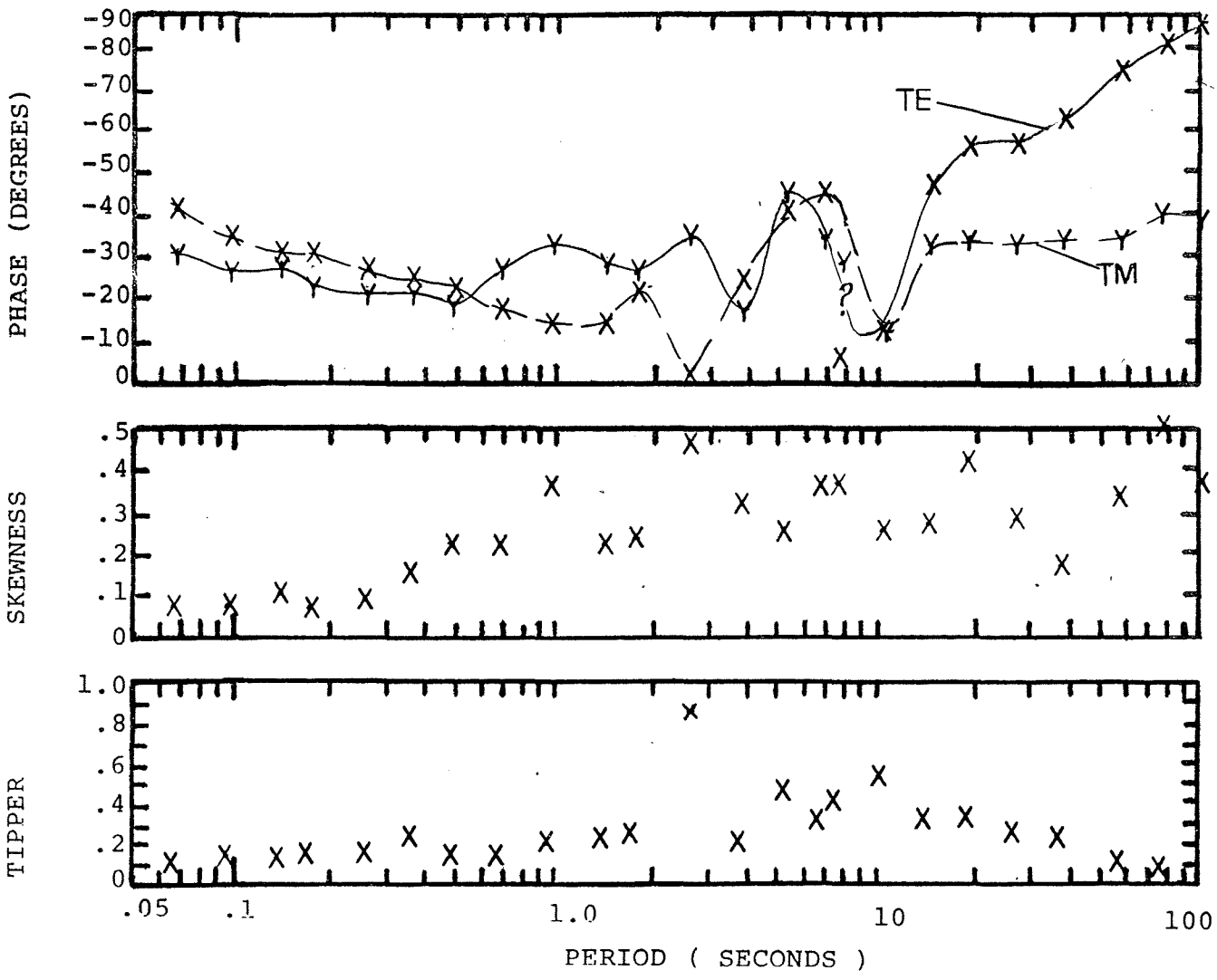
PROSPECT BULLY CREEK, OREGON

STATION 5A



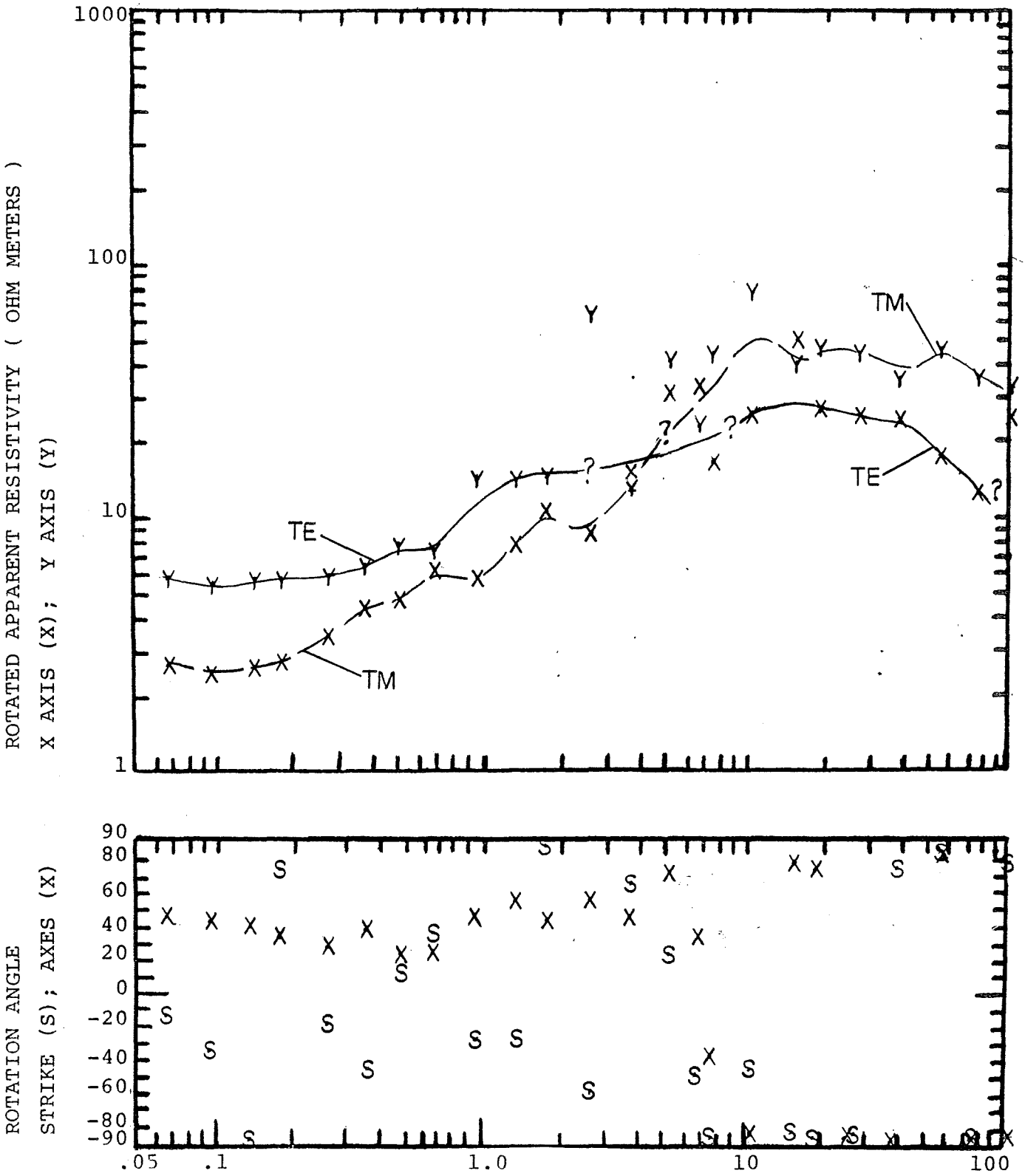
PROSPECT BULLY CREEK, OREGON

STATION 5A



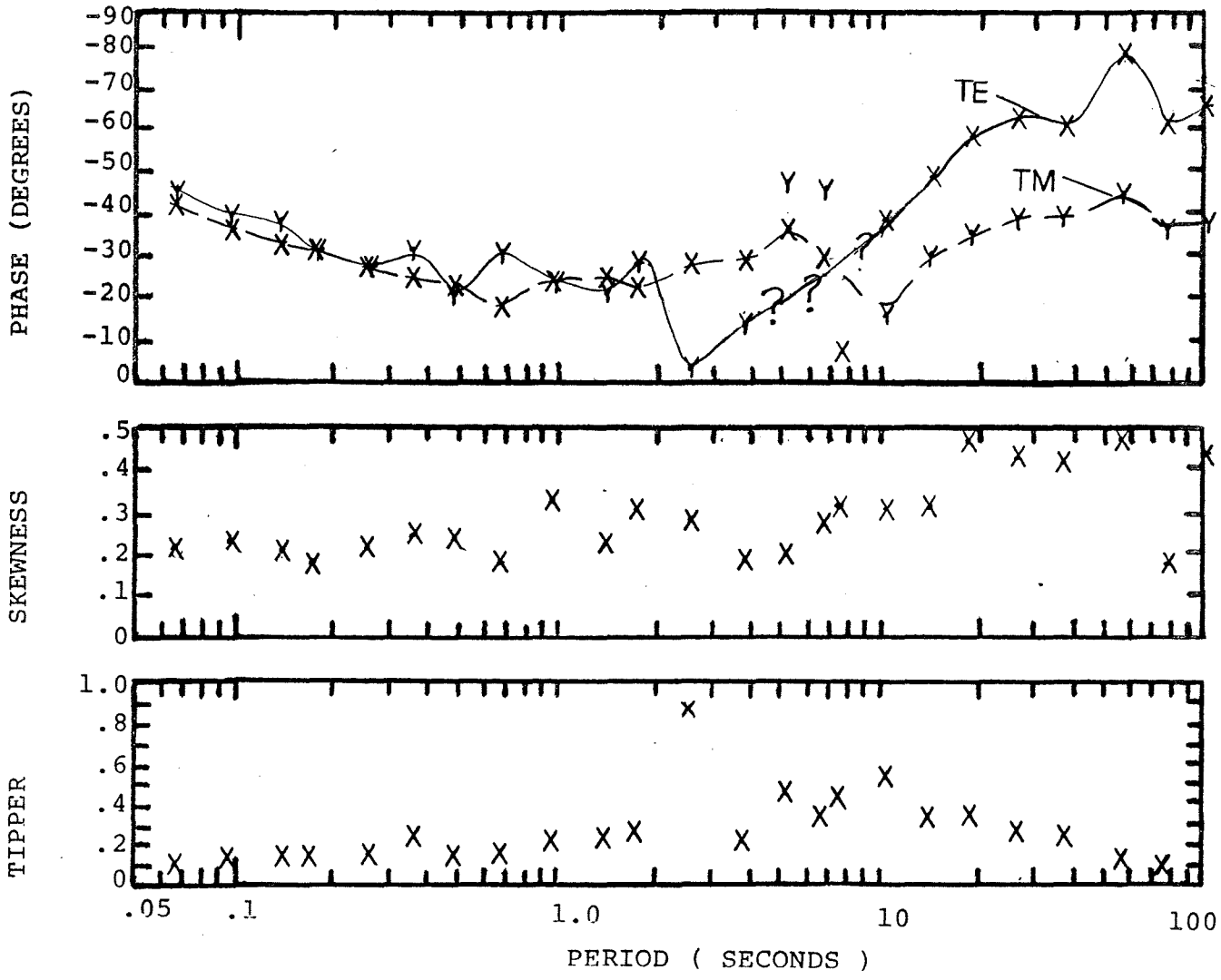
PROSPECT BULLY CREEK, OREGON

STATION 5B



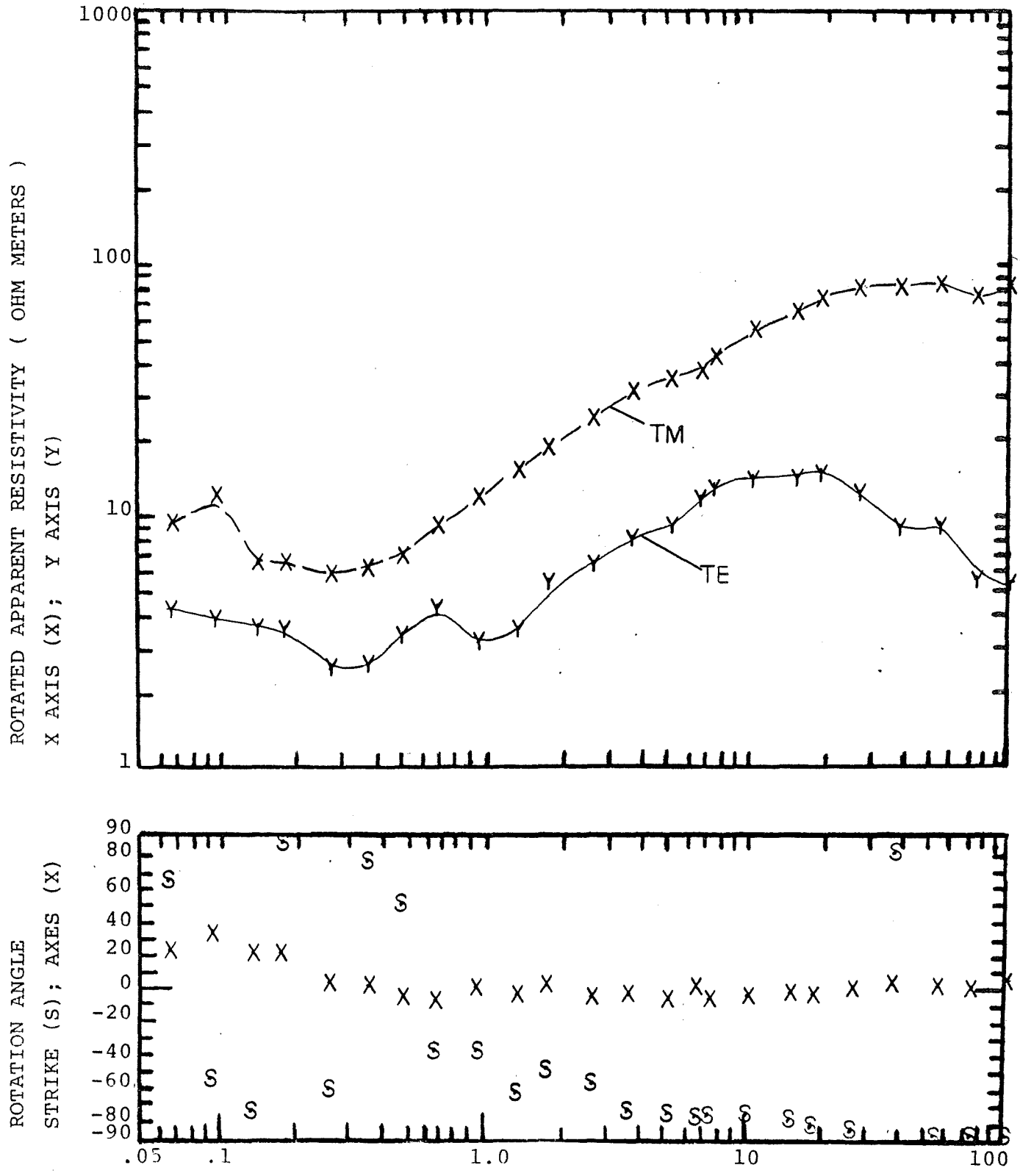
PROSPECT BULLY CREEK, OREGON

STATION 5B



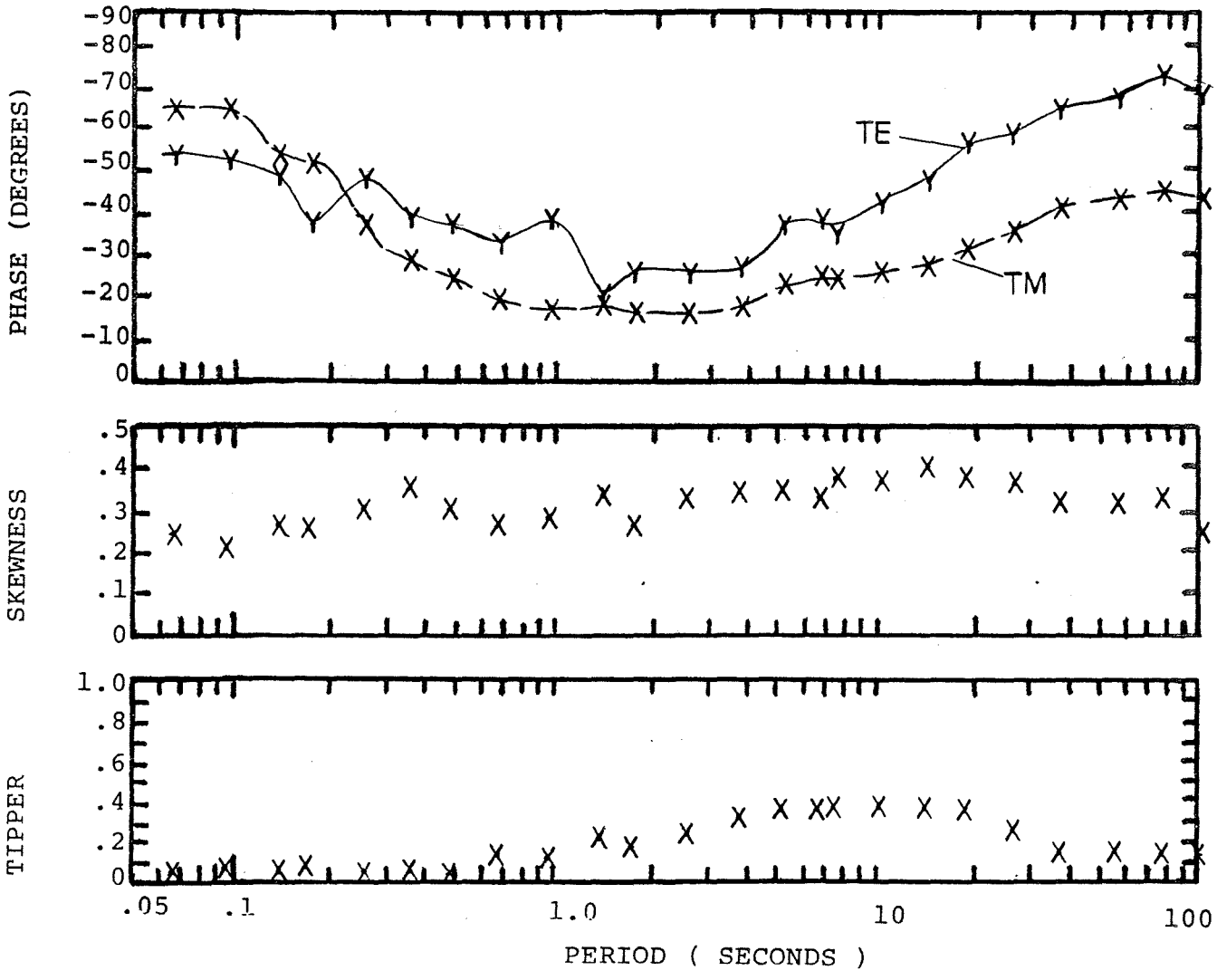
PROSPECT BULLY CREEK, OREGON

STATION 6M



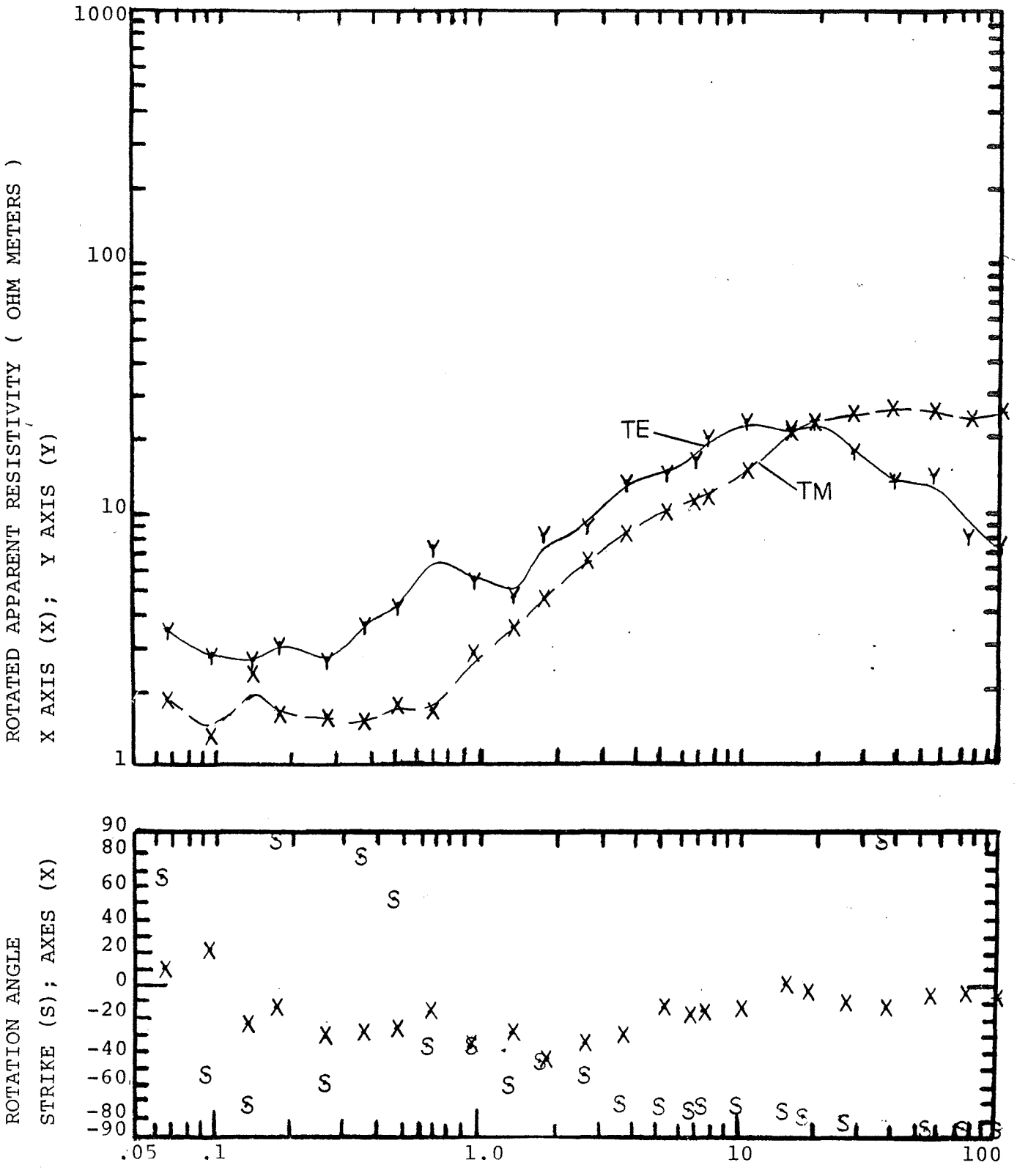
PROSPECT BULLY CREEK, OREGON

STATION 6M



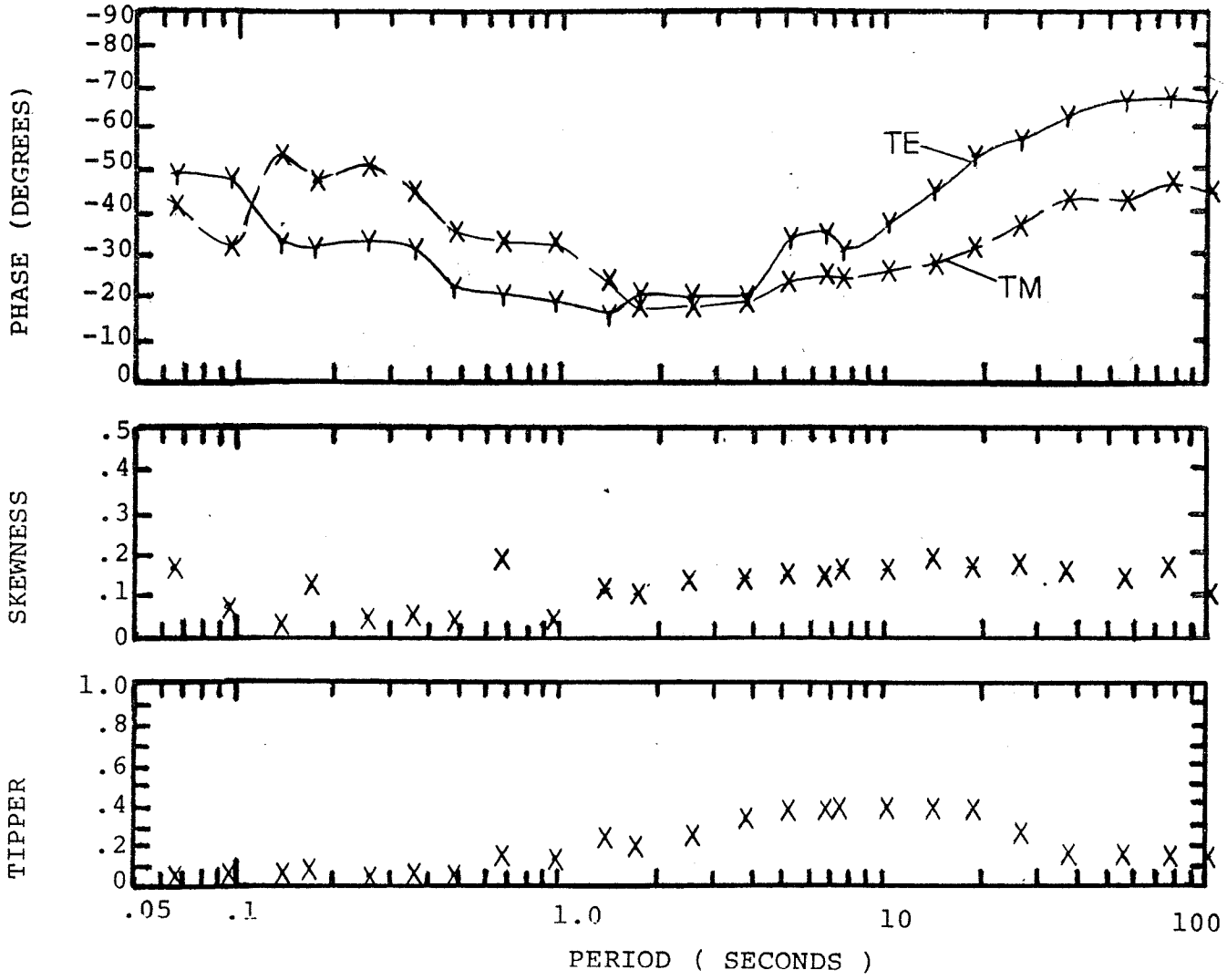
PROSPECT BULLY CREEK, OREGON

STATION 6A



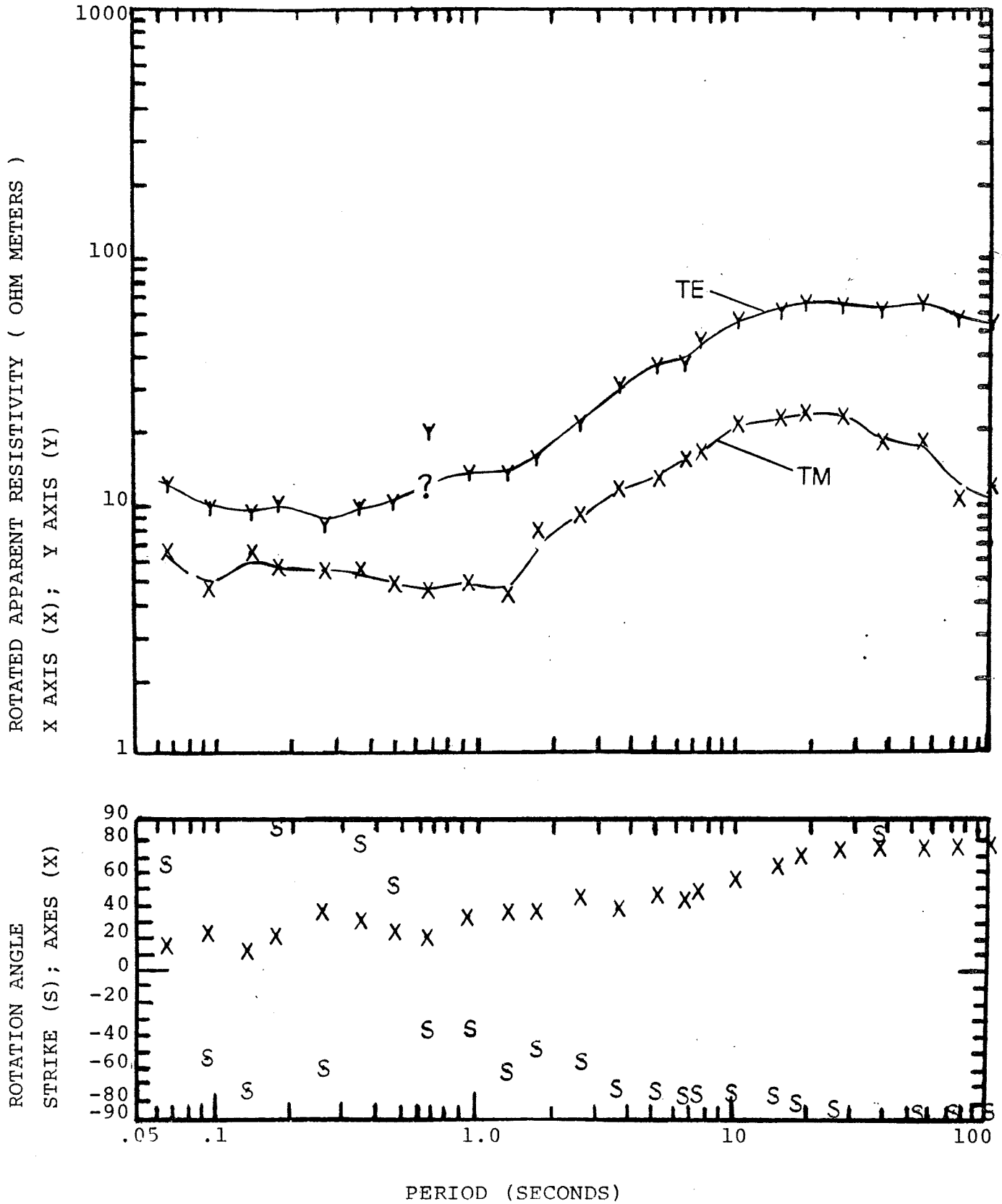
PROSPECT BULLY CREEK, OREGON

STATION 6A



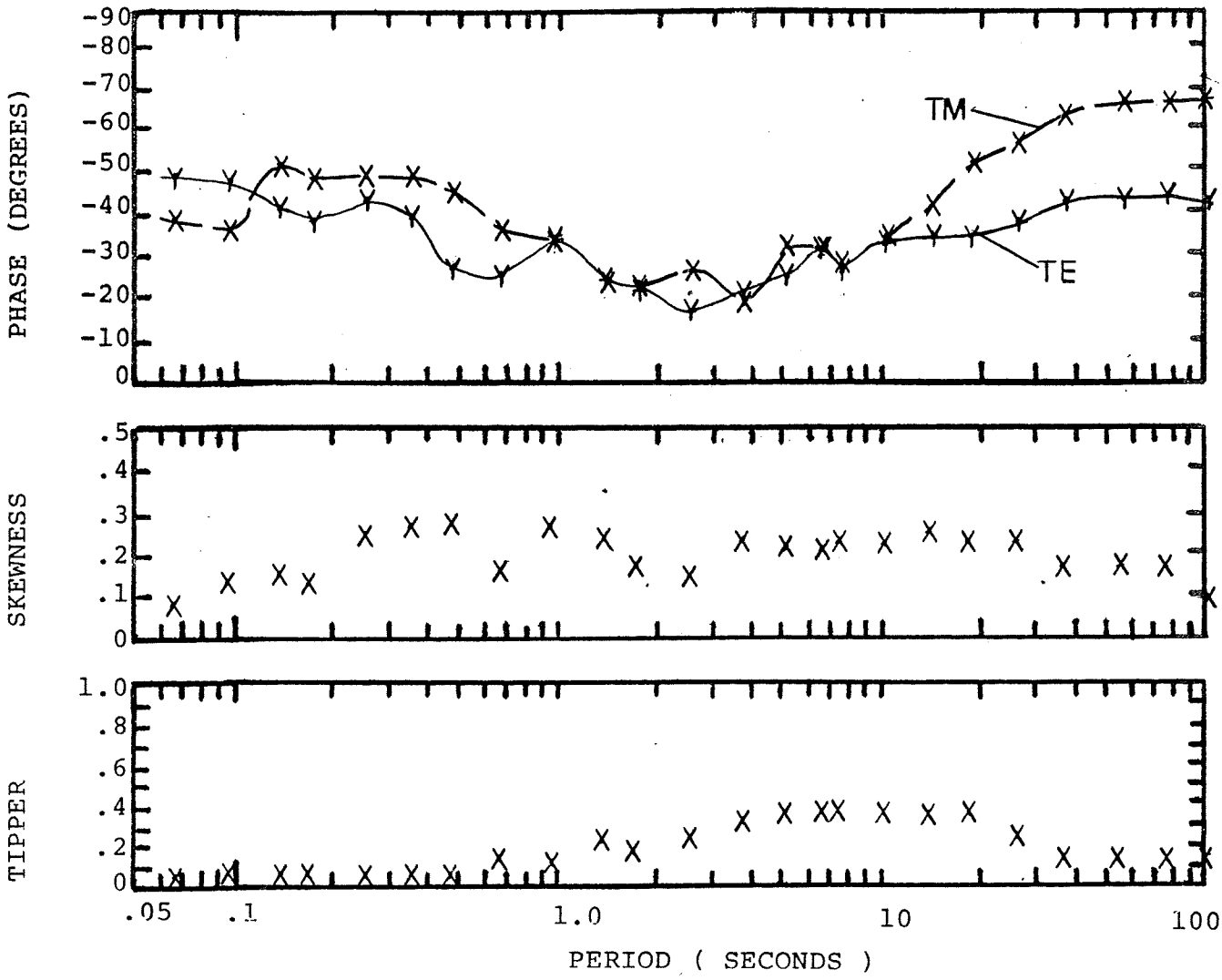
PROSPECT BULLY CREEK, OREGON

STATION 6B



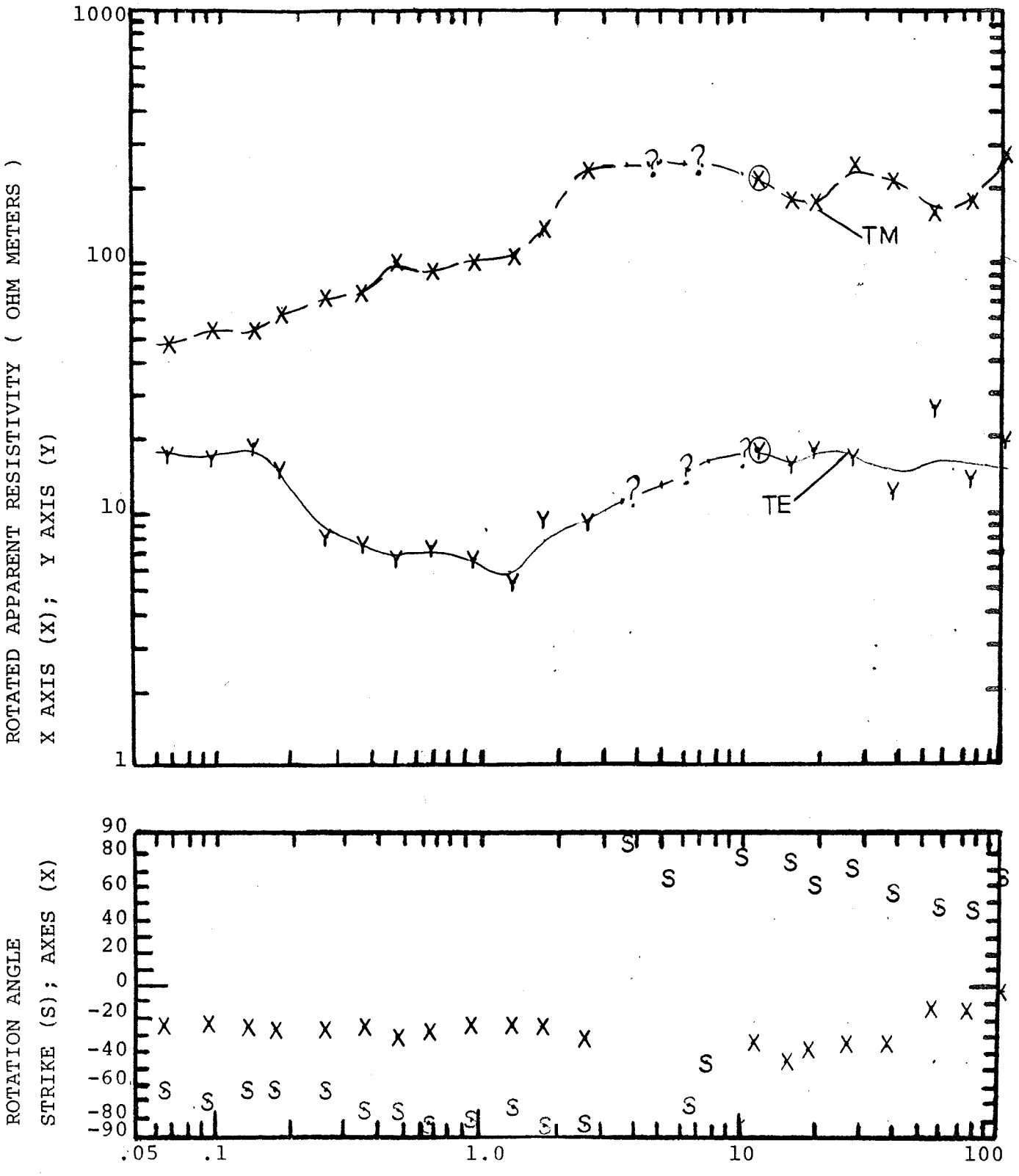
PROSPECT BULLY CREEK, OREGON

STATION 6B



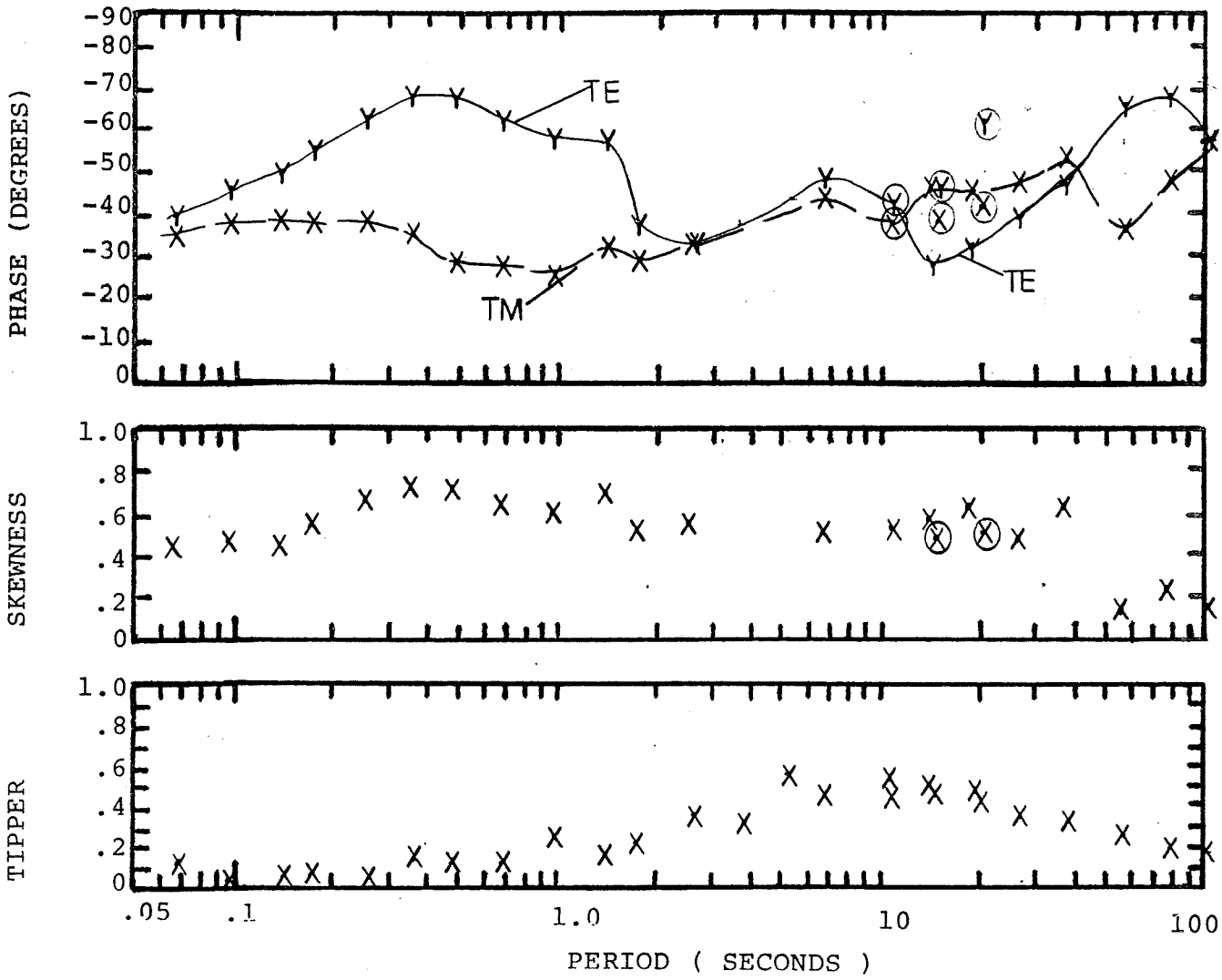
PROSPECT BULLY CREEK, OREGON

STATION 7M



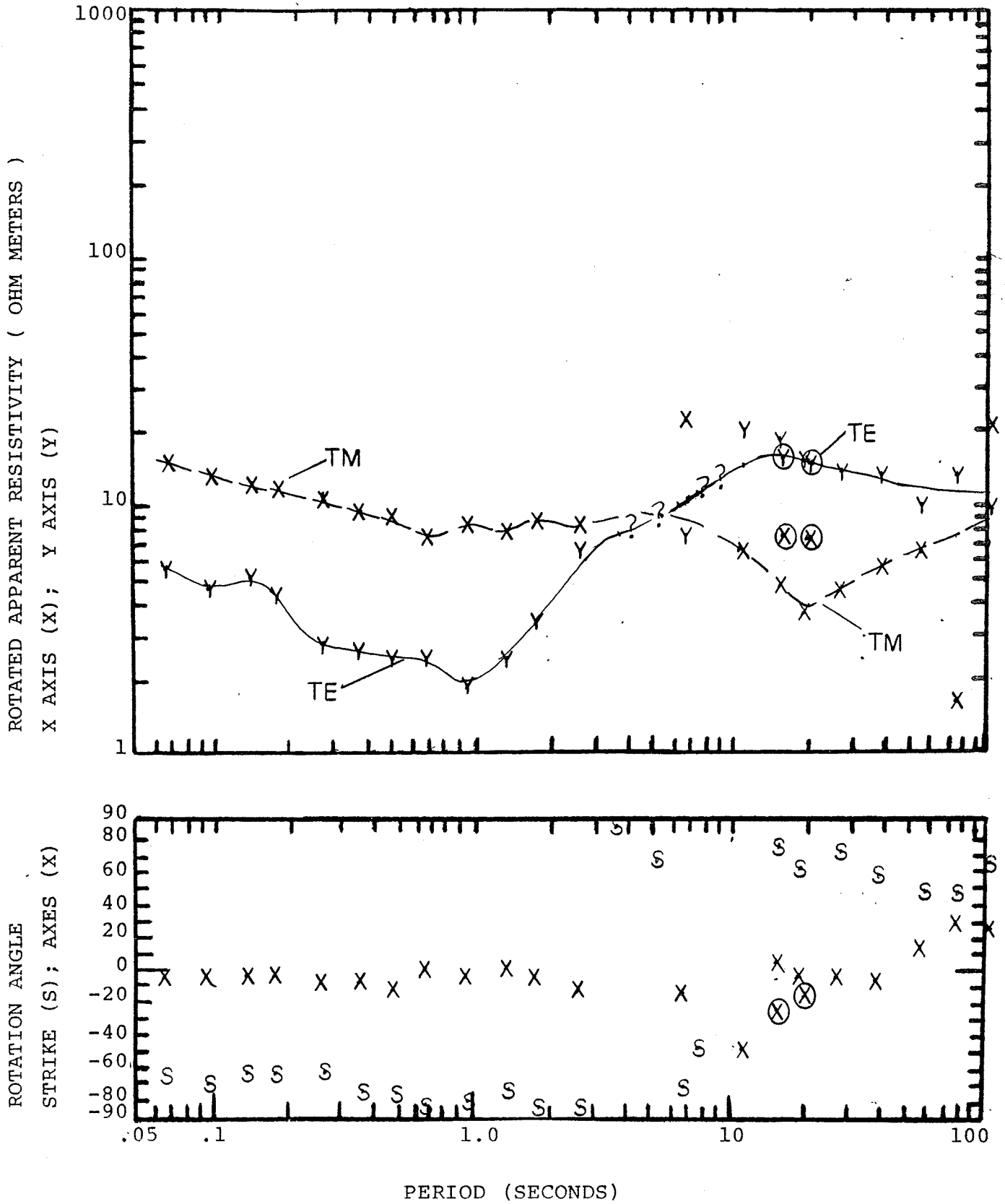
PROSPECT BULLY CREEK, OREGON

STATION 7M



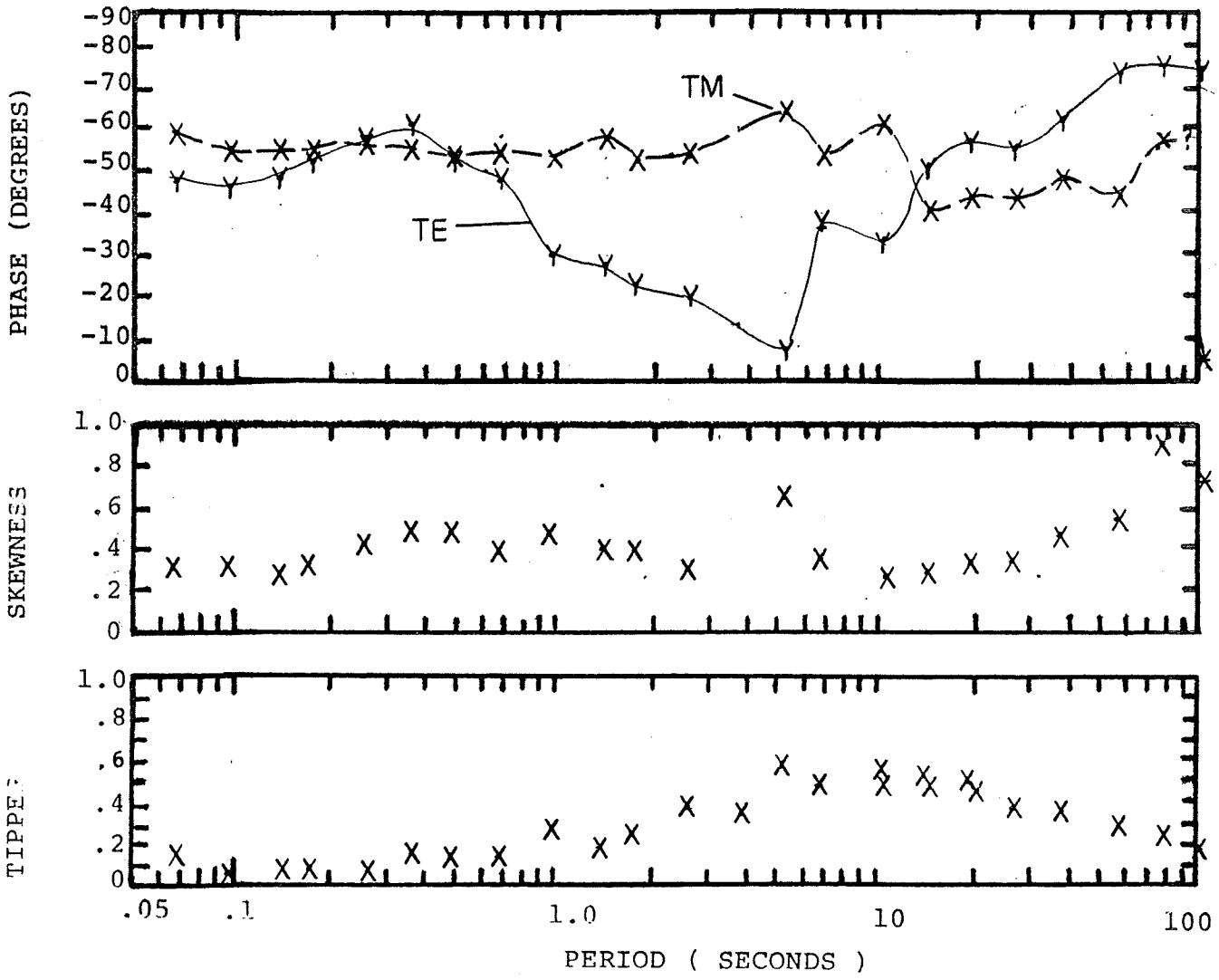
PROSPECT BULLY CREEK, OREGON

STATION 7A



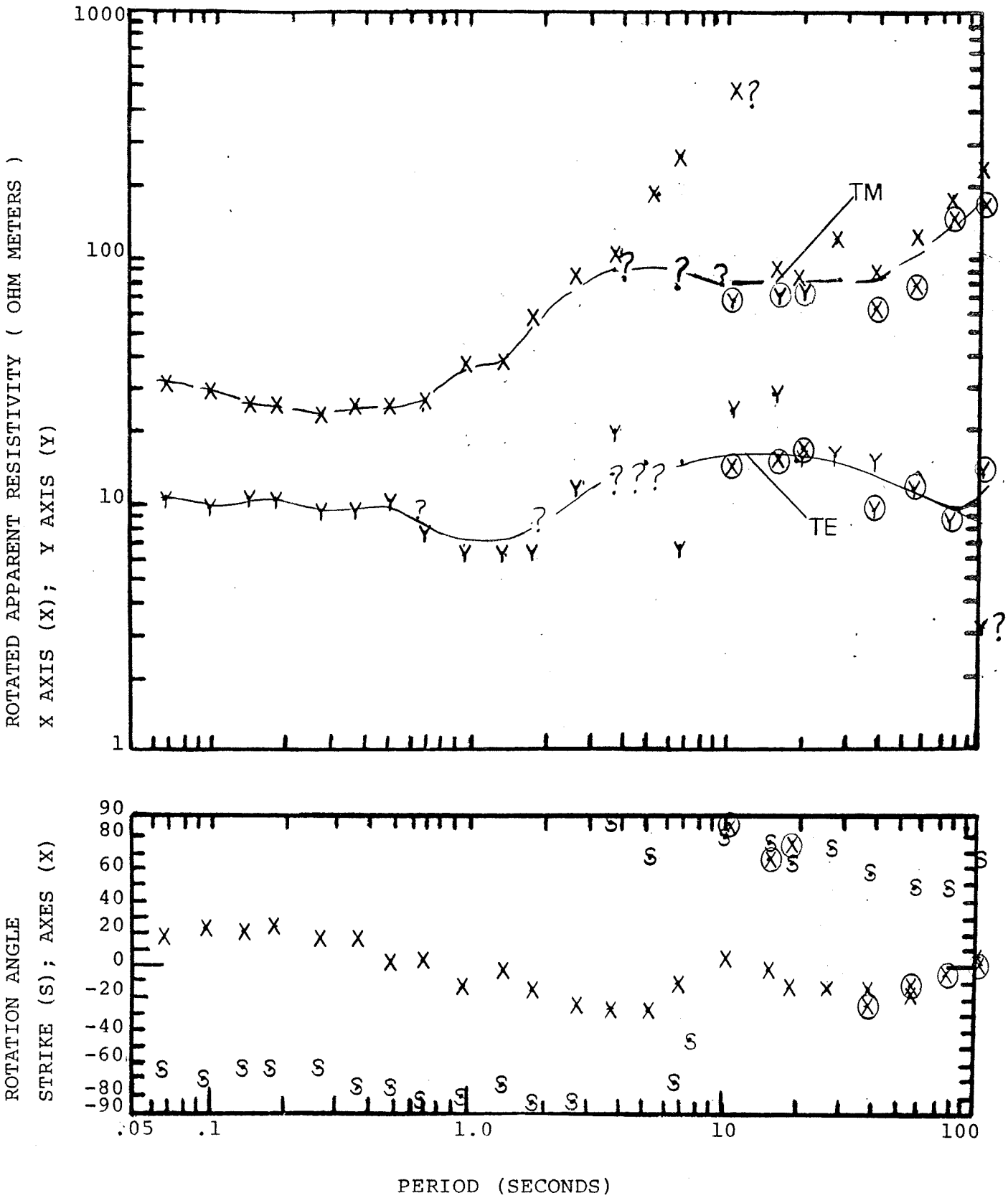
PROSPECT BULLY CREEK, OREGON

STATION 7A



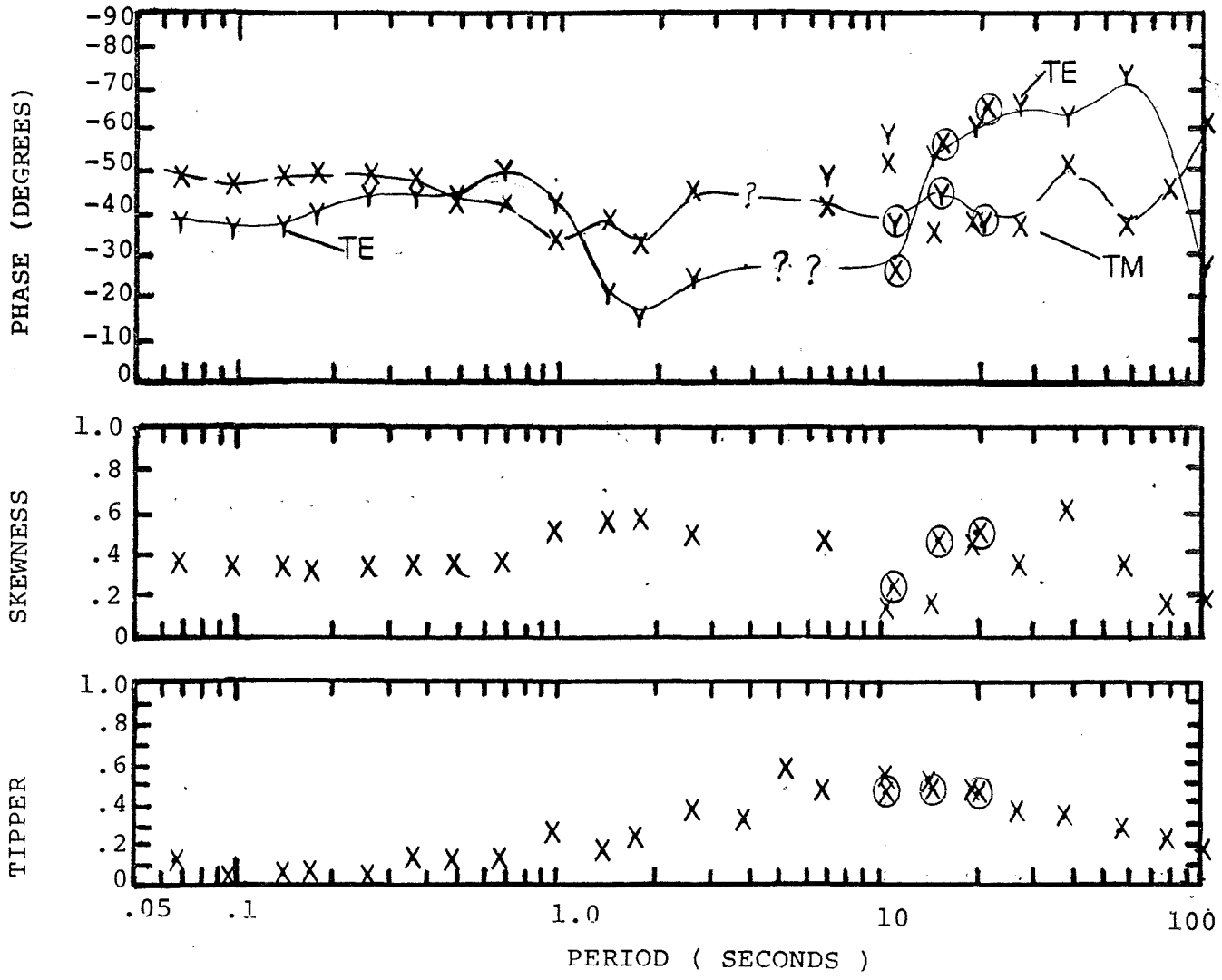
PROSPECT BULLY CREEK, OREGON

STATION 7B



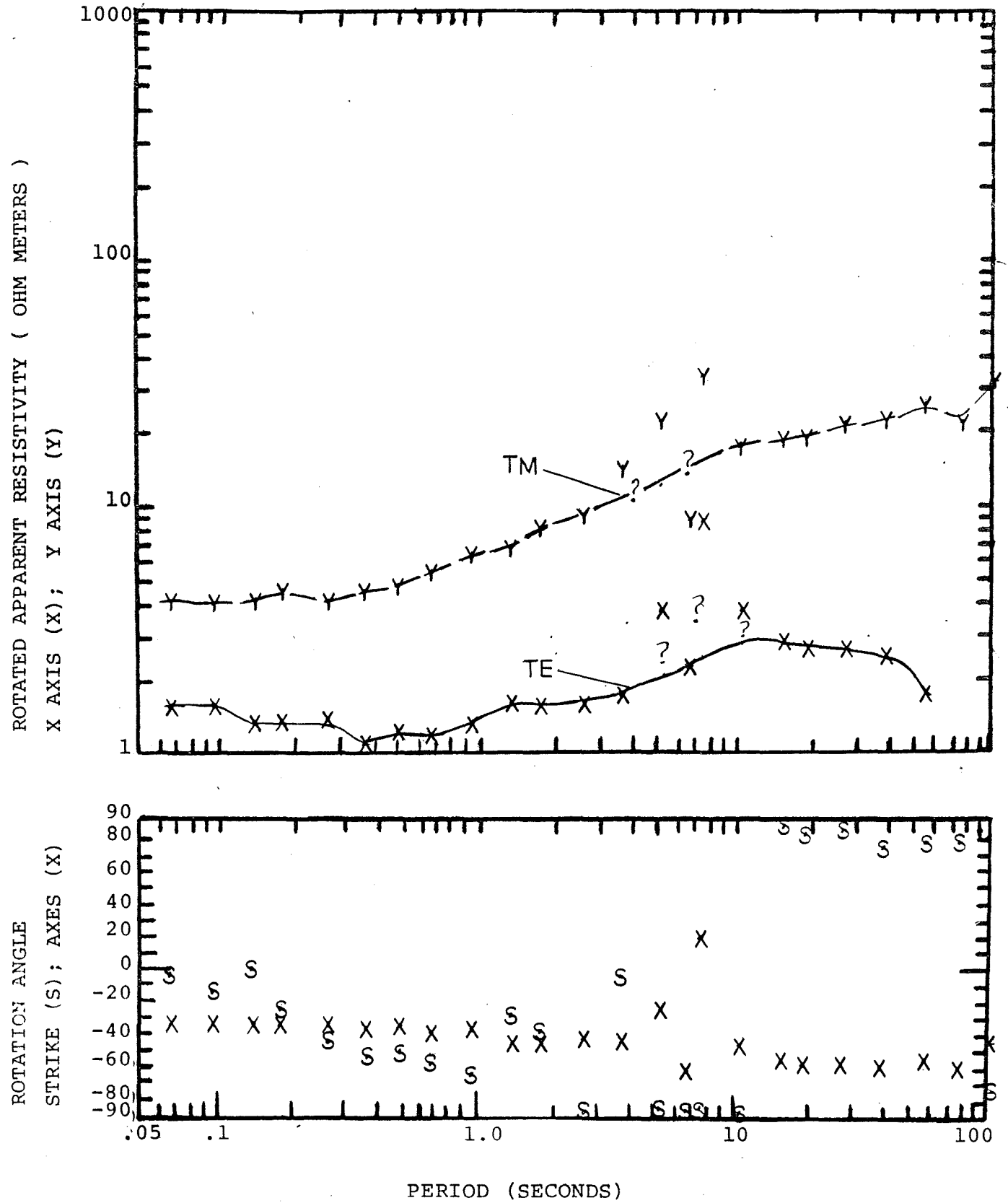
PROSPECT BULLY CREEK, OREGON

STATION 7B



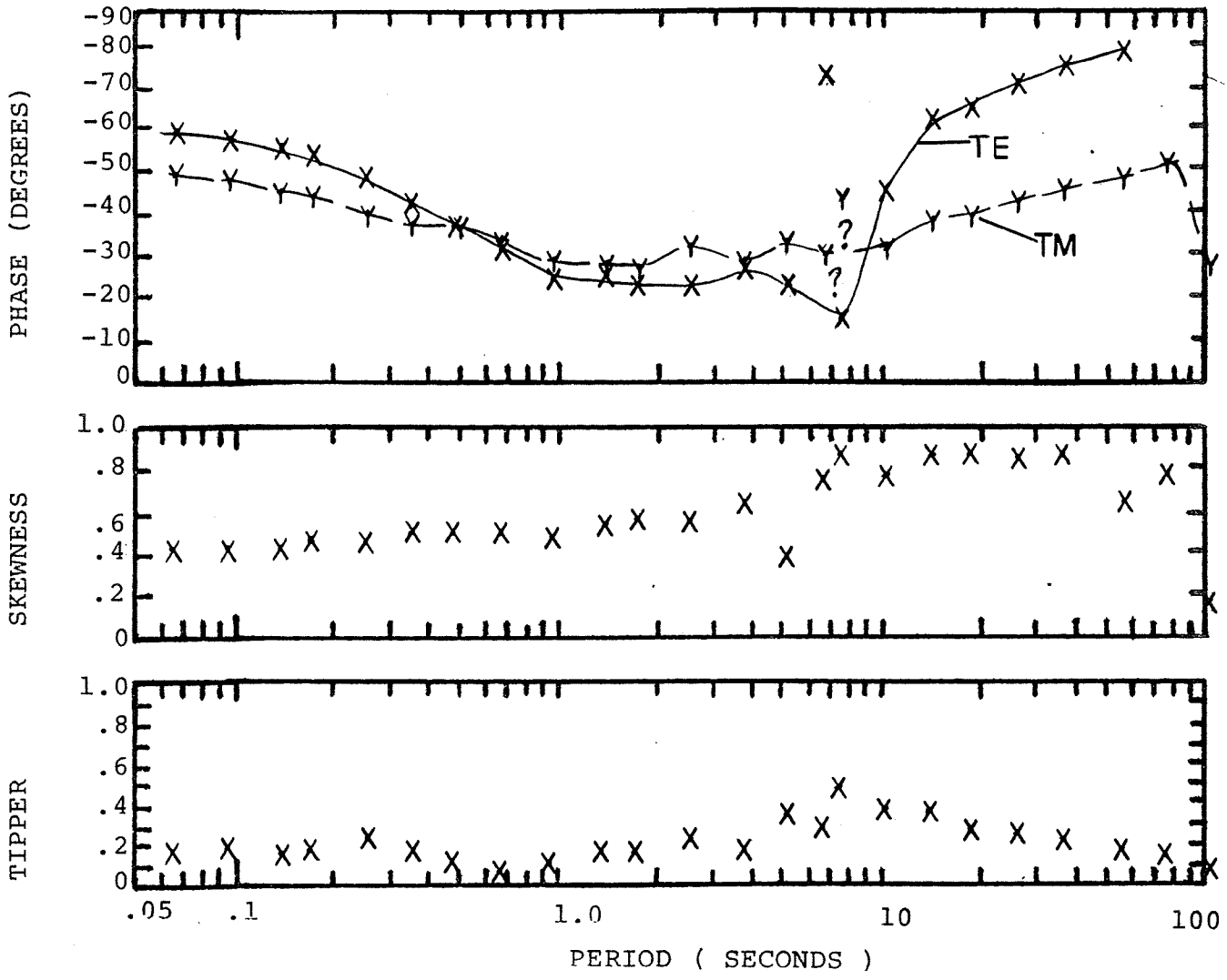
PROSPECT BULLY CREEK, OREGON

STATION 8M



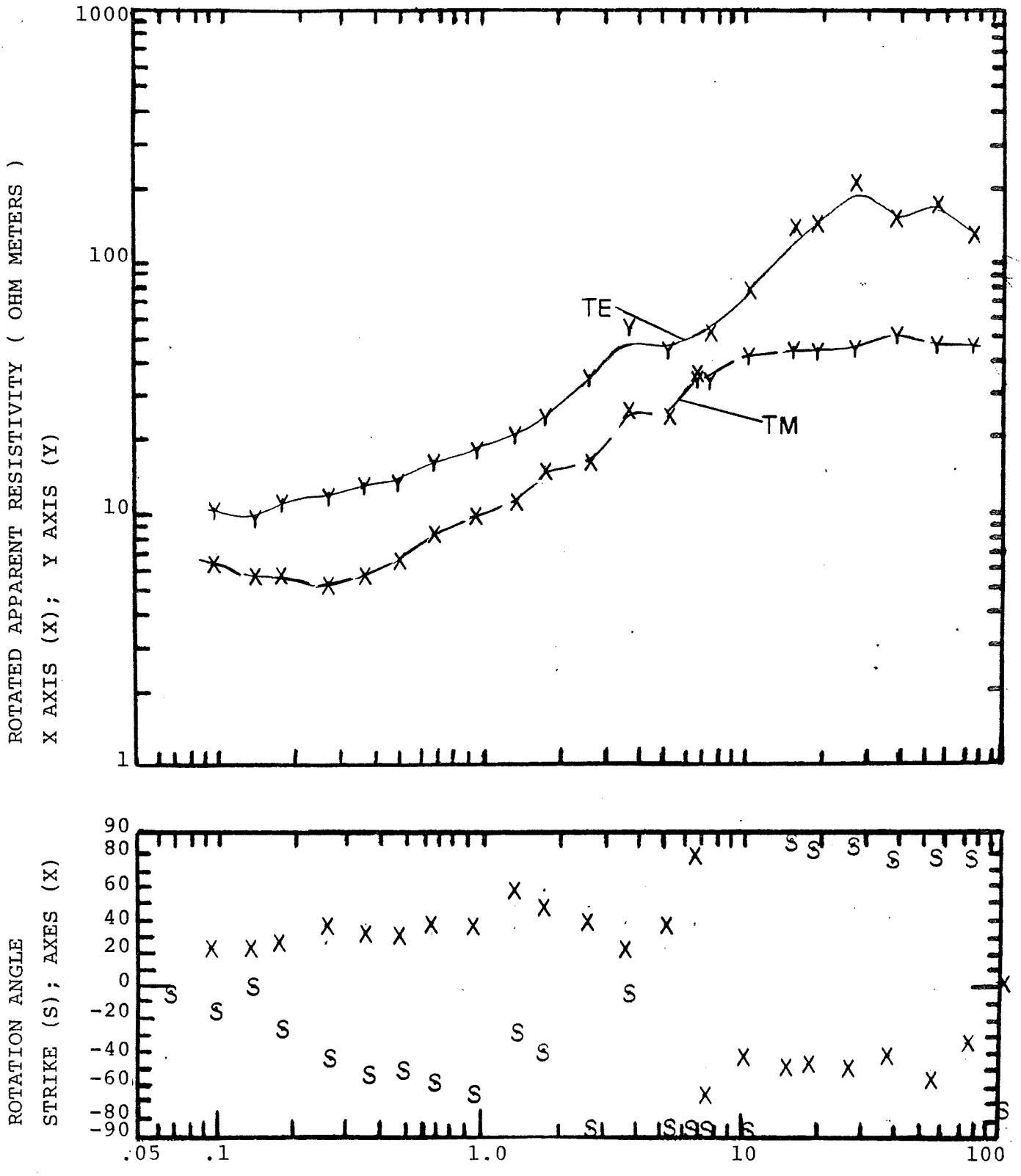
PROSPECT BULLY CREEK, OREGON

STATION 8M



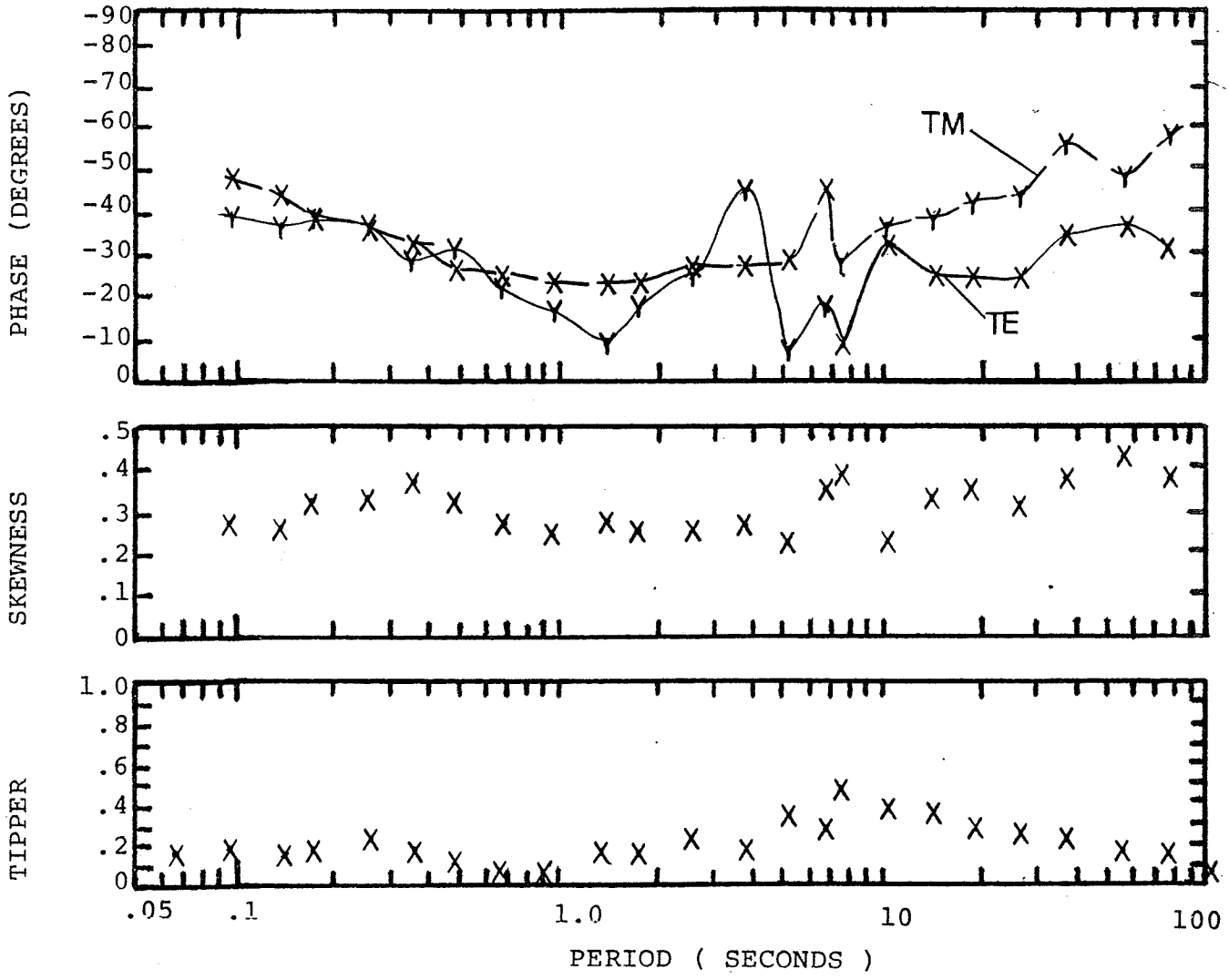
PROSPECT BULLY CREEK, OREGON

STATION 8A



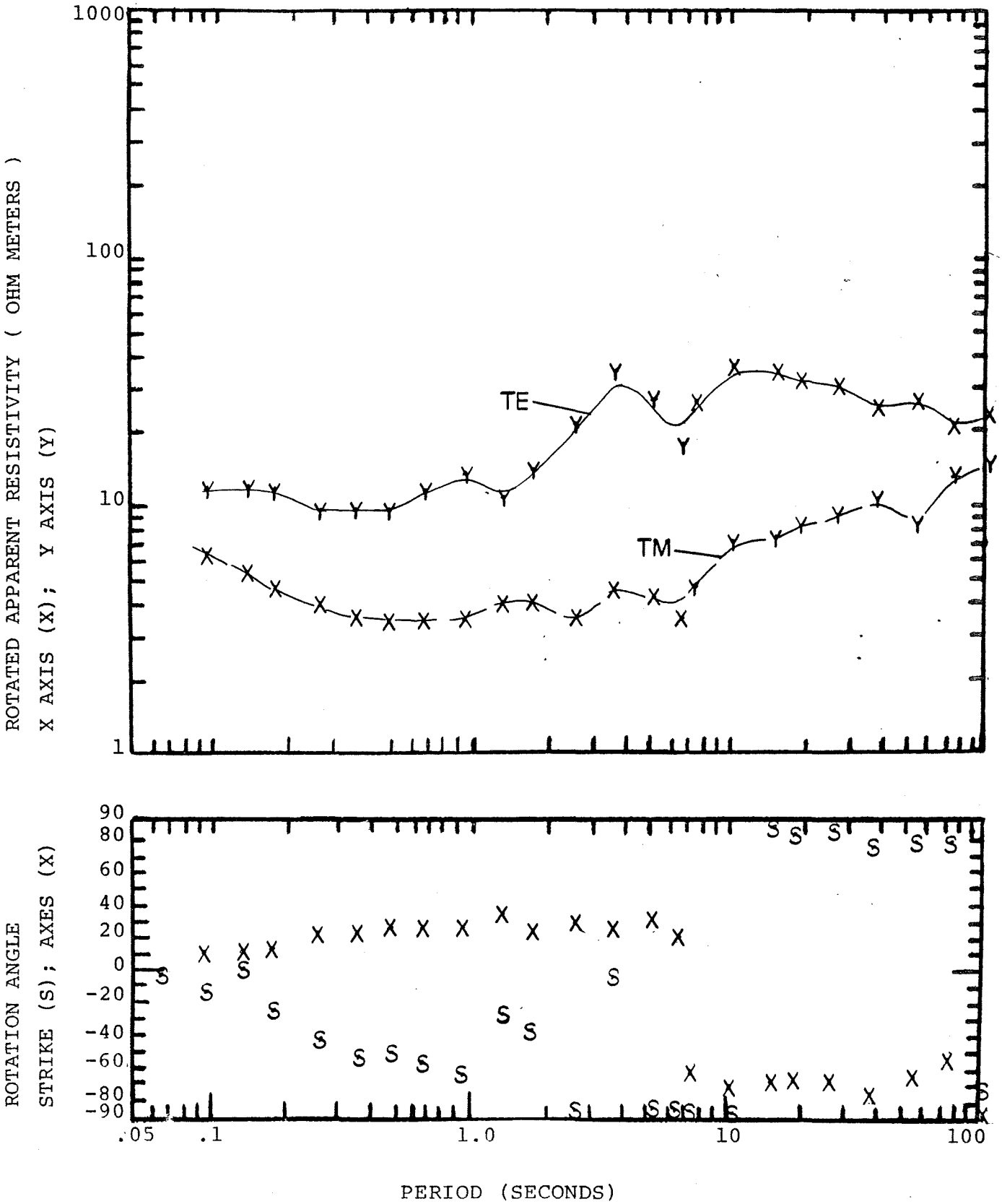
PROSPECT BULLY CREEK, OREGON

STATION 8A



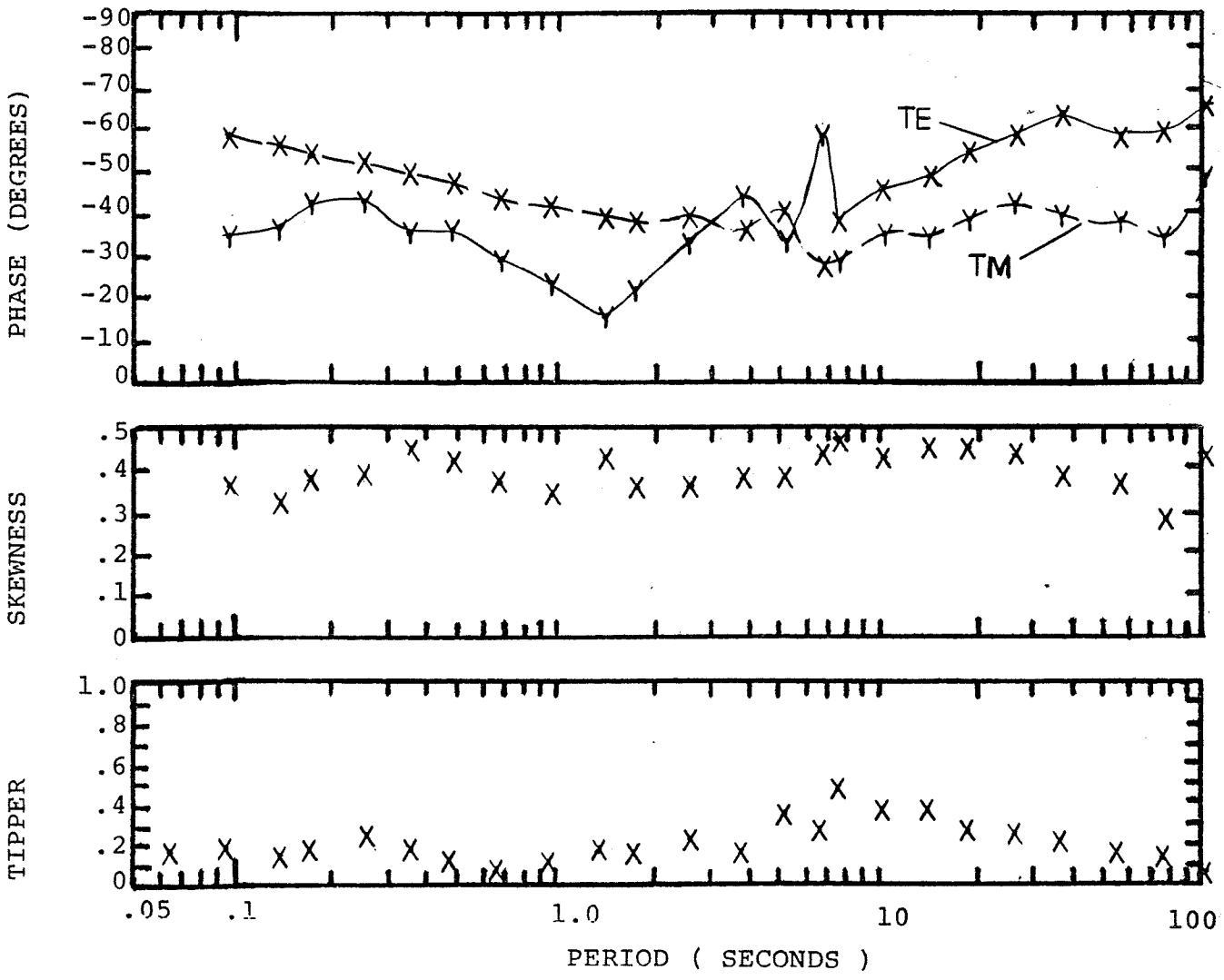
PROSPECT BULLY CREEK, OREGON

STATION 8B



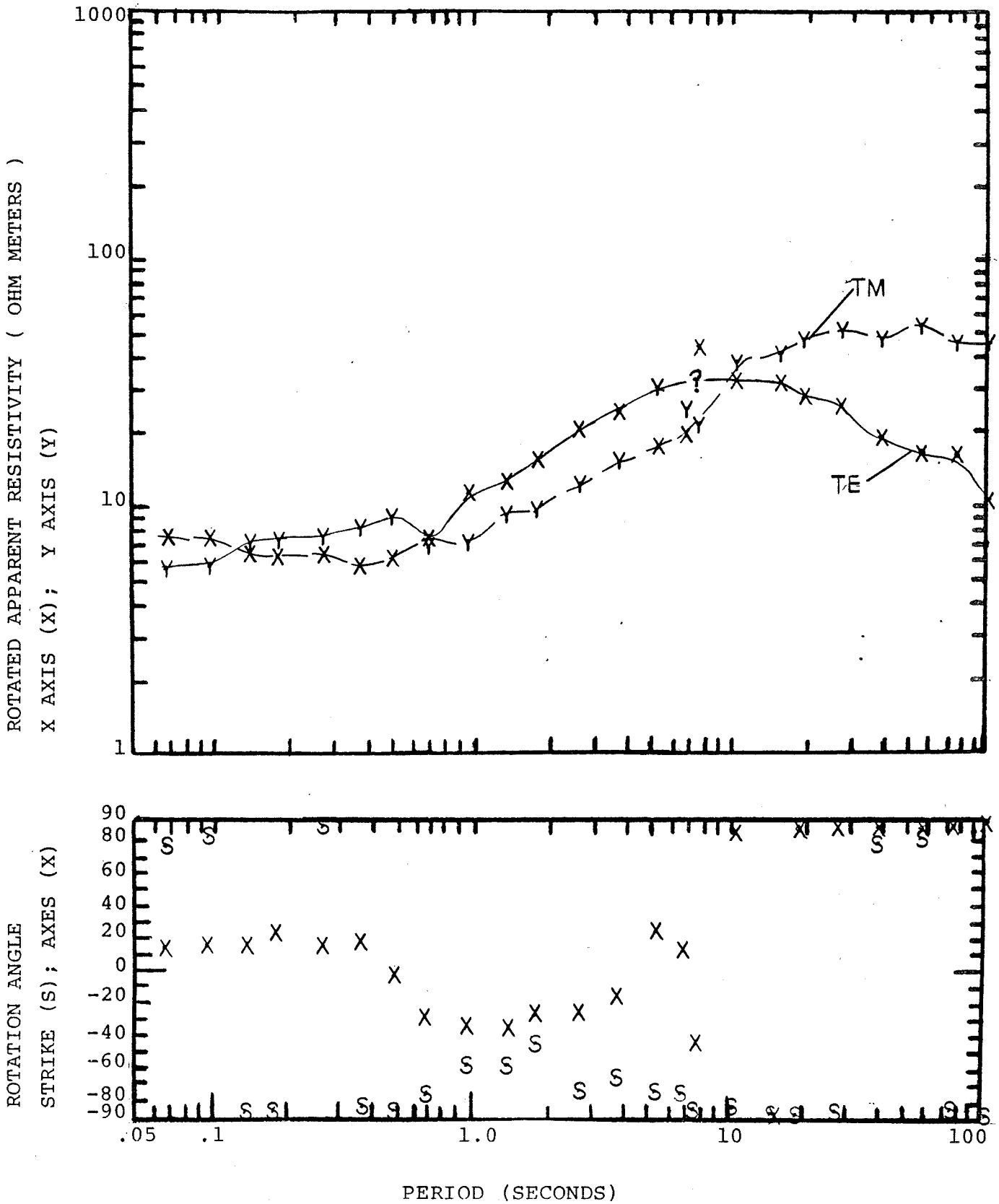
PROSPECT BULLY CREEK, OREGON

STATION 8B



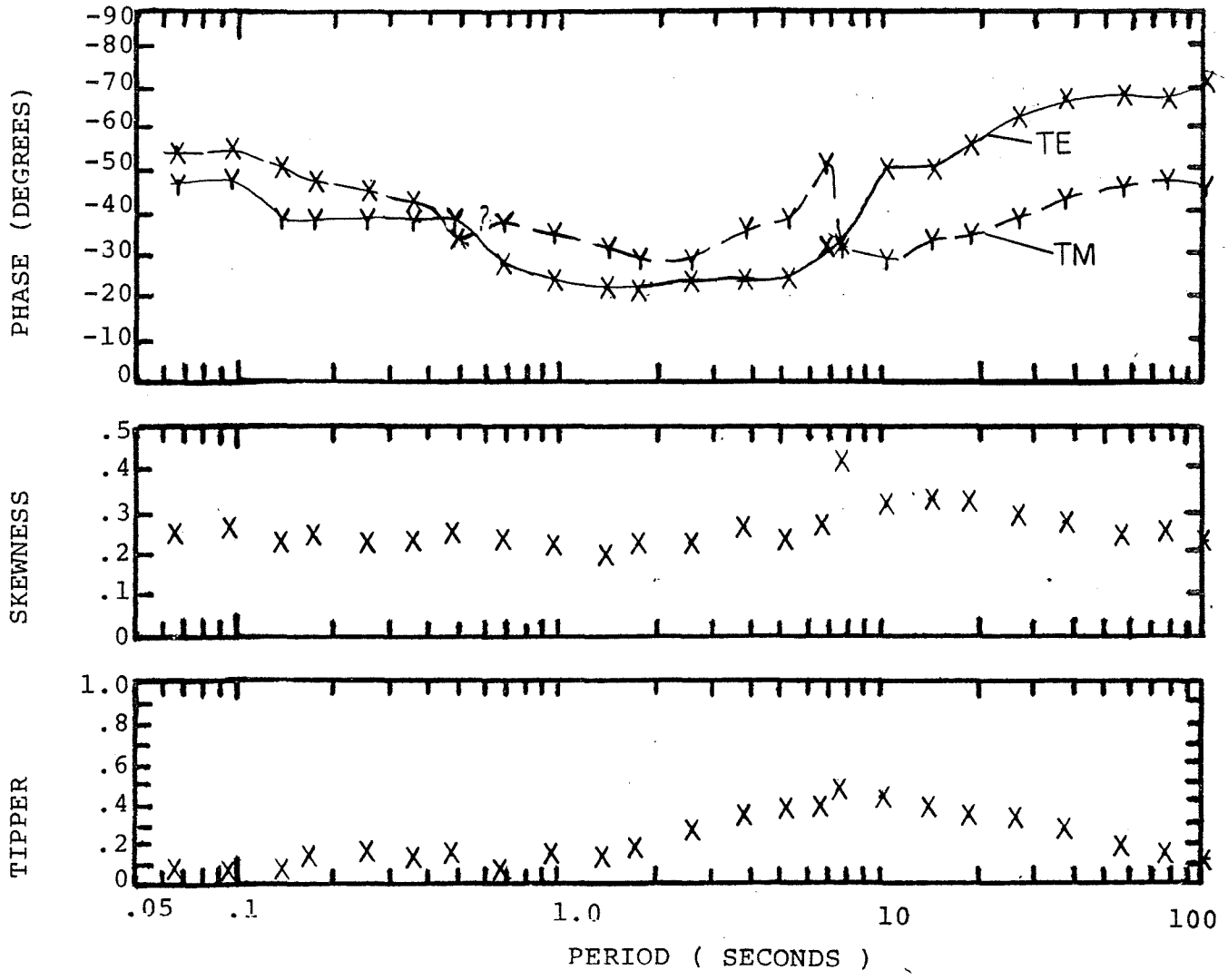
PROSPECT BULLY CREEK, OREGON

STATION 9M



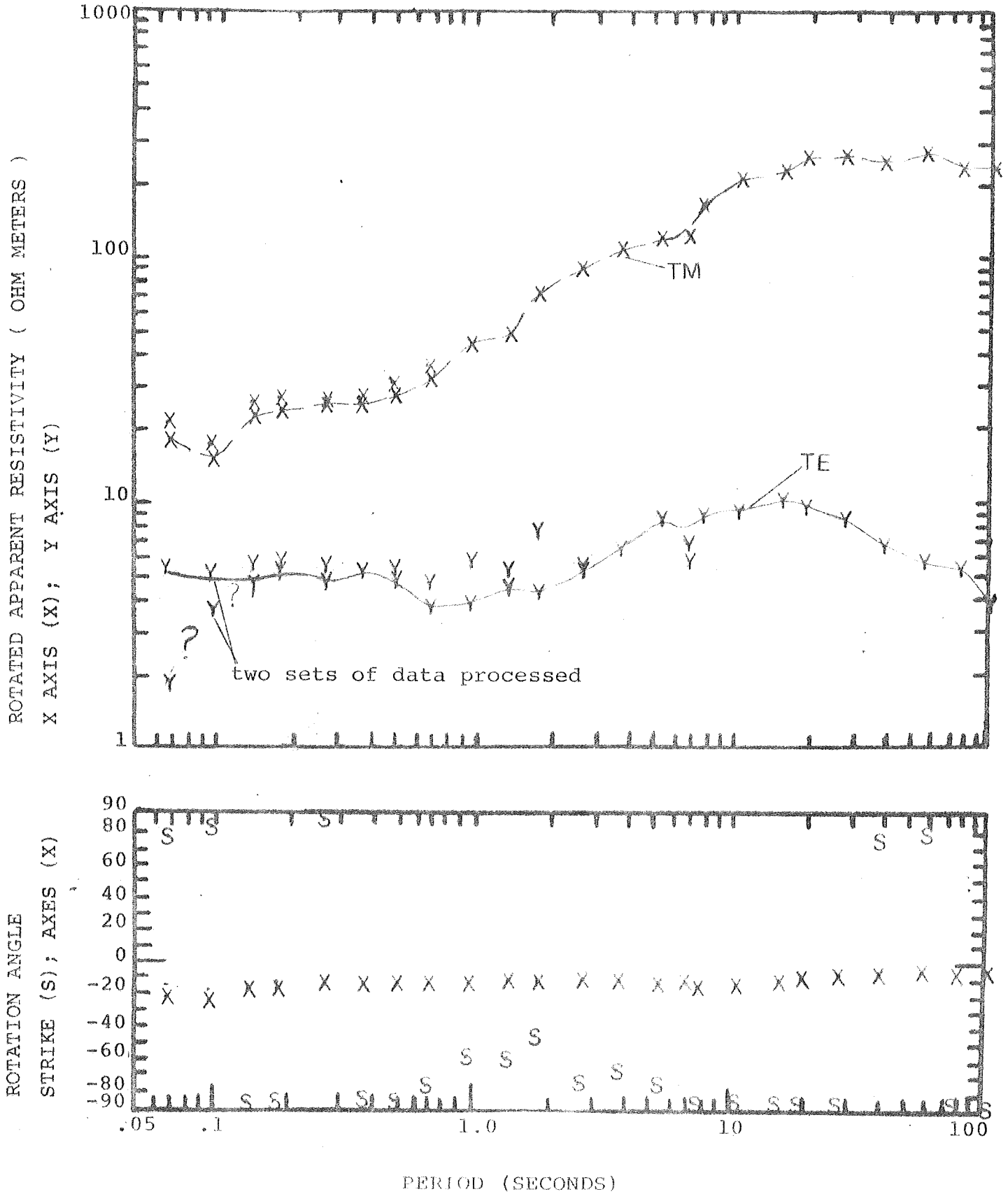
PROSPECT BULLY CREEK, OREGON

STATION 9M



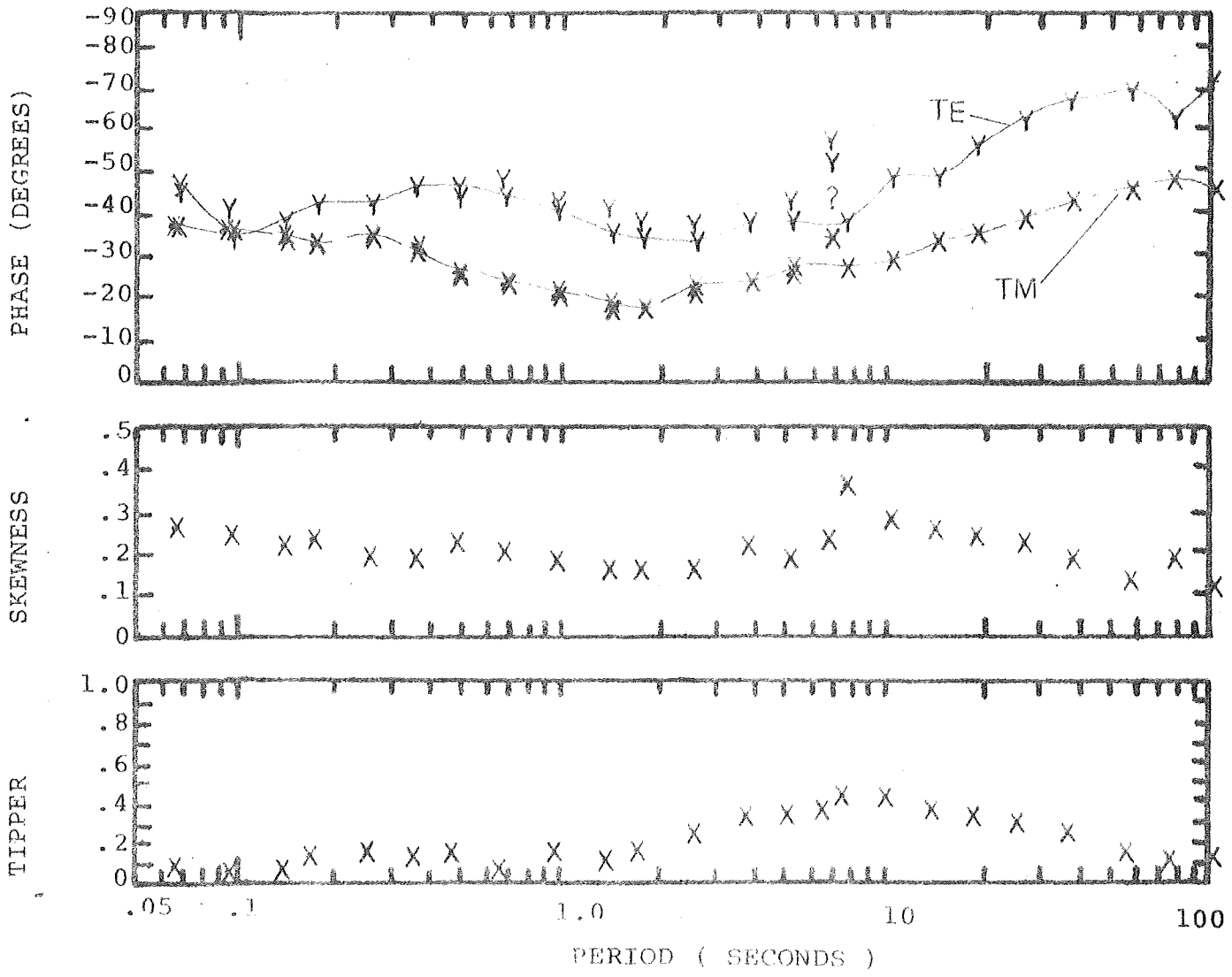
PROSPECT BULLY CREEK, OREGON

STATION 9A



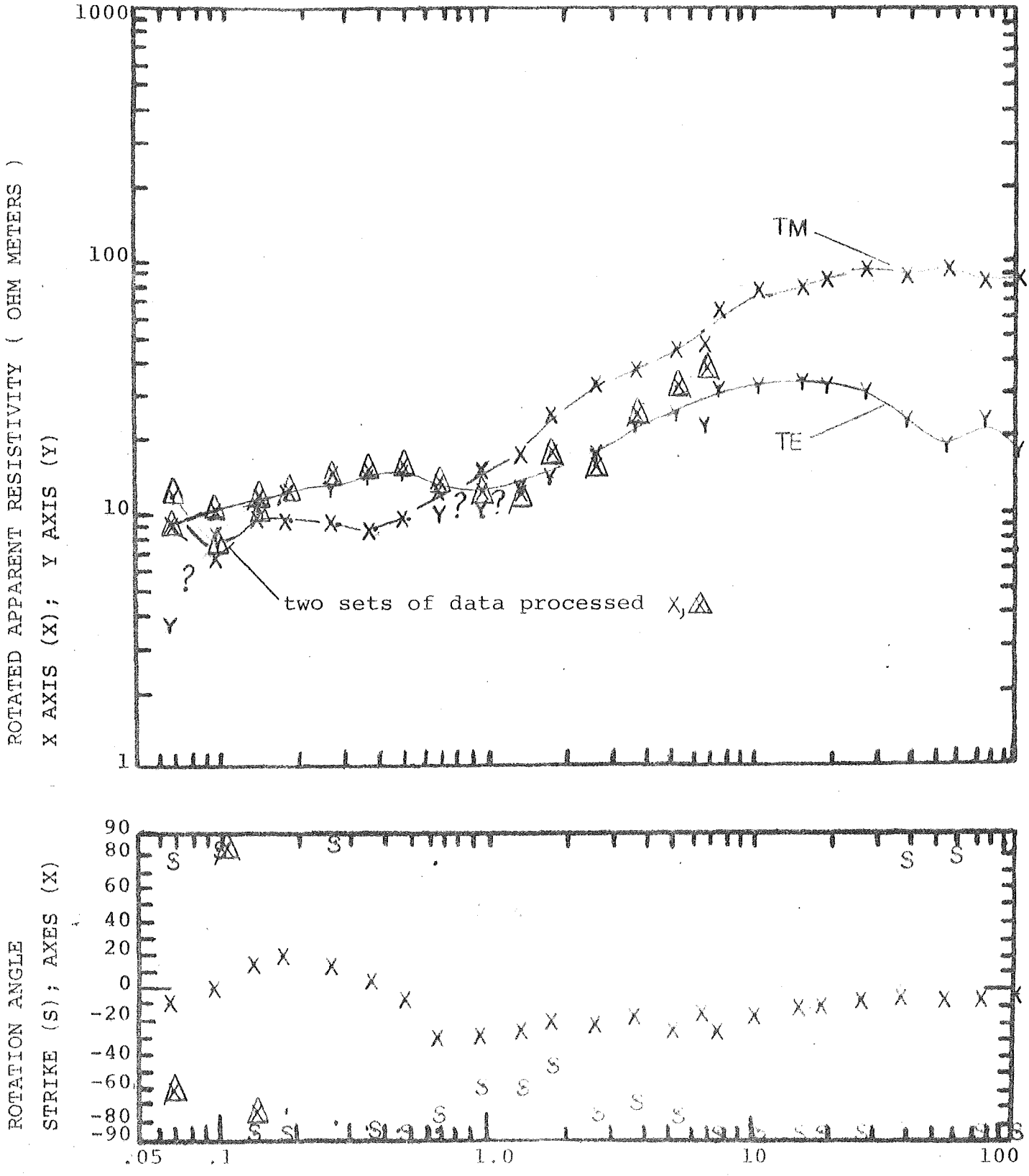
PROSPECT BULLY CREEK, OREGON

STATION 9A



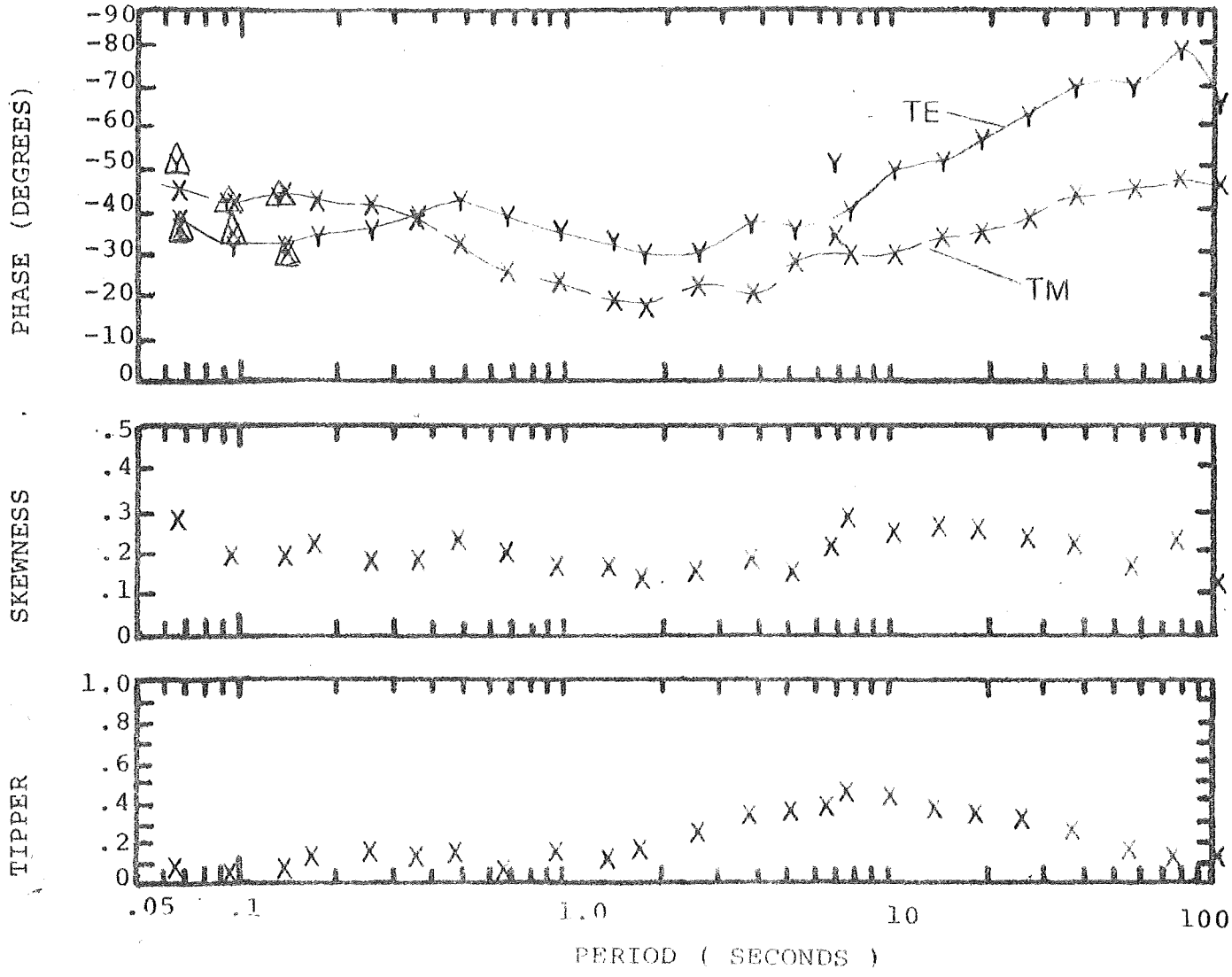
PROSPECT BULLY CREEK, OREGON

STATION 9B



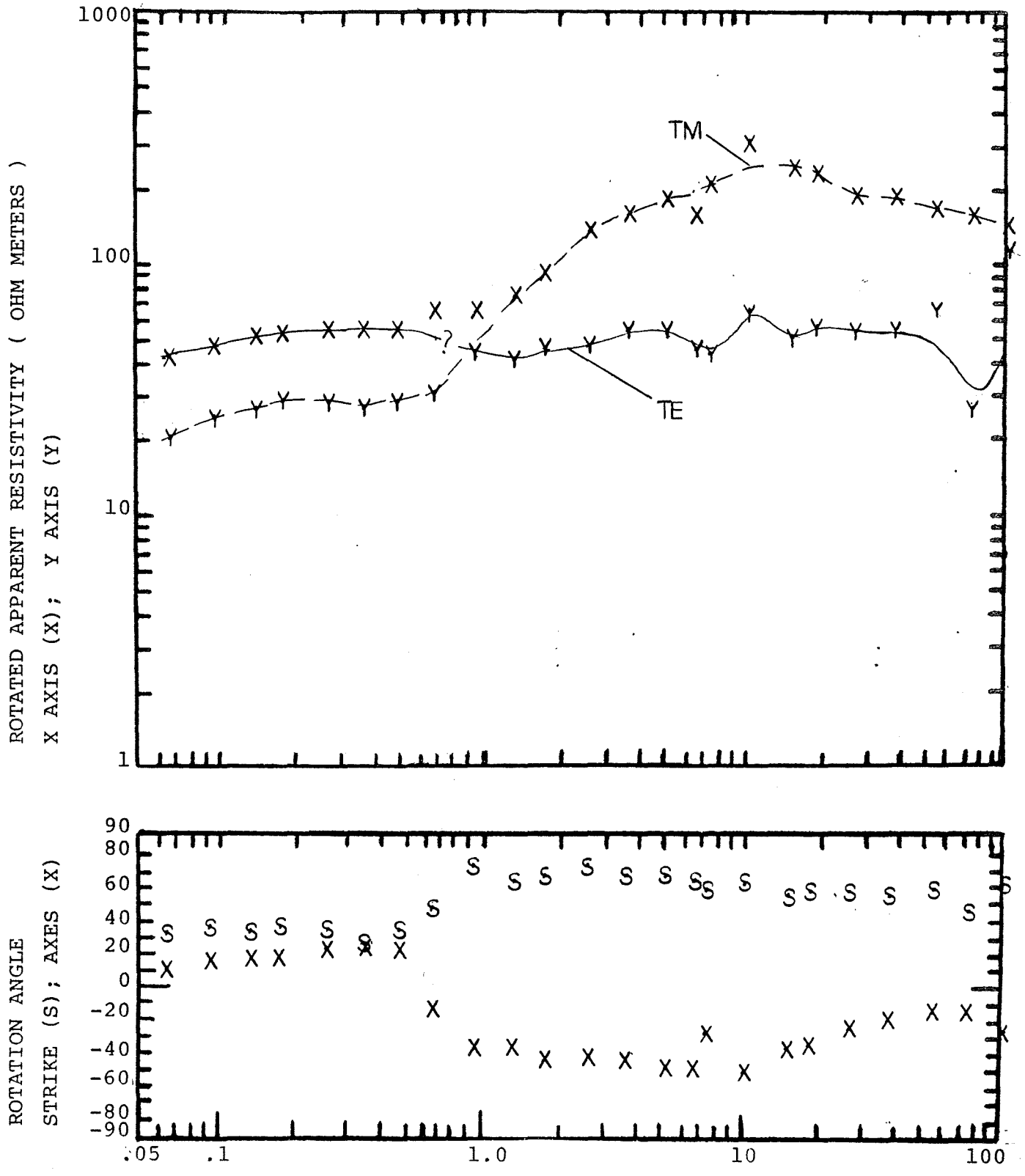
PROSPECT BULLY CREEK, OREGON

STATION 9B



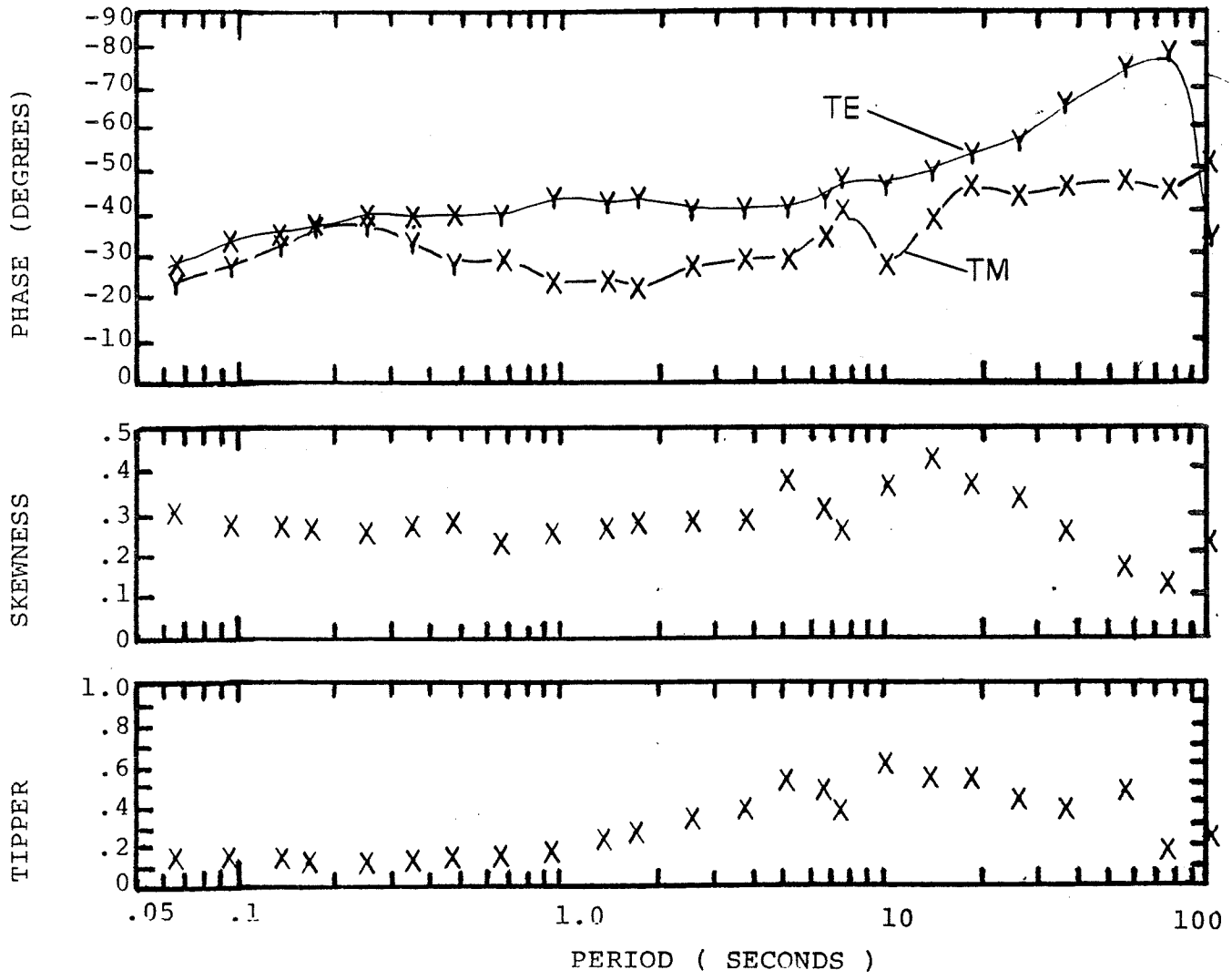
PROSPECT BULLY CREEK, OREGON

STATION 10M



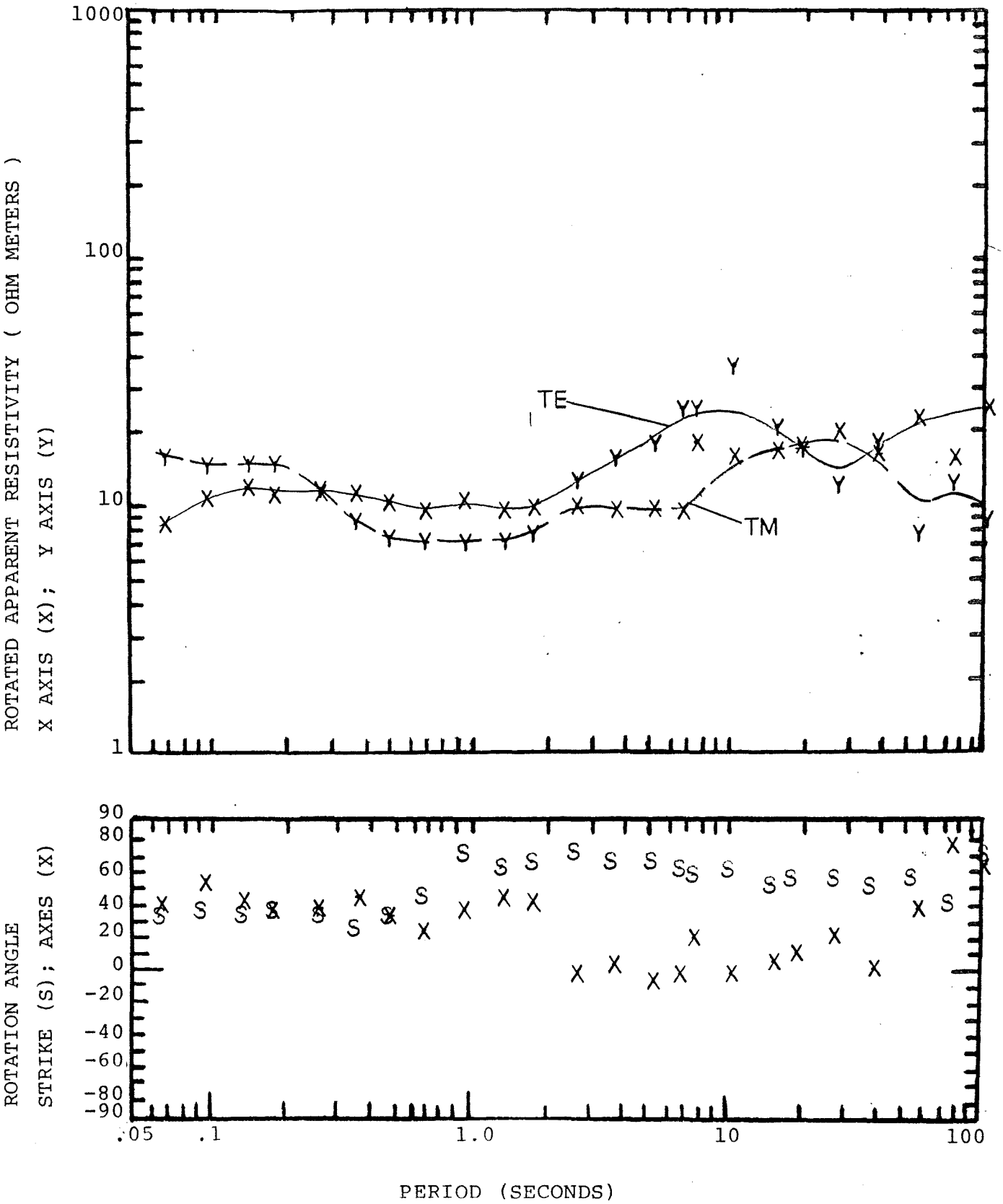
PROSPECT BULLY CREEK, OREGON

STATION 10M



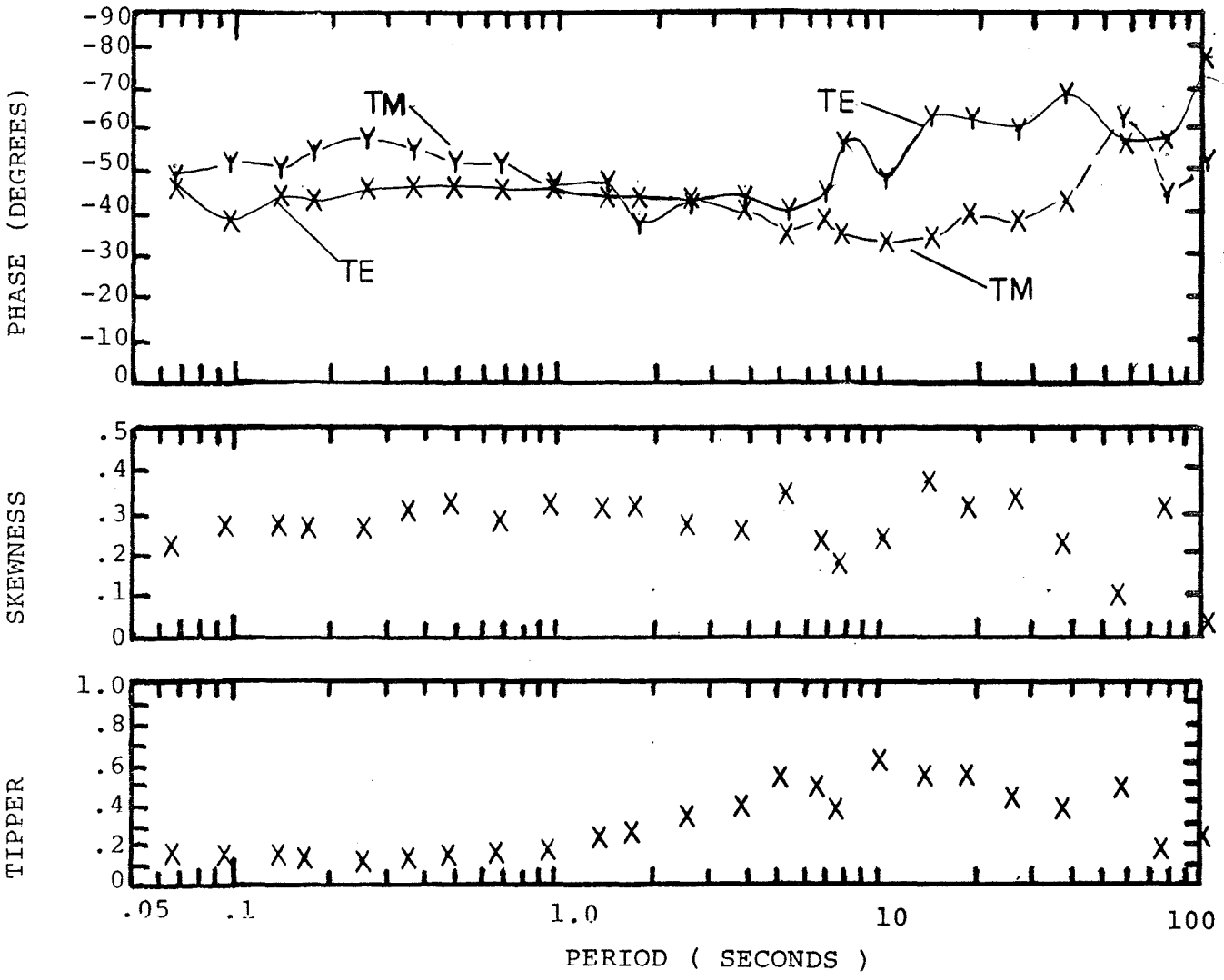
PROSPECT BULLY CREEK, OREGON

STATION 10A



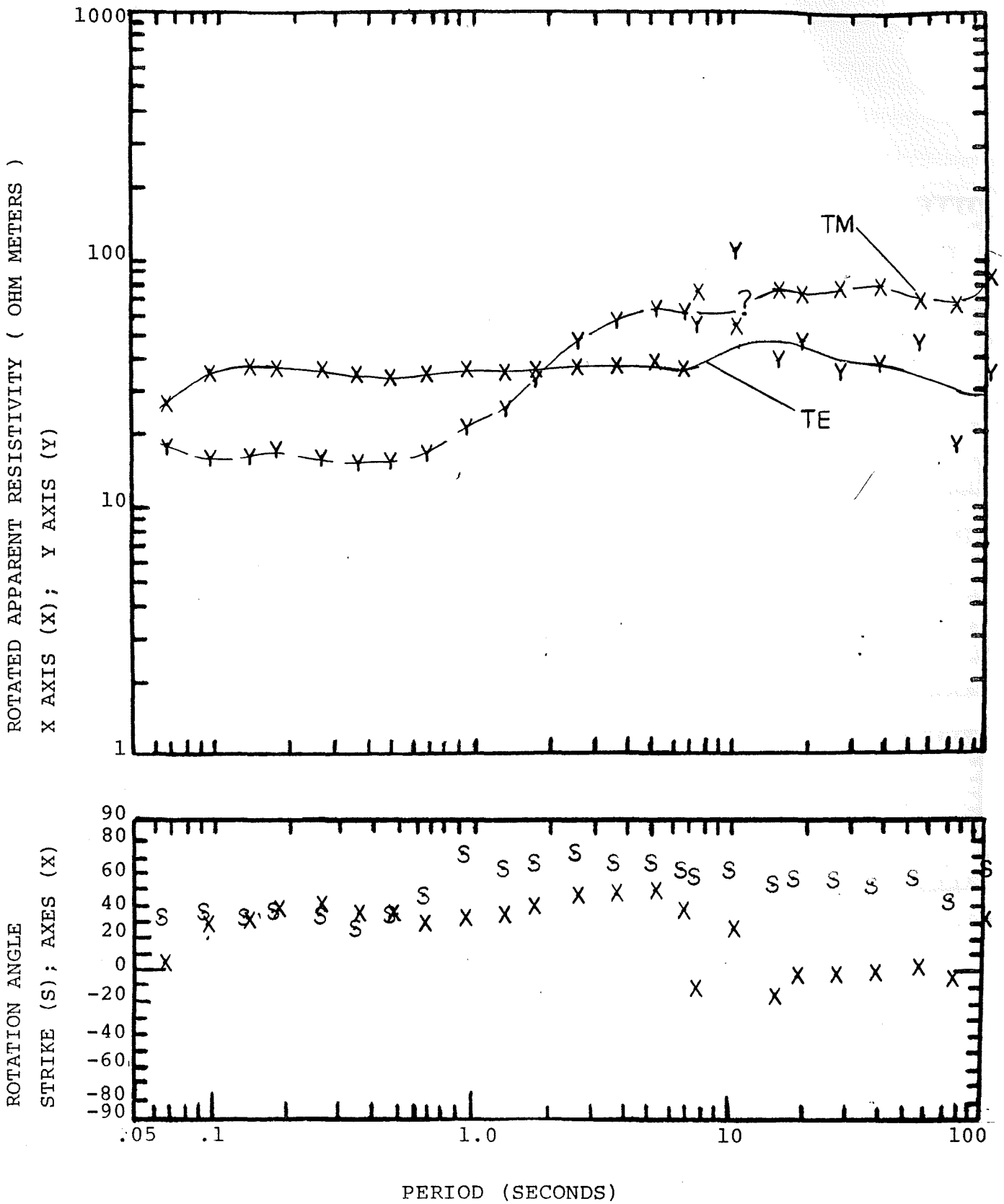
PROSPECT BULLY CREEK, OREGON

STATION 10A



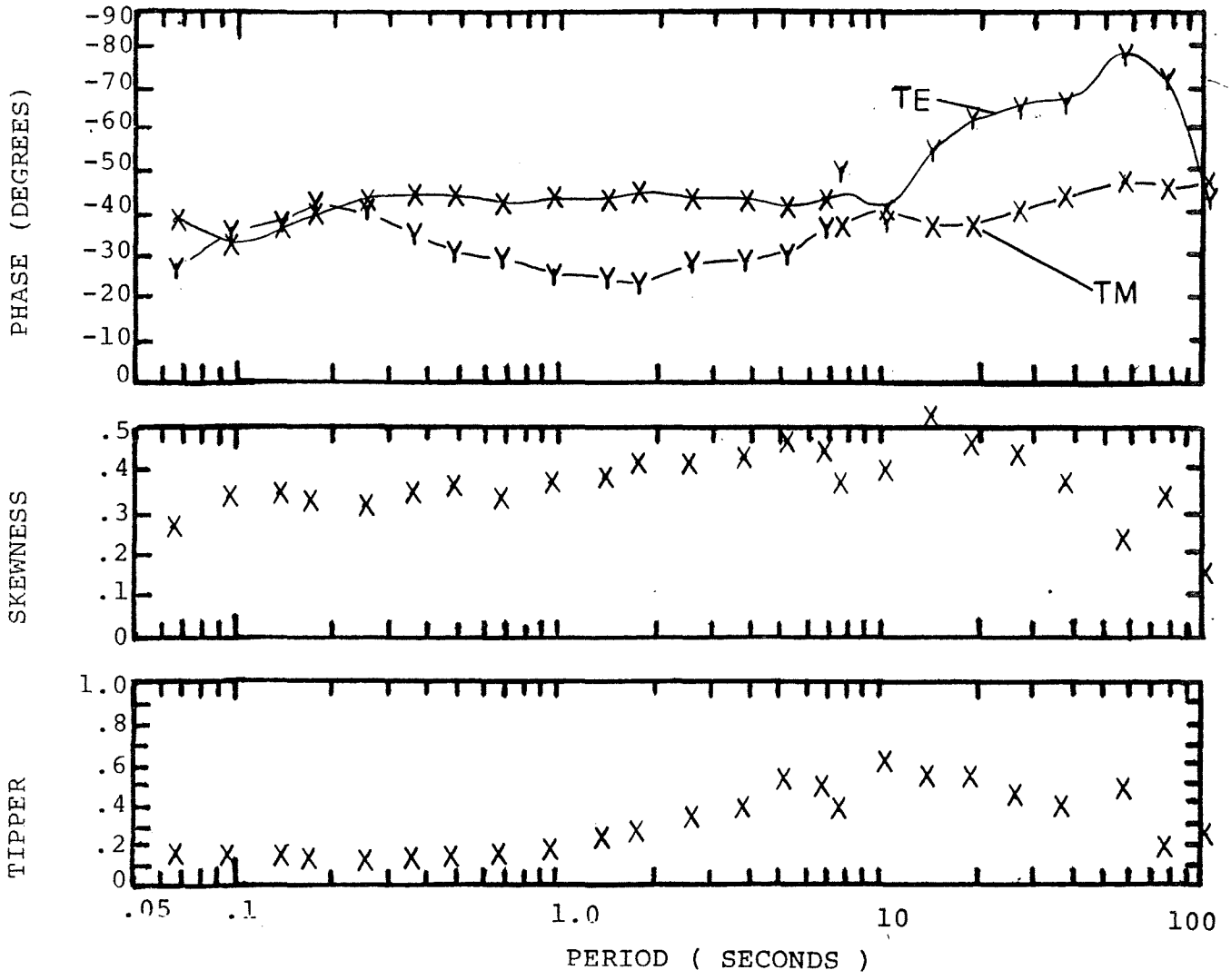
PROSPECT BULLY CREEK, OREGON

STATION 10B



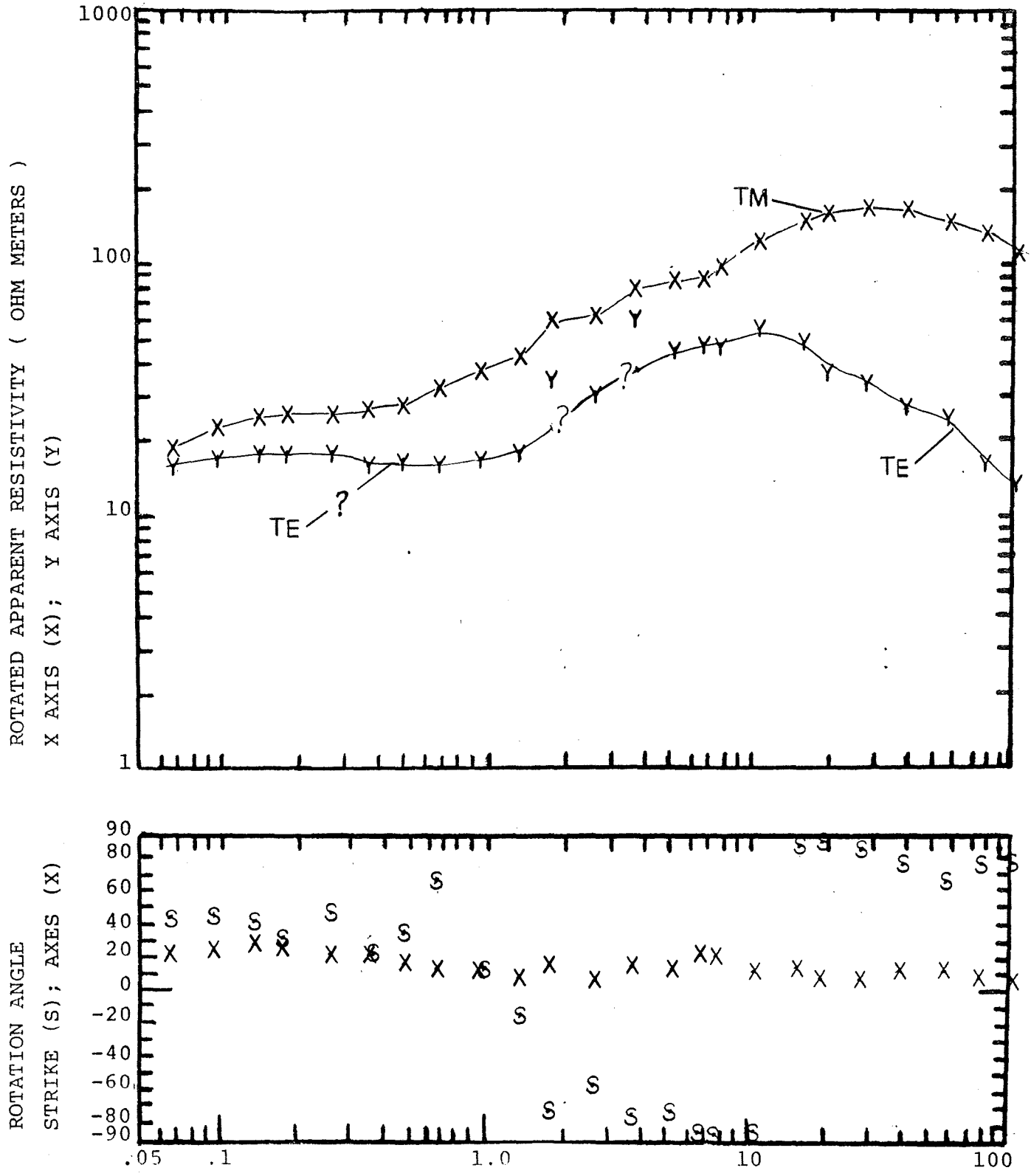
PROSPECT BULLY CREEK, OREGON

STATION 10B



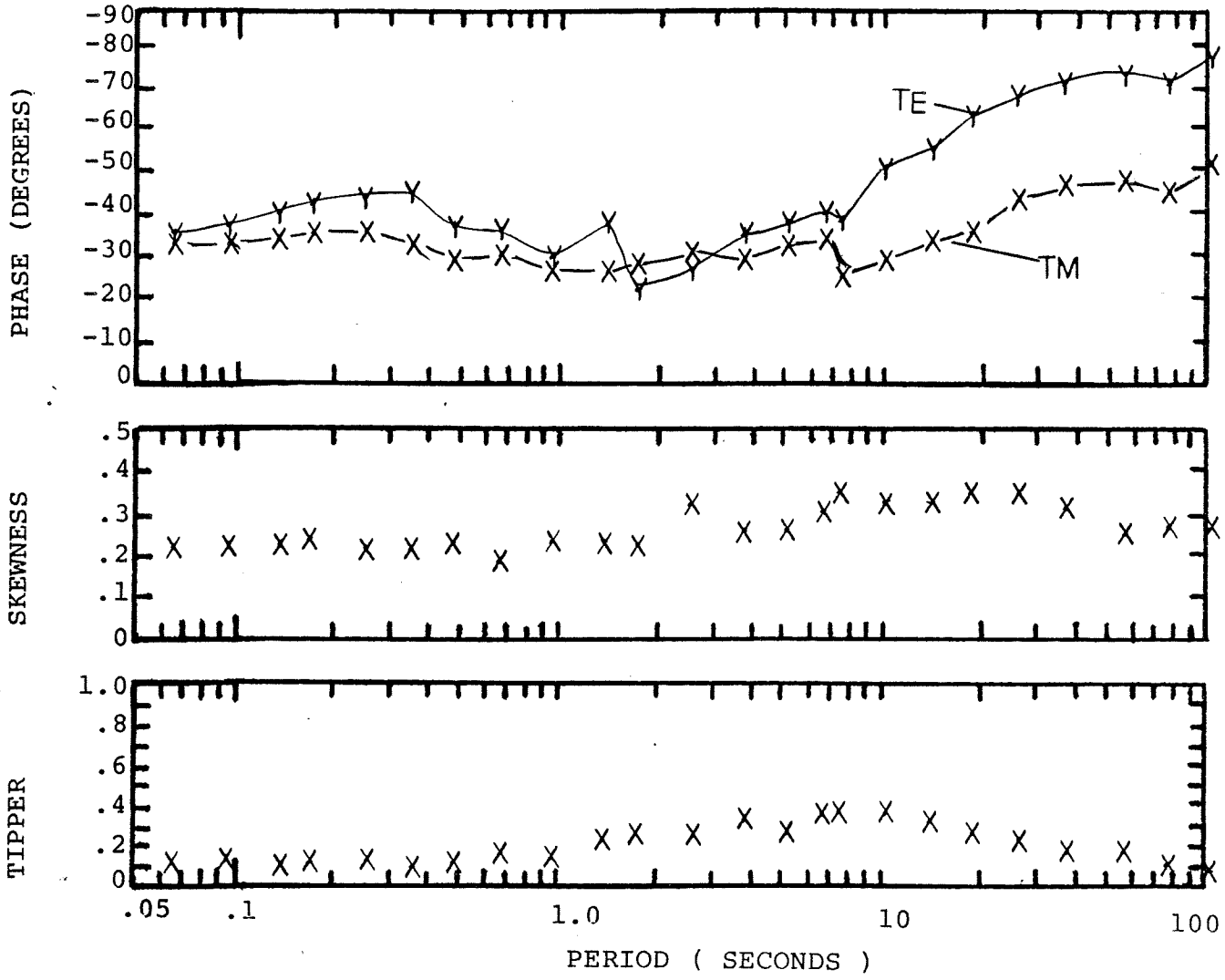
PROSPECT BULLY CREEK, OREGON

STATION 11M



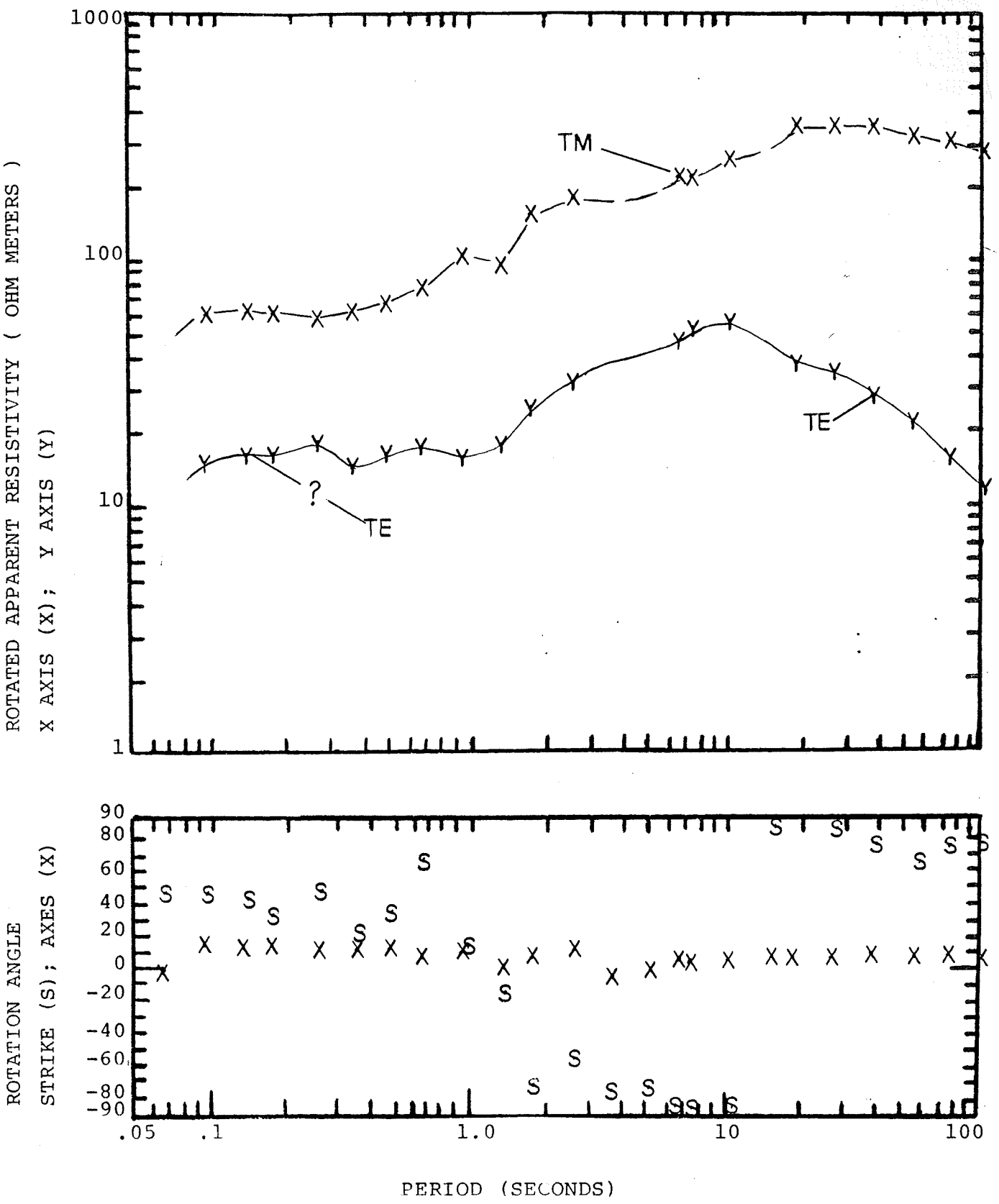
PROSPECT BULLY CREEK, OREGON

STATION 11M



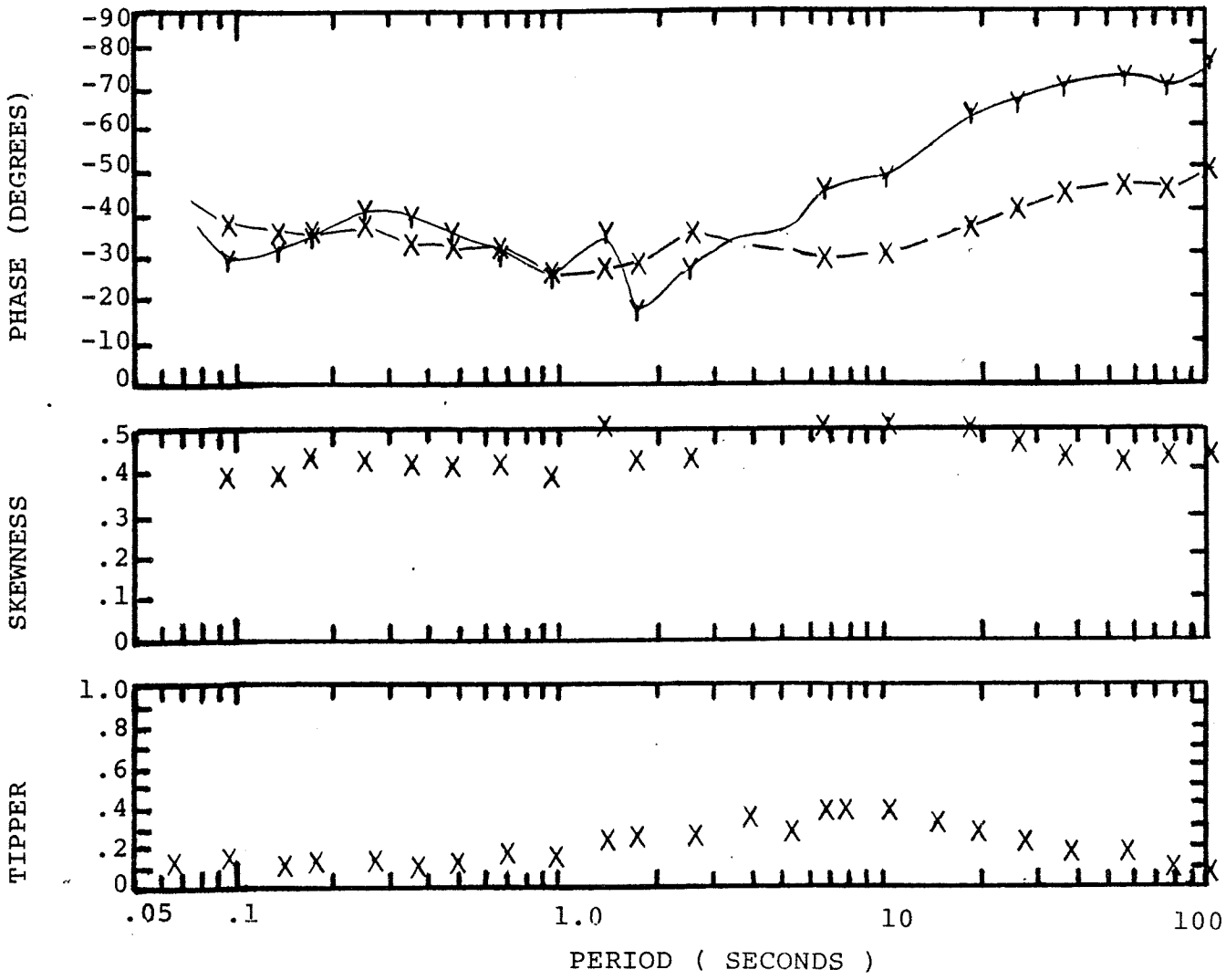
PROSPECT BULLY CREEK, OREGON

STATION 11A



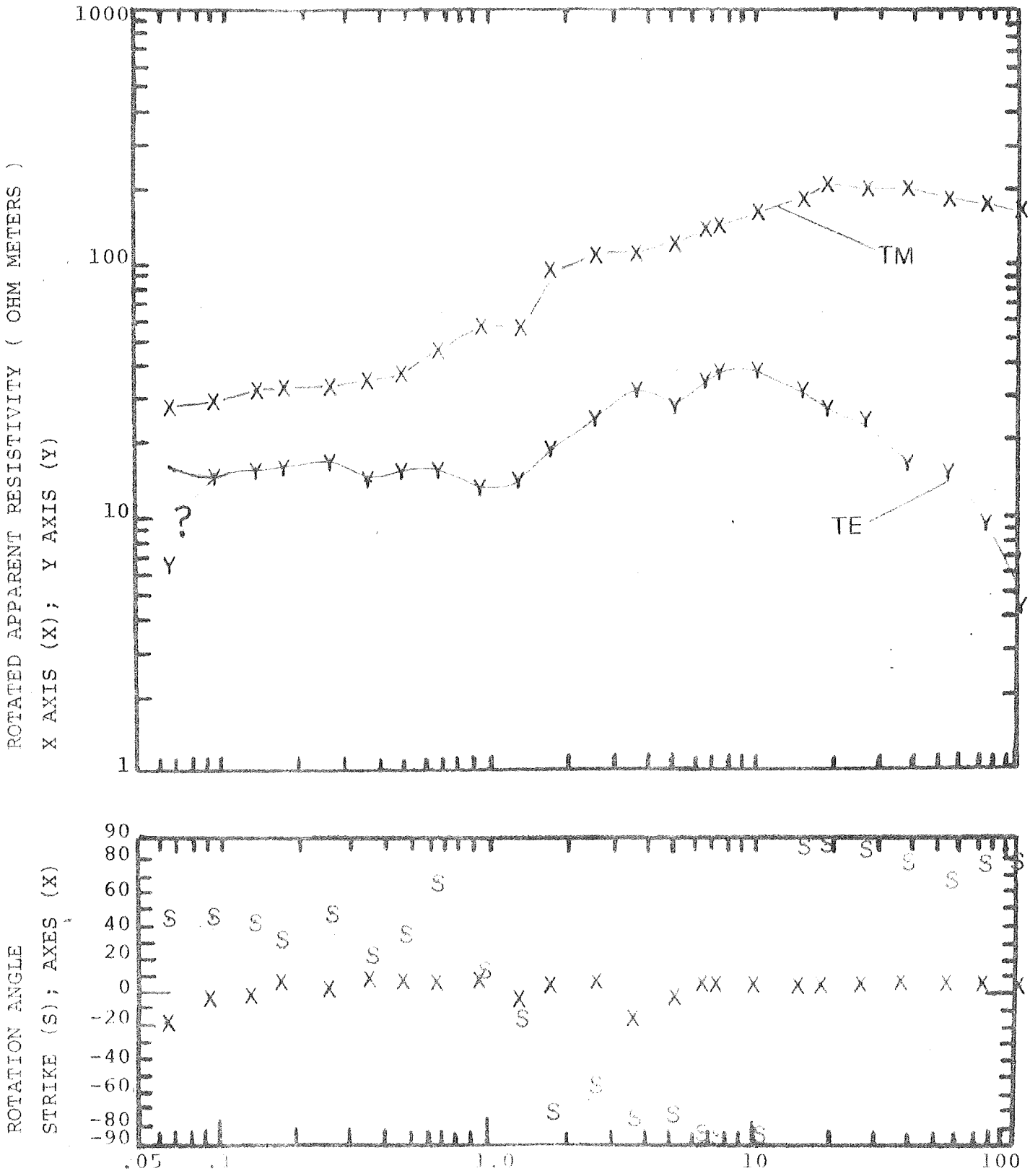
PROSPECT BULLY CREEK, OREGON

STATION 11A



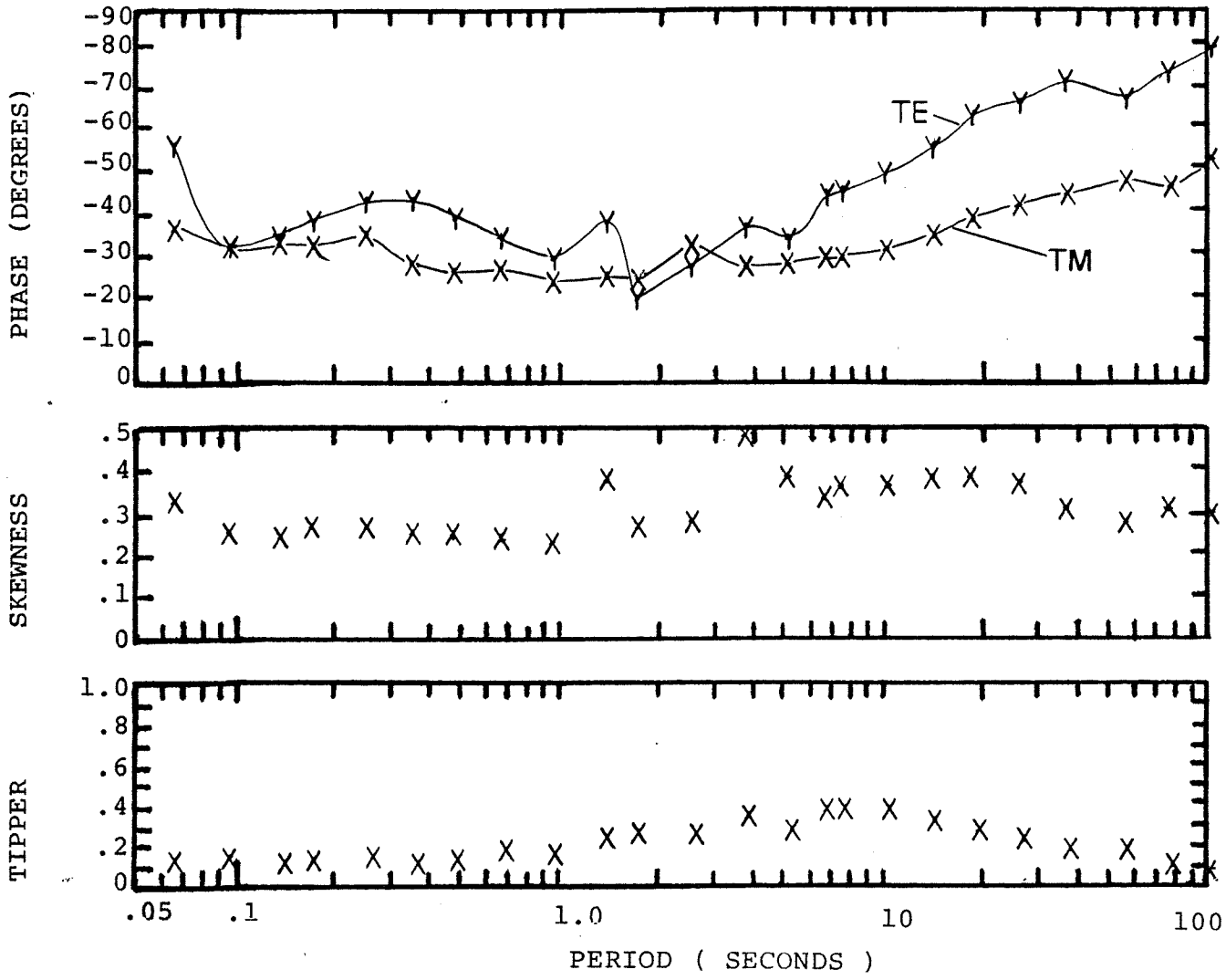
PROSPECT BULLY CREEK, OREGON

STATION 11B



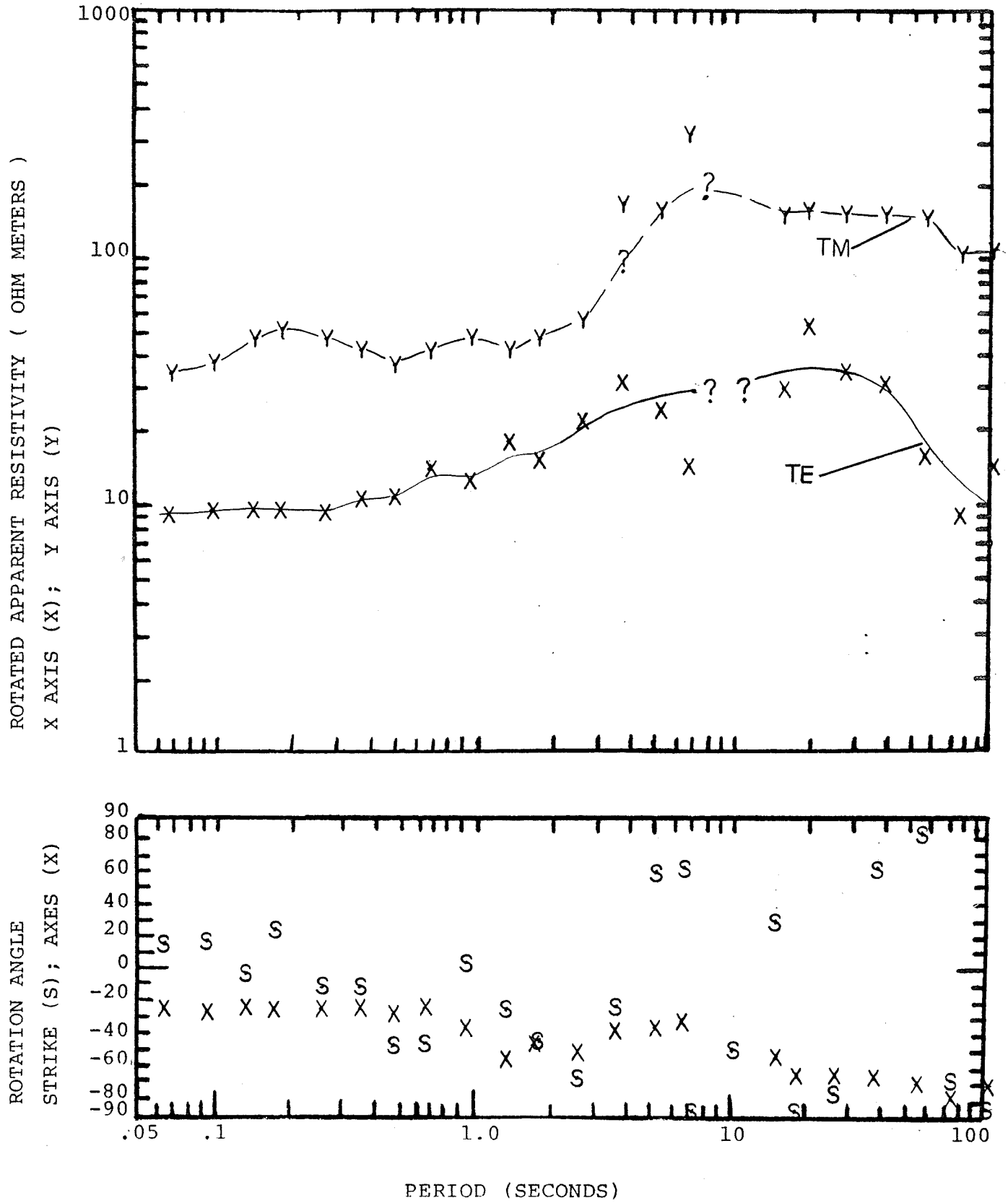
PROSPECT BULLY CREEK, OREGON

STATION 11B



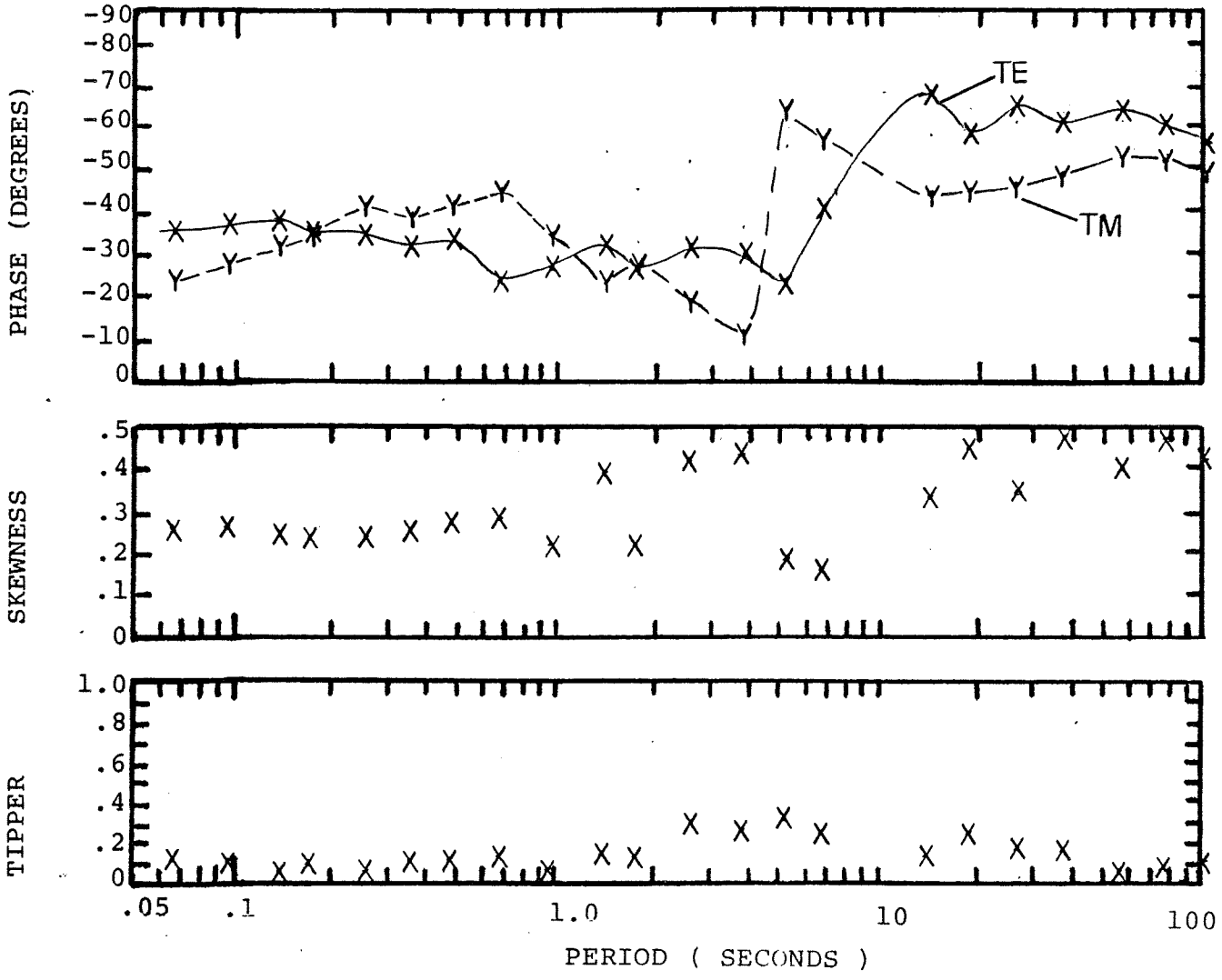
PROSPECT BULLY CREEK, OREGON

STATION 12M



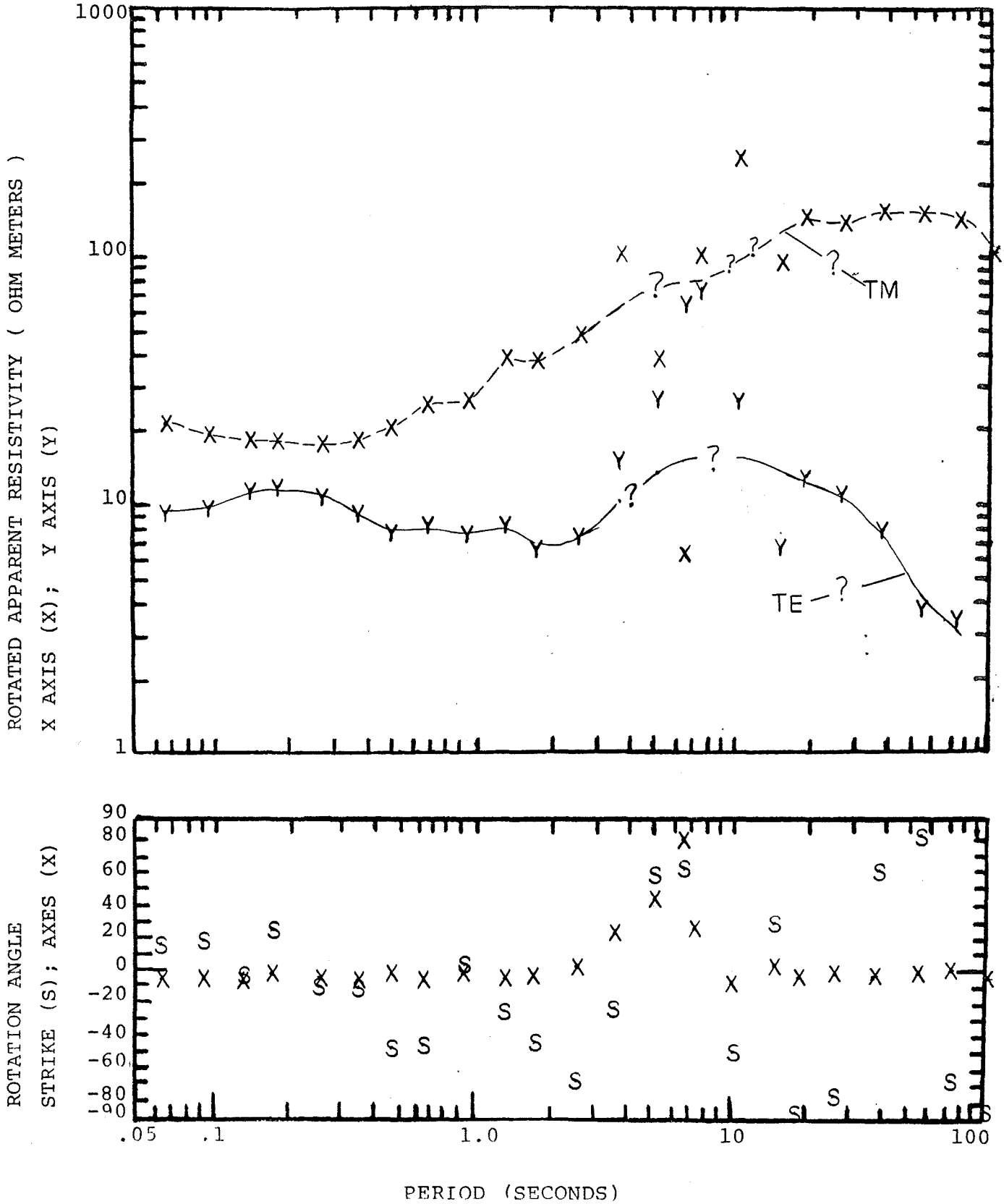
PROSPECT BULLY CREEK, OREGON

STATION 12M



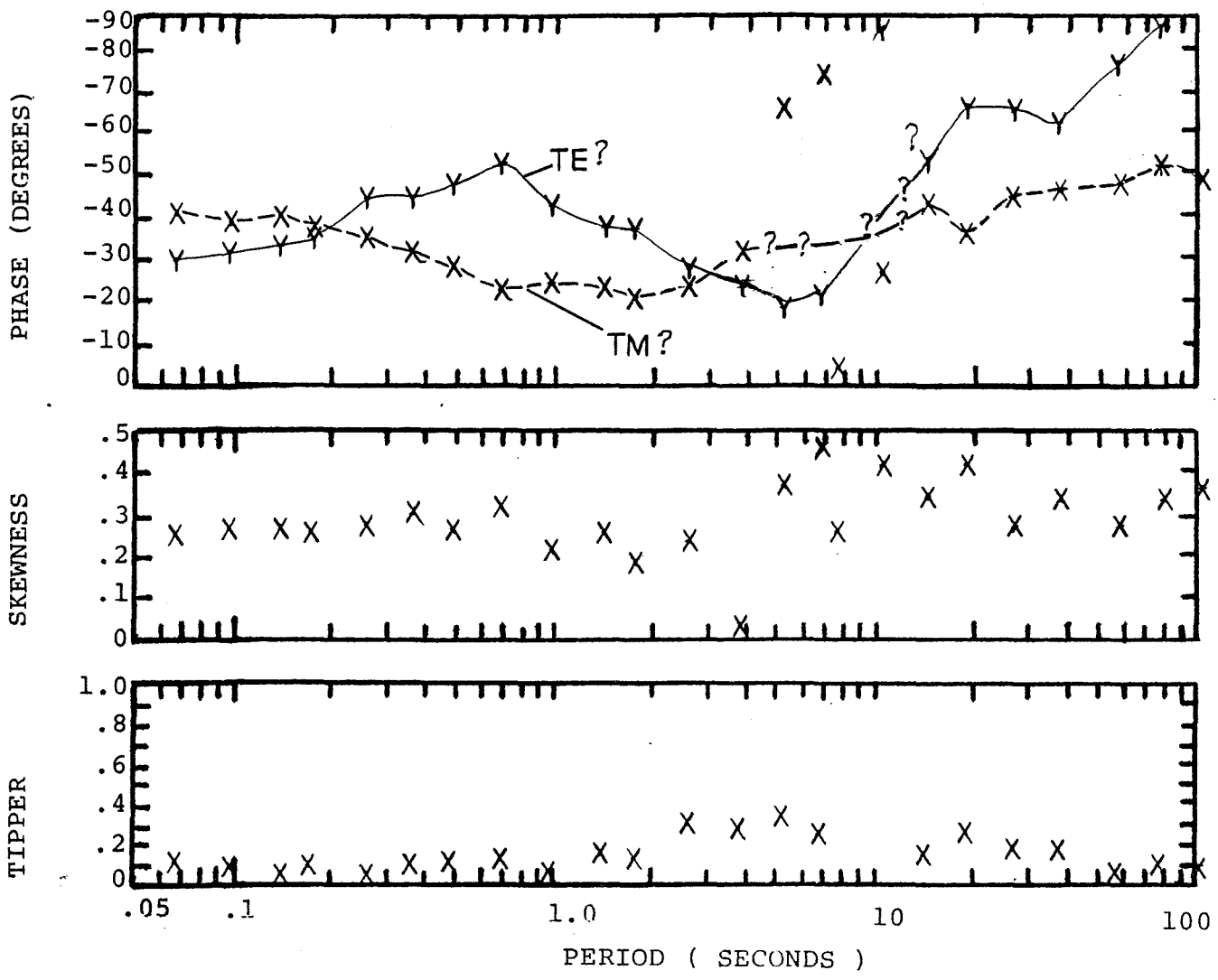
PROSPECT BULLY CREEK, OREGON

STATION 12B



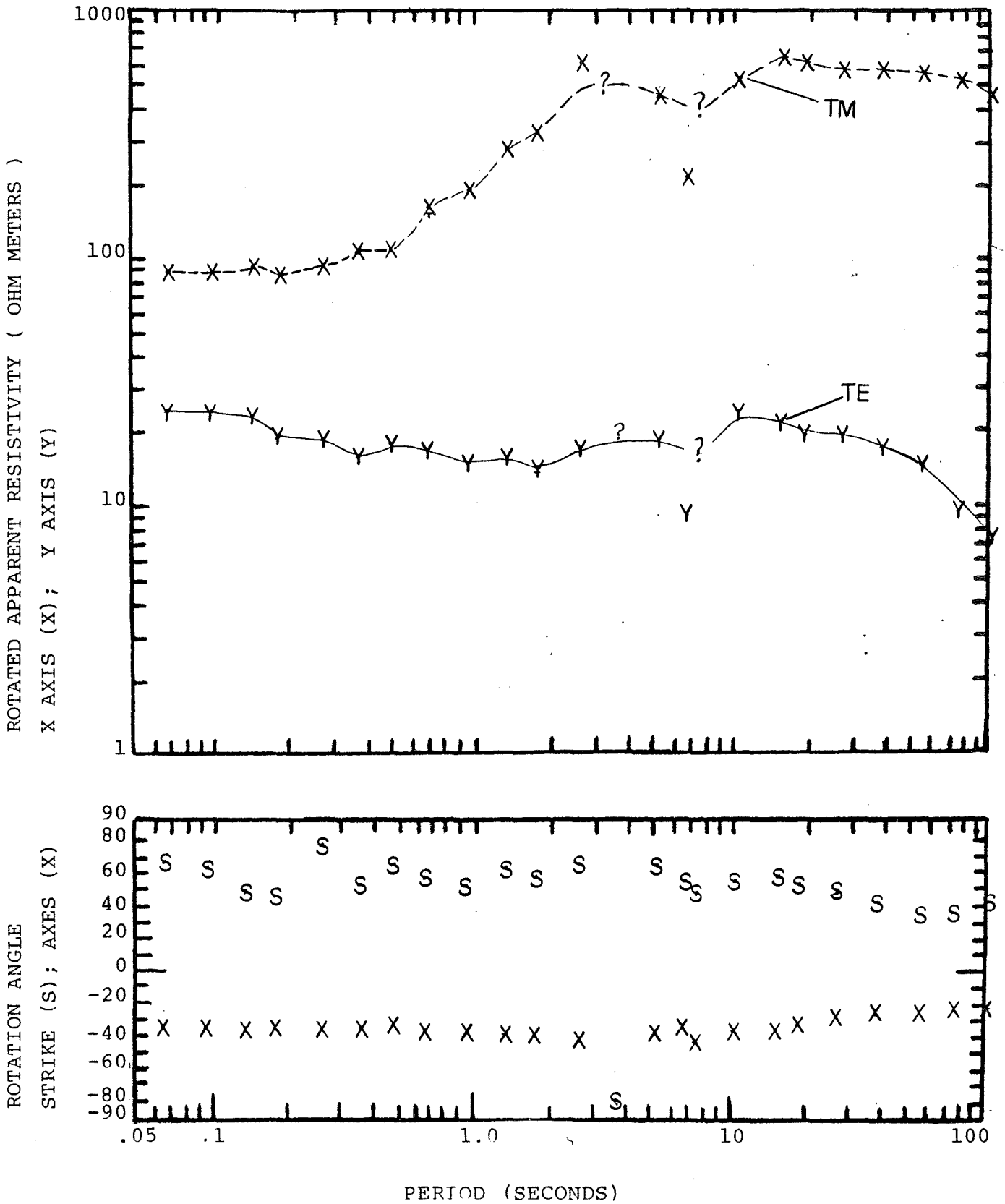
PROSPECT BULLY CREEK, OREGON

STATION 12B



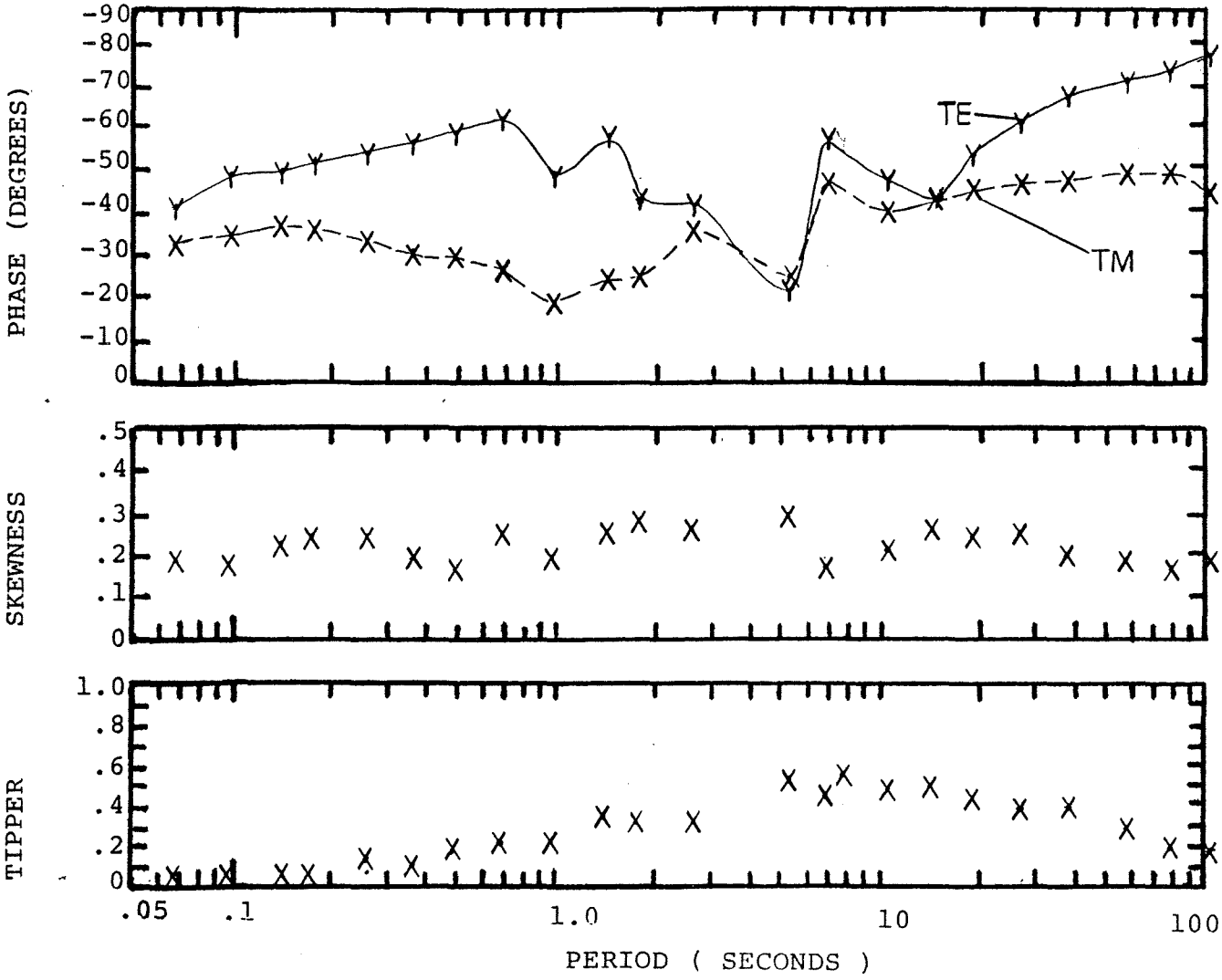
PROSPECT BULLY CREEK, OREGON

STATION 13M



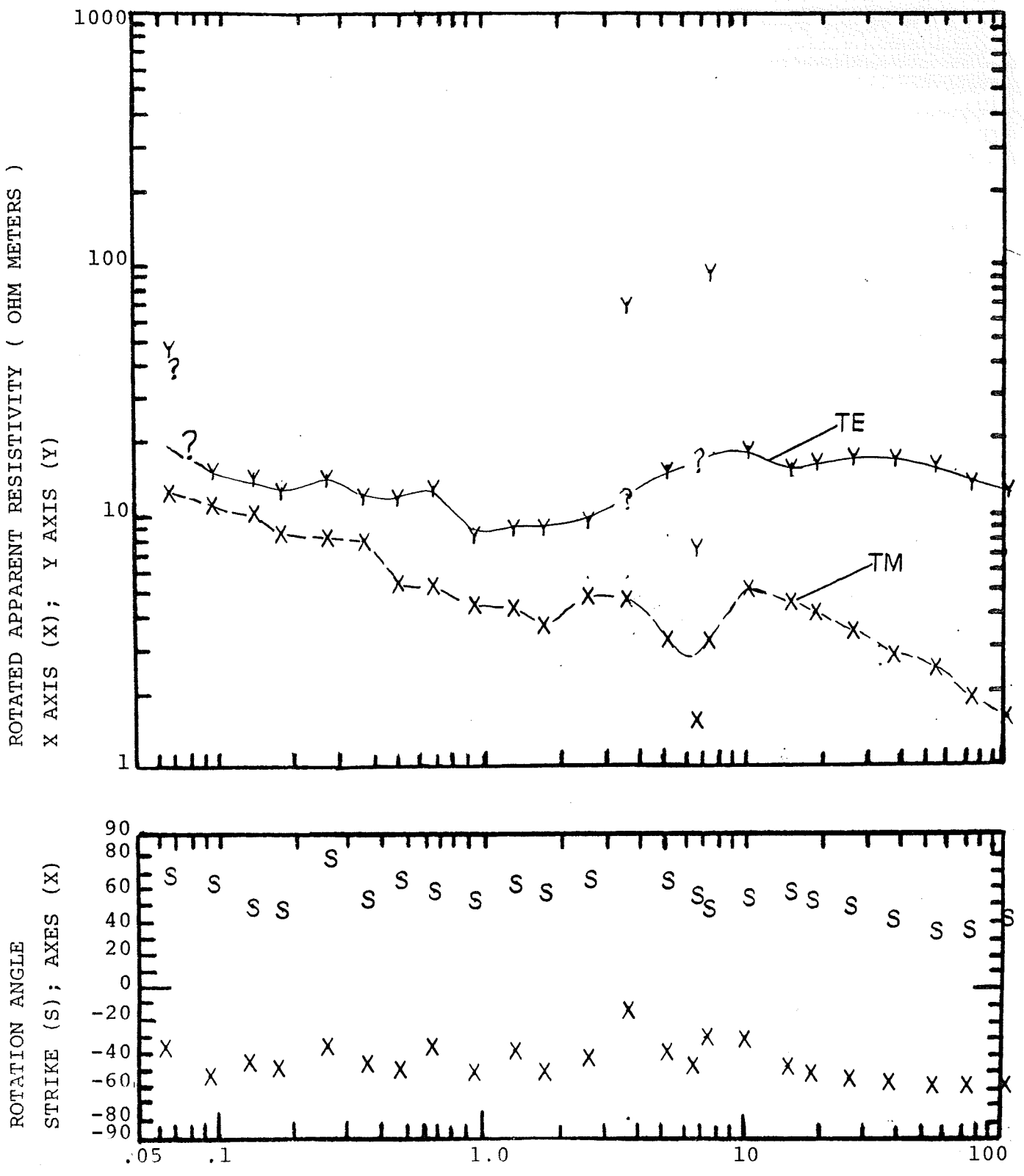
PROSPECT BULLY CREEK, OREGON

STATION 13M



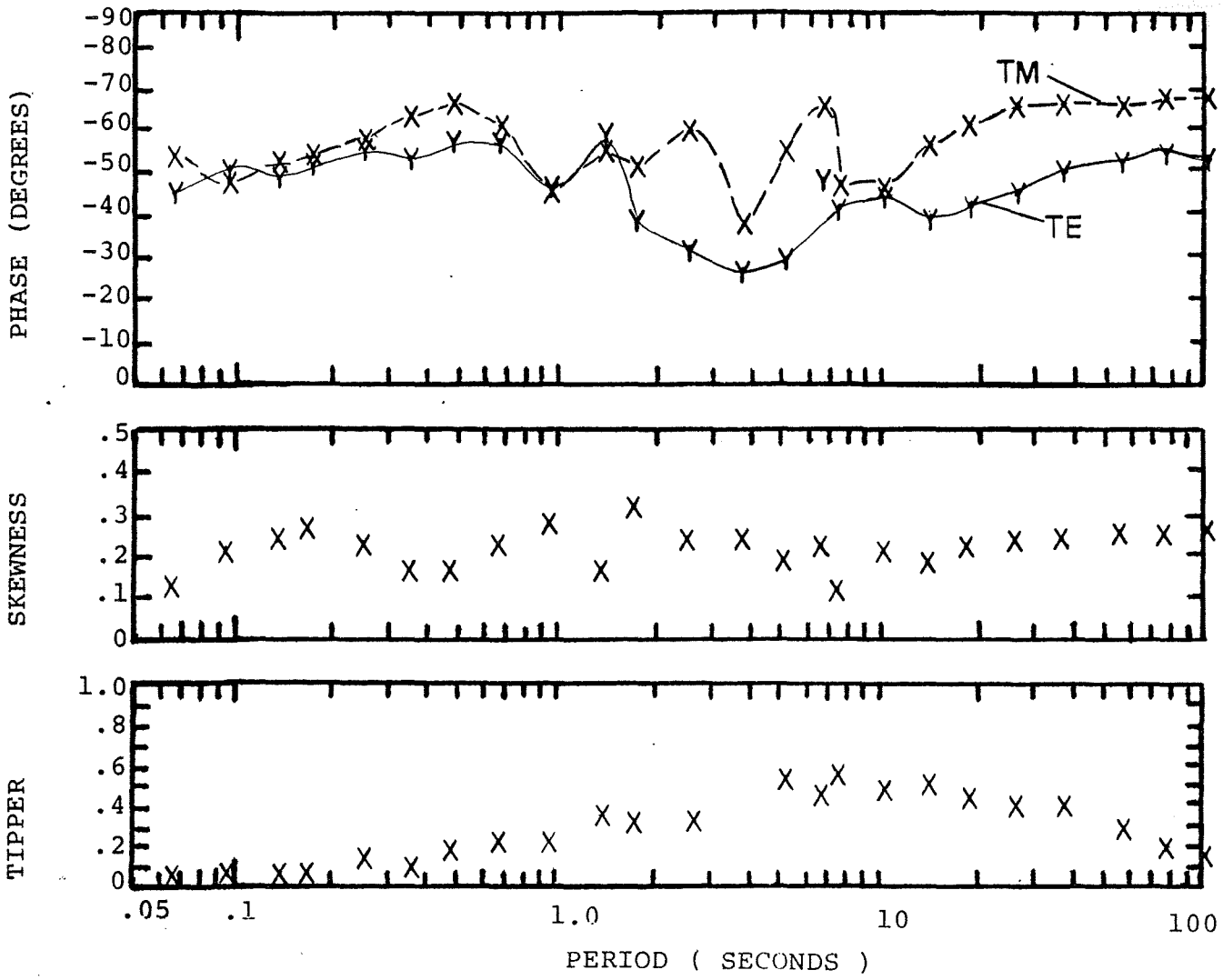
PROSPECT BULLY CREEK, OREGON

STATION 13A



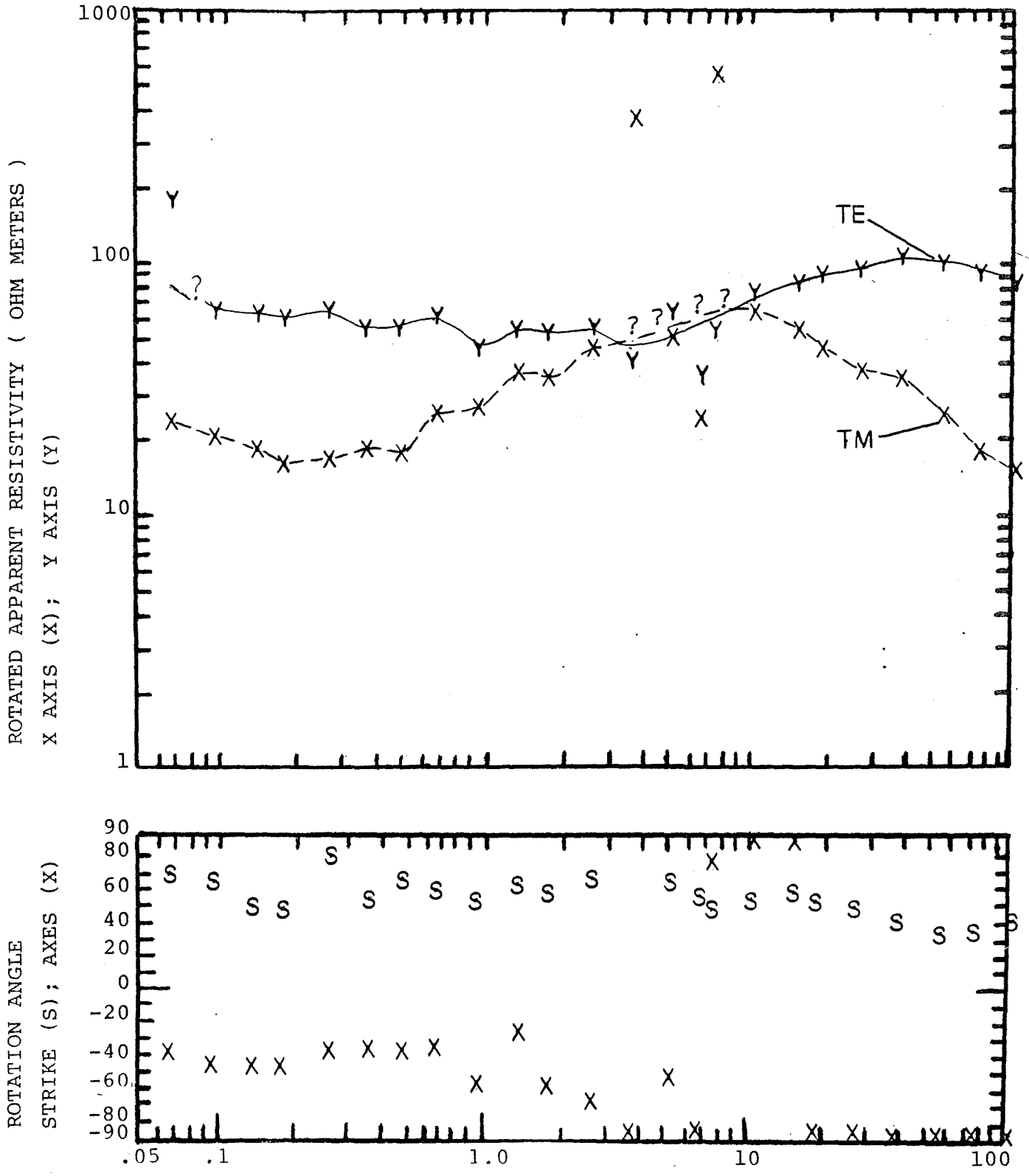
PROSPECT BULLY CREEK, OREGON

STATION 13A



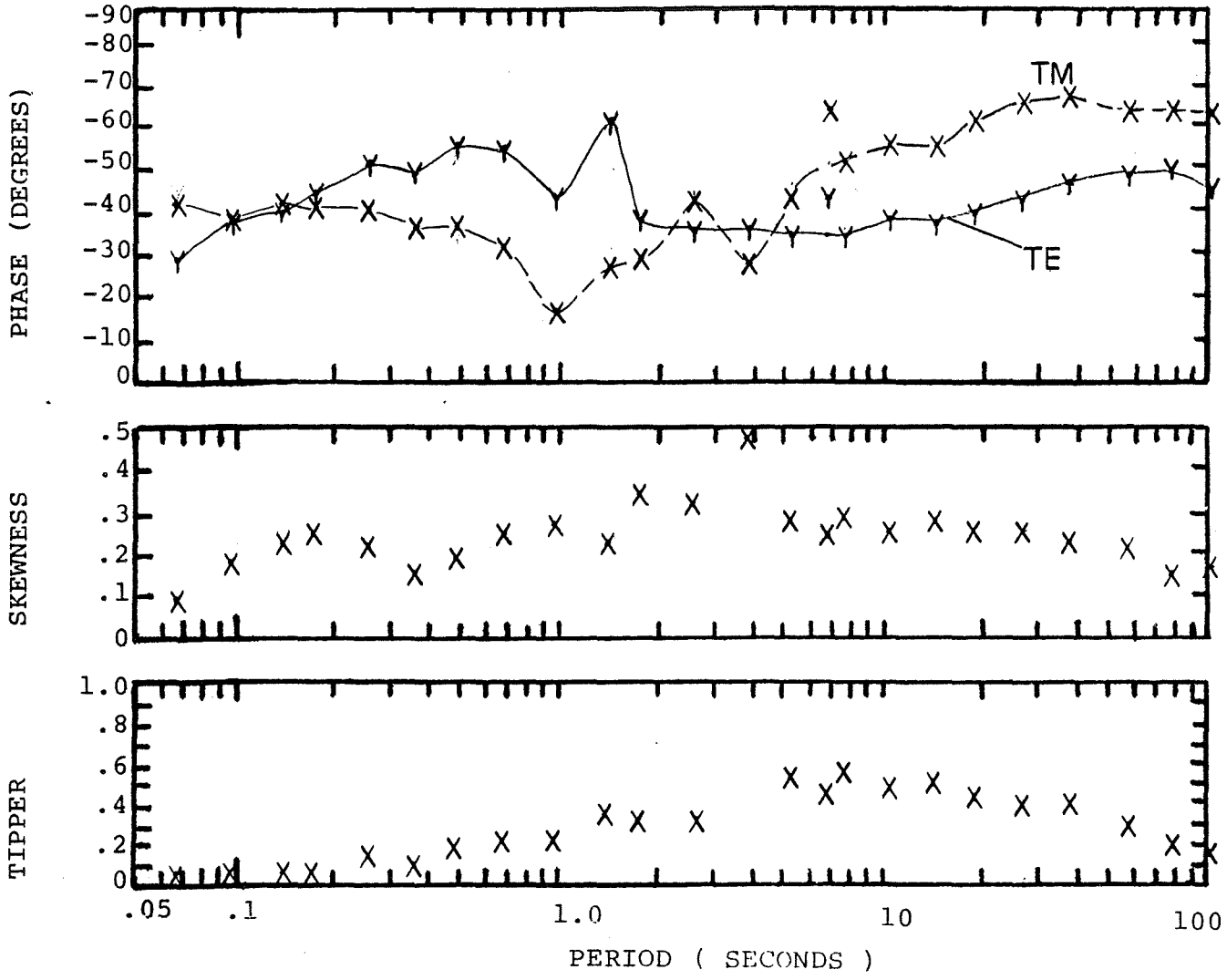
PROSPECT BULLY CREEK, OREGON

STATION 13B



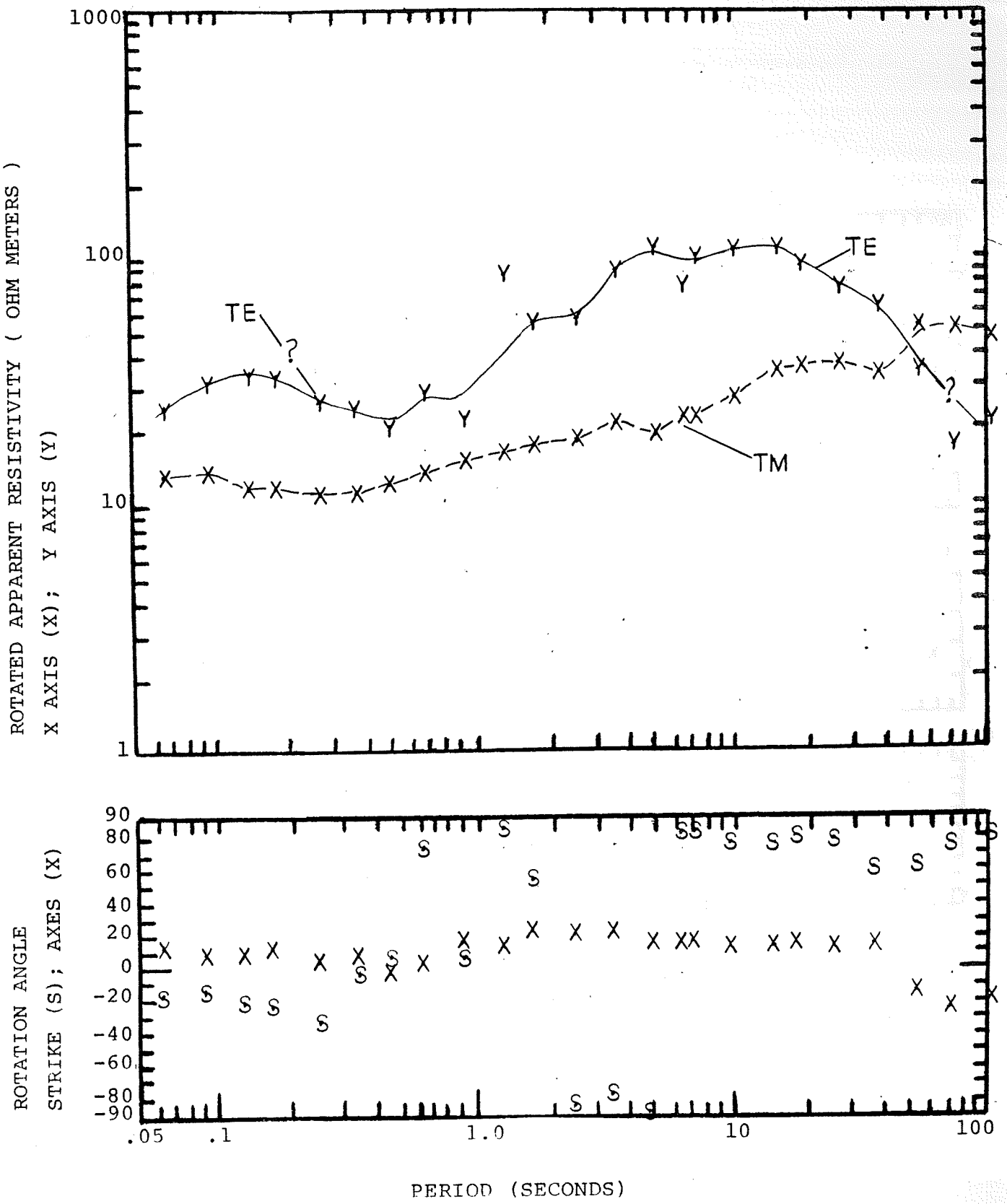
PROSPECT BULLY CREEK, OREGON

STATION 13B



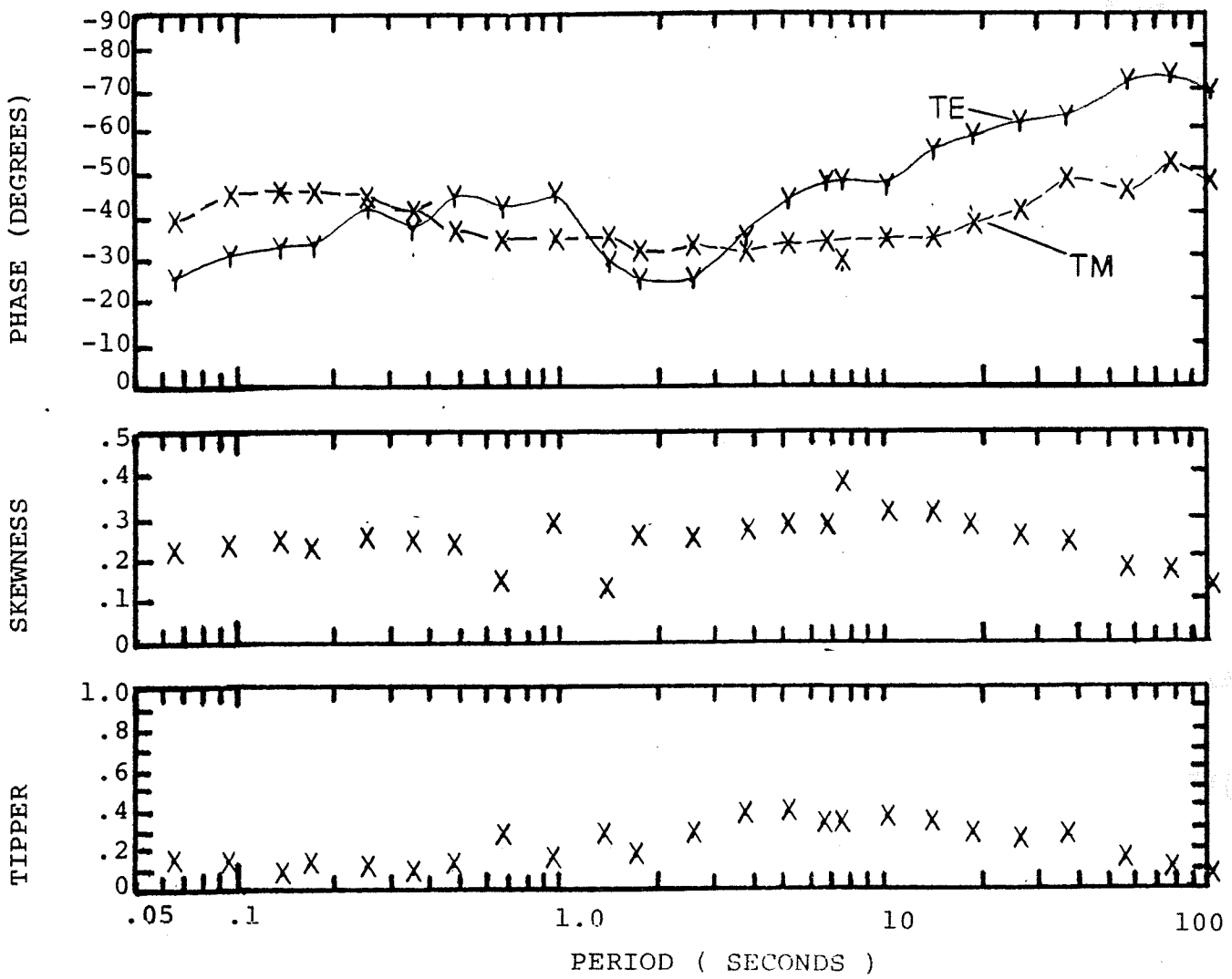
PROSPECT BULLY CREEK, OREGON

STATION 14M



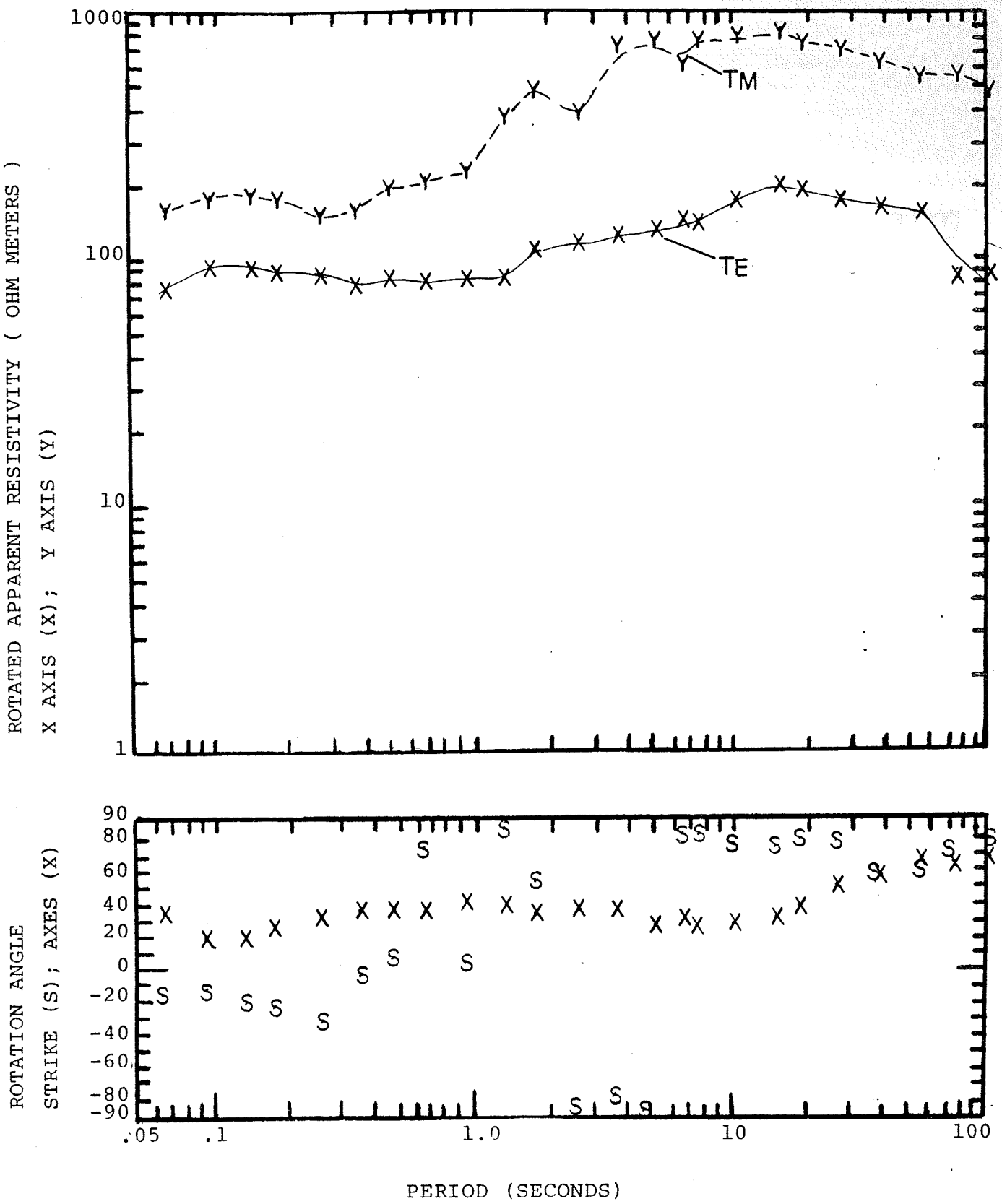
PROSPECT BULLY CREEK, OREGON

STATION 14M



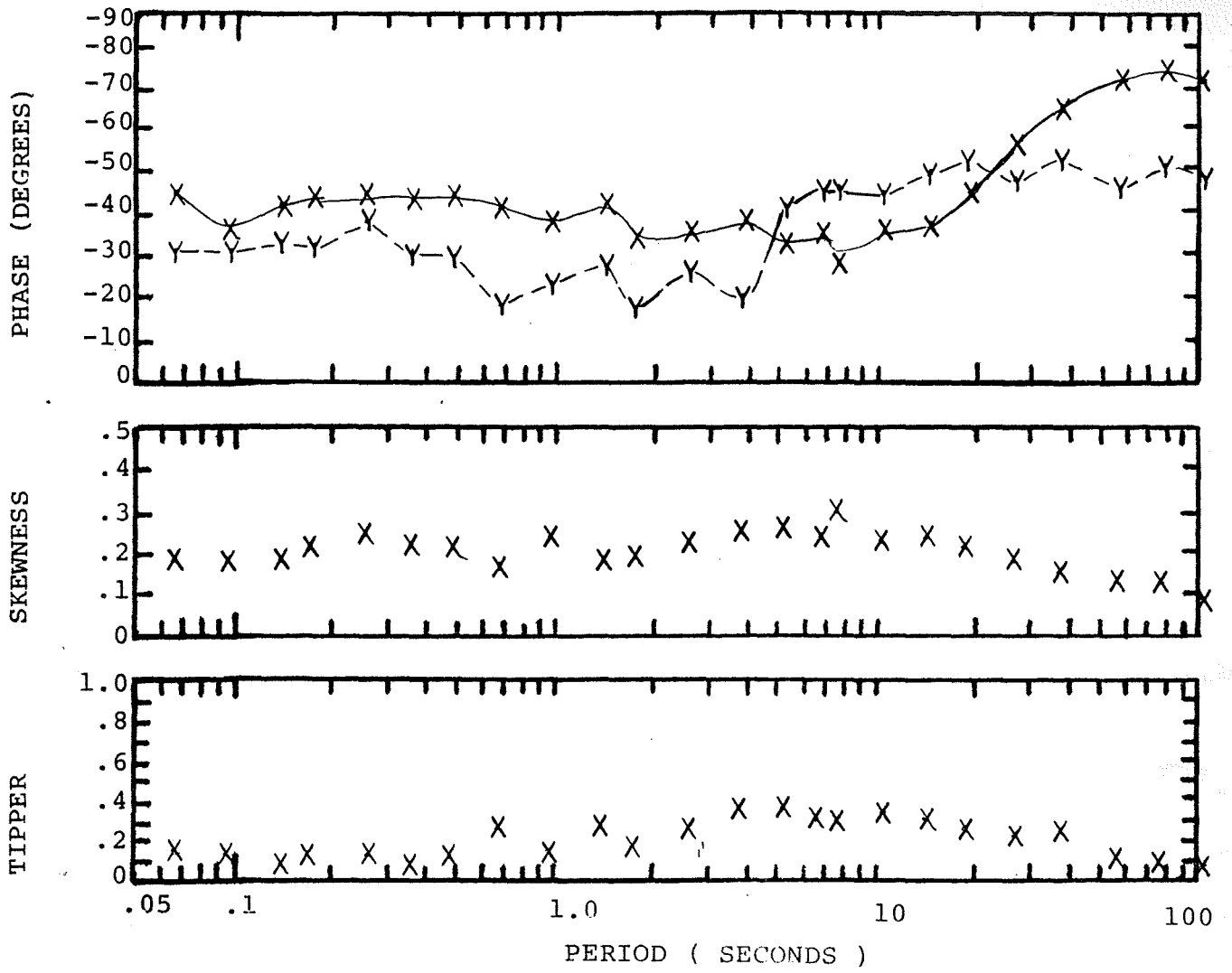
PROSPECT BULLY CREEK, OREGON

STATION 14A



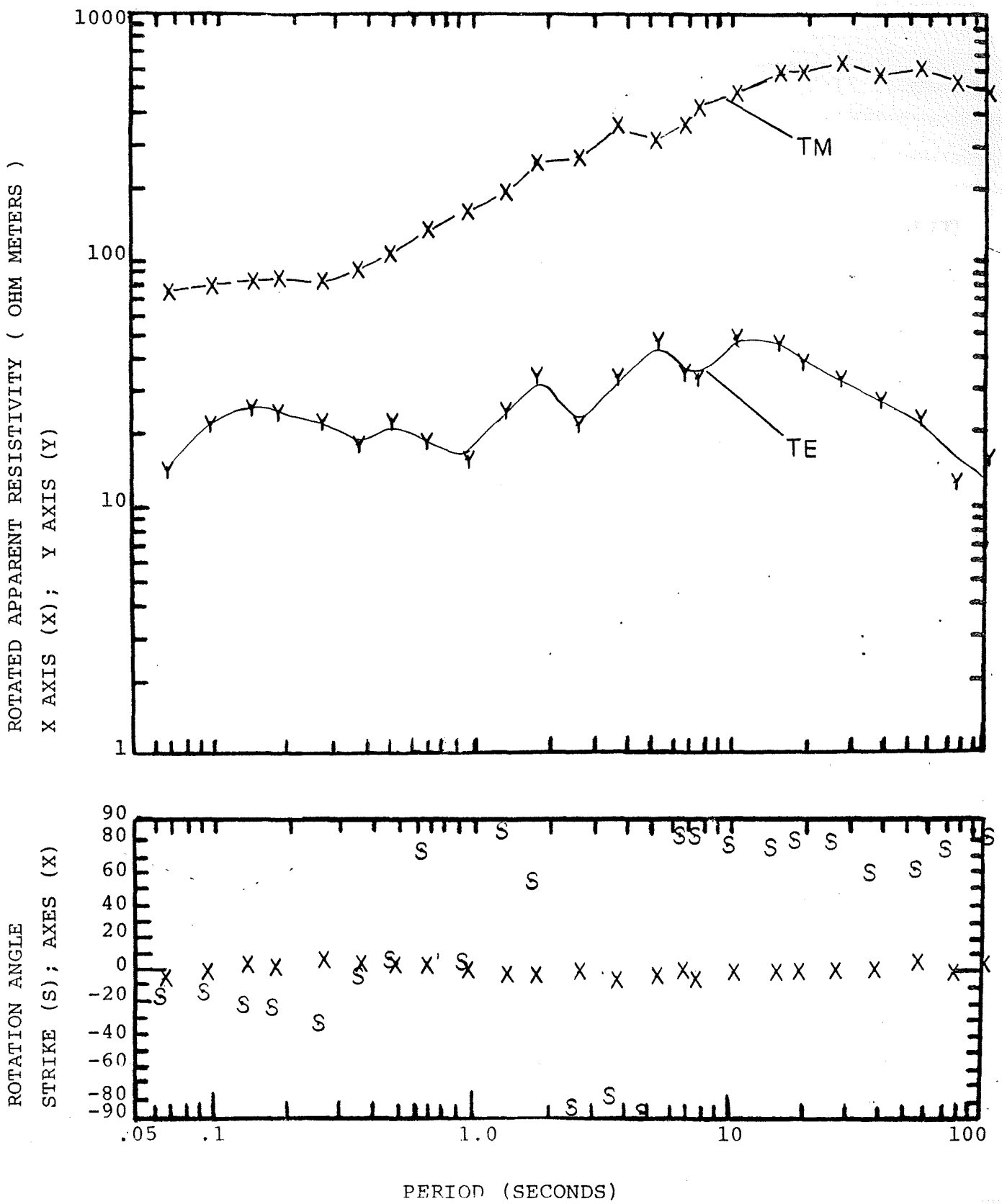
PROSPECT BULLY CREEK, OREGON

STATION 14A



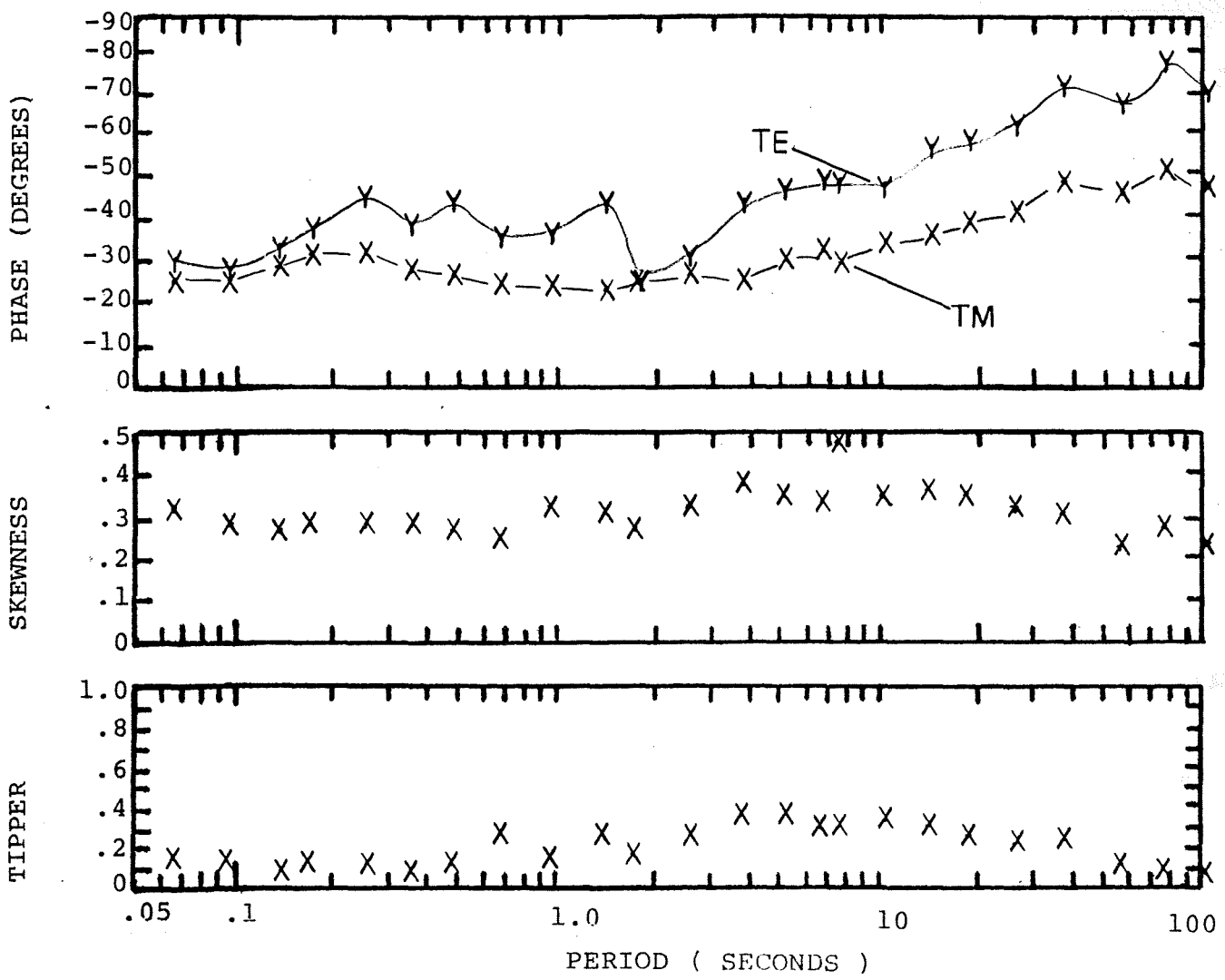
PROSPECT BULLY CREEK, OREGON

STATION 14B



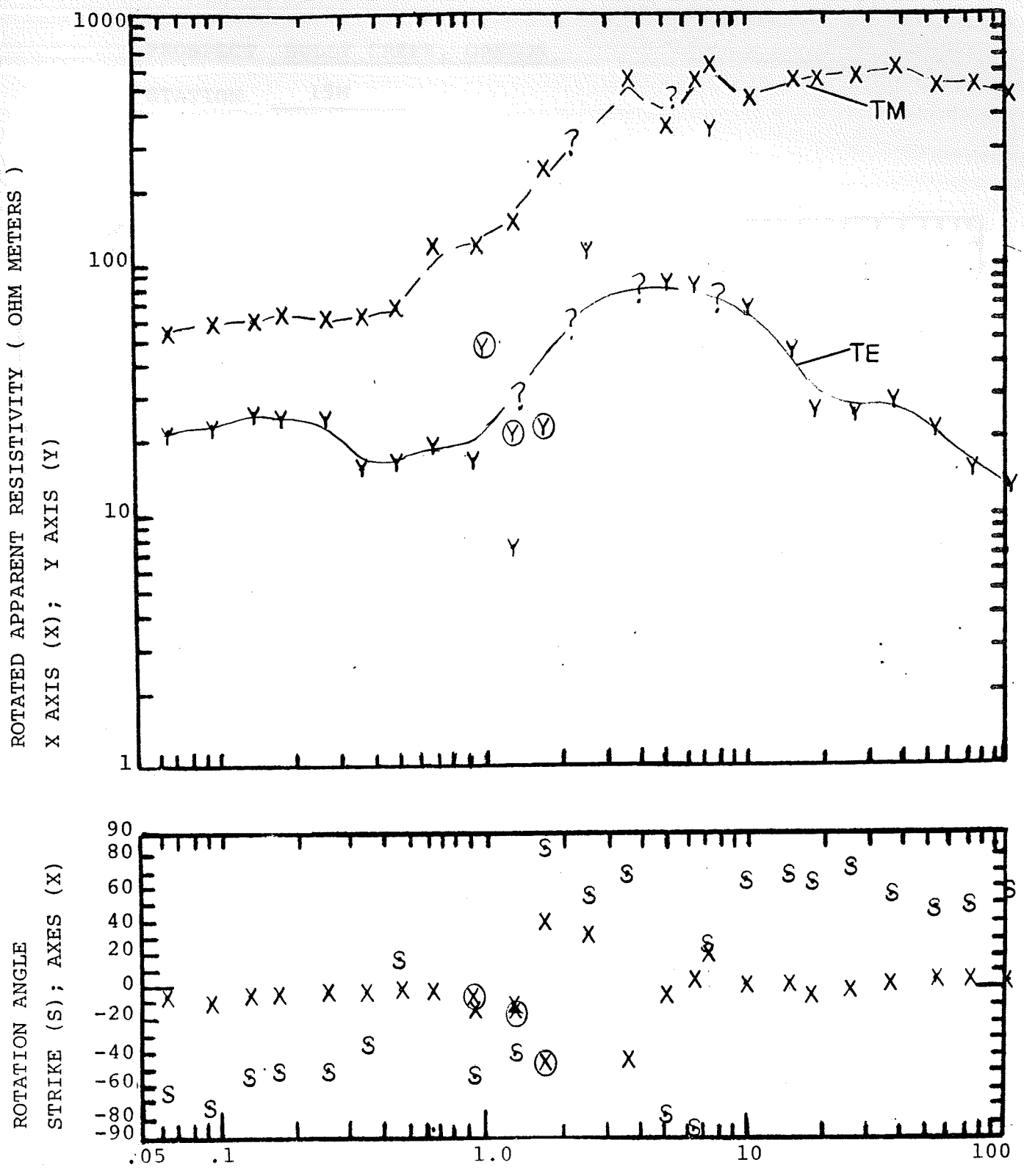
PROSPECT BULLY CREEK, OREGON

STATION 14B



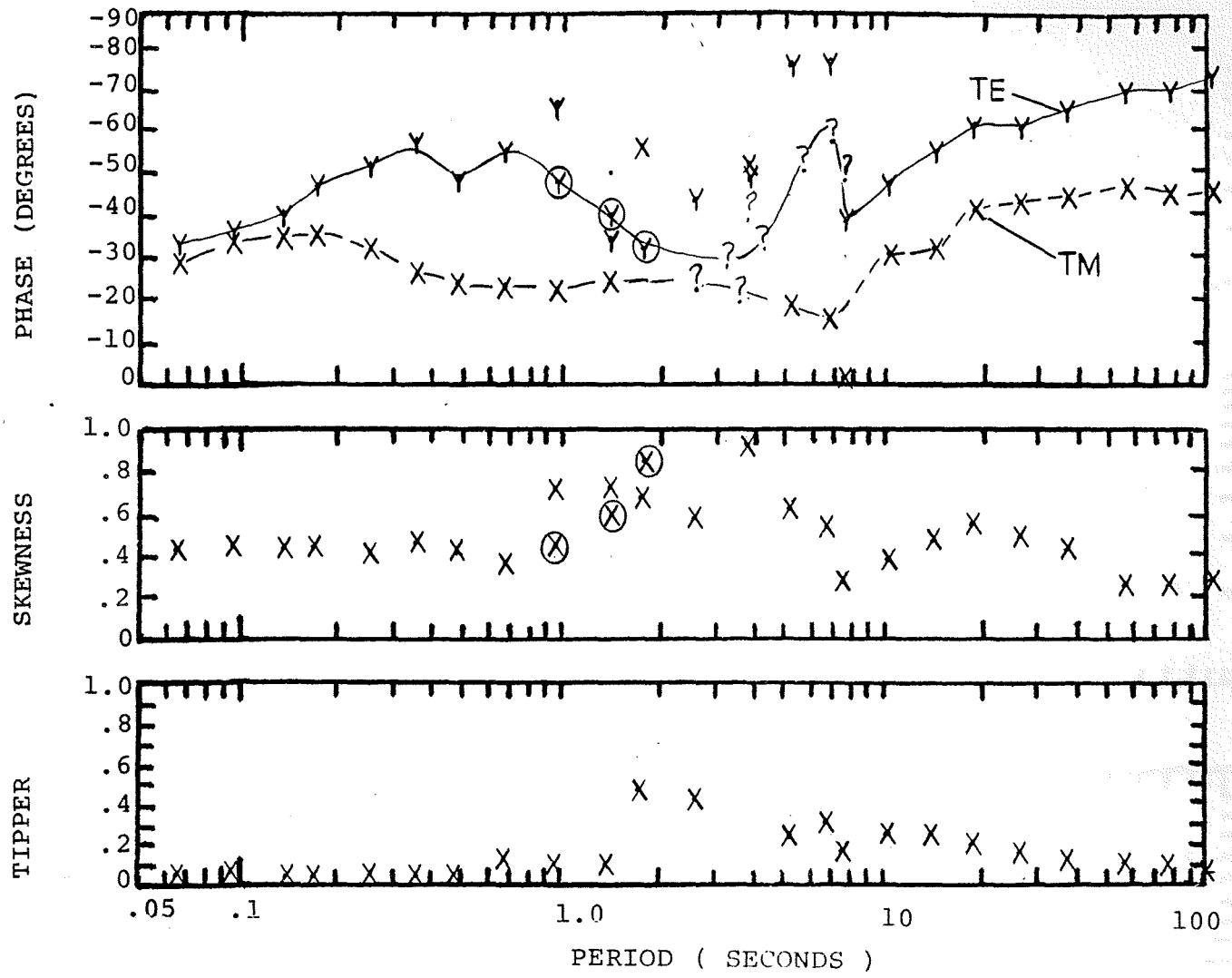
PROSPECT BULLY CREEK, OREGON

STATION 15M



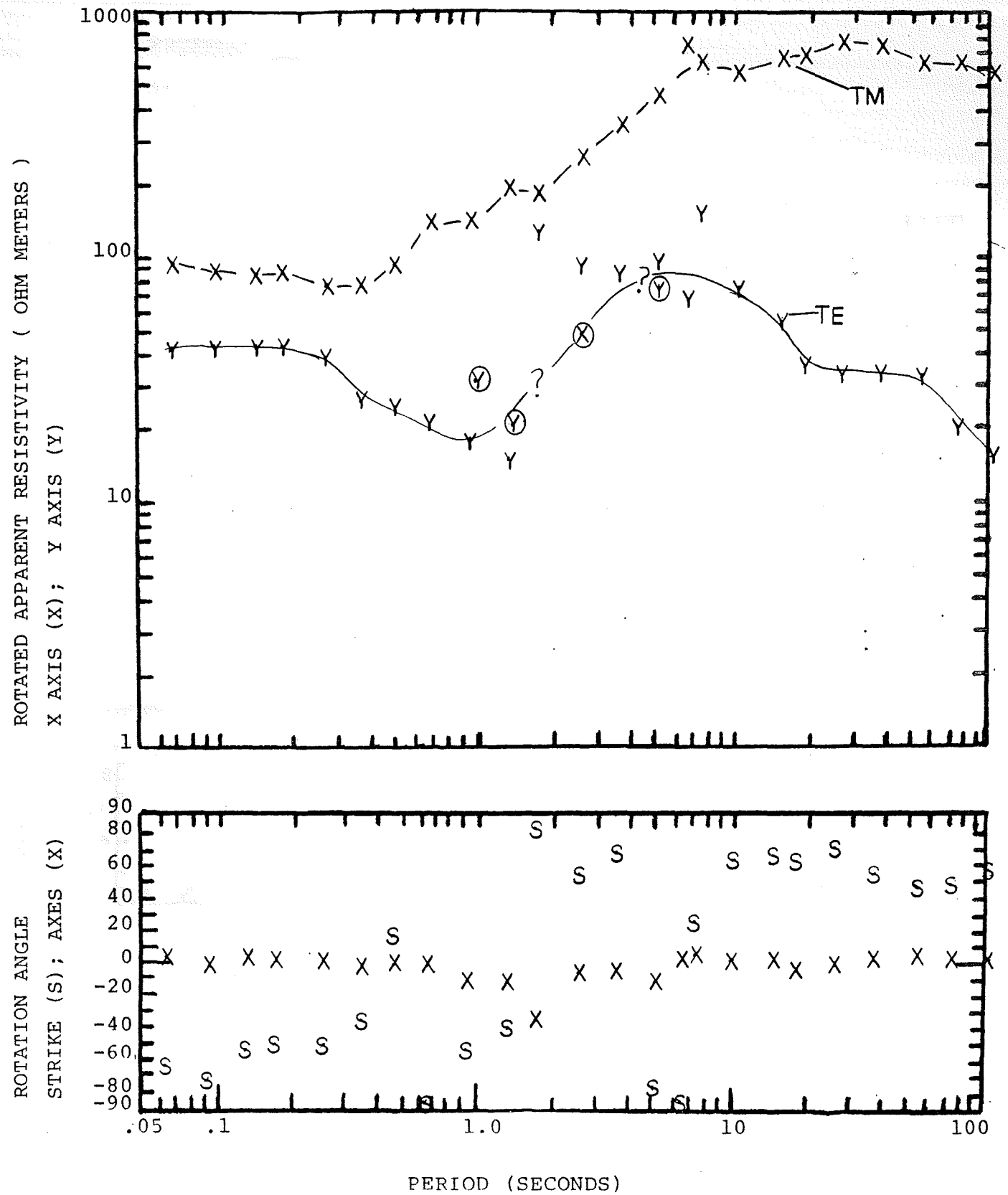
PROSPECT BULLY CREEK, OREGON

STATION 15M



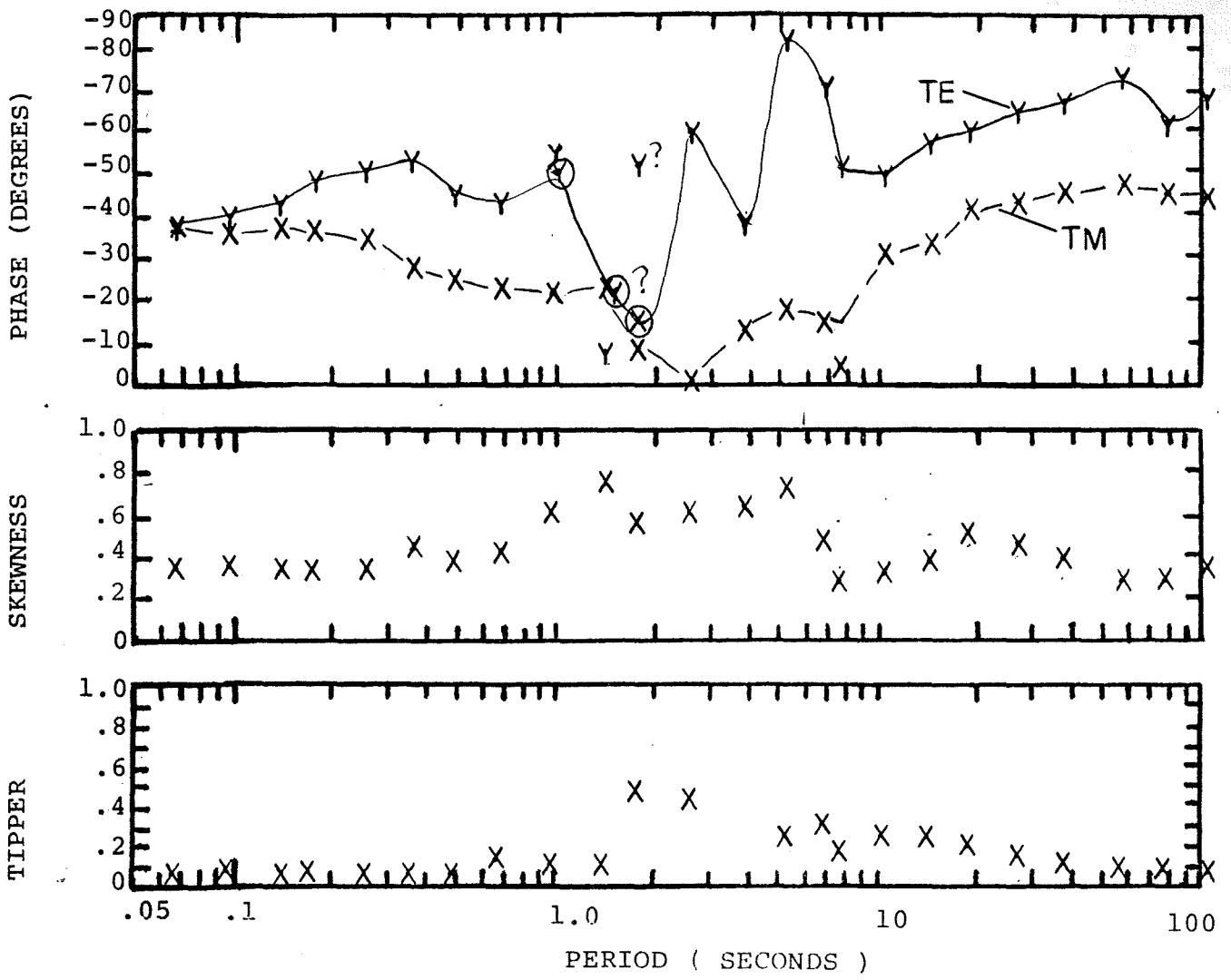
PROSPECT BULLY CREEK, OREGON

STATION 15B



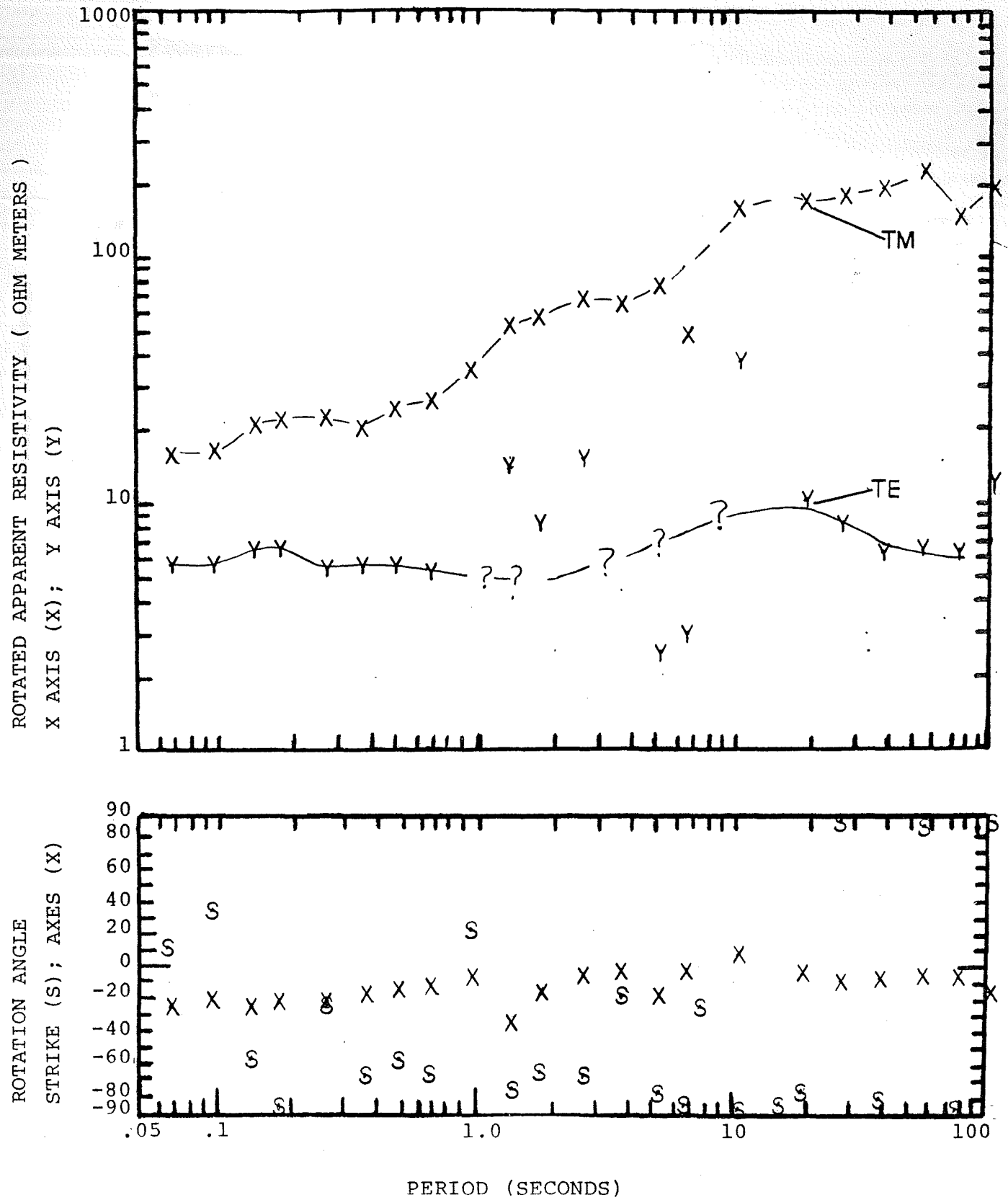
PROSPECT BULLY CREEK, OREGON

STATION 15B



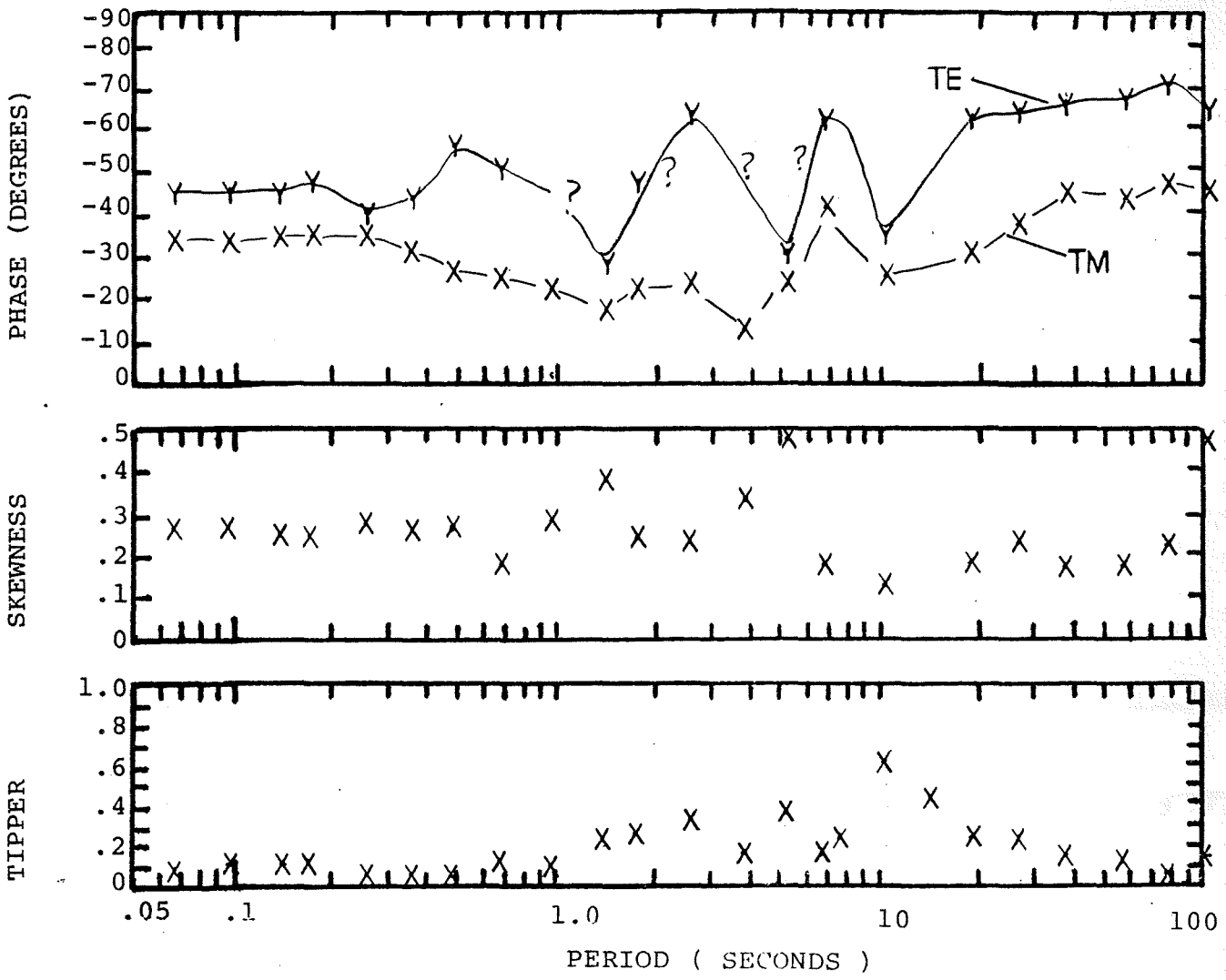
PROSPECT BULLY CREEK, OREGON

STATION 17M



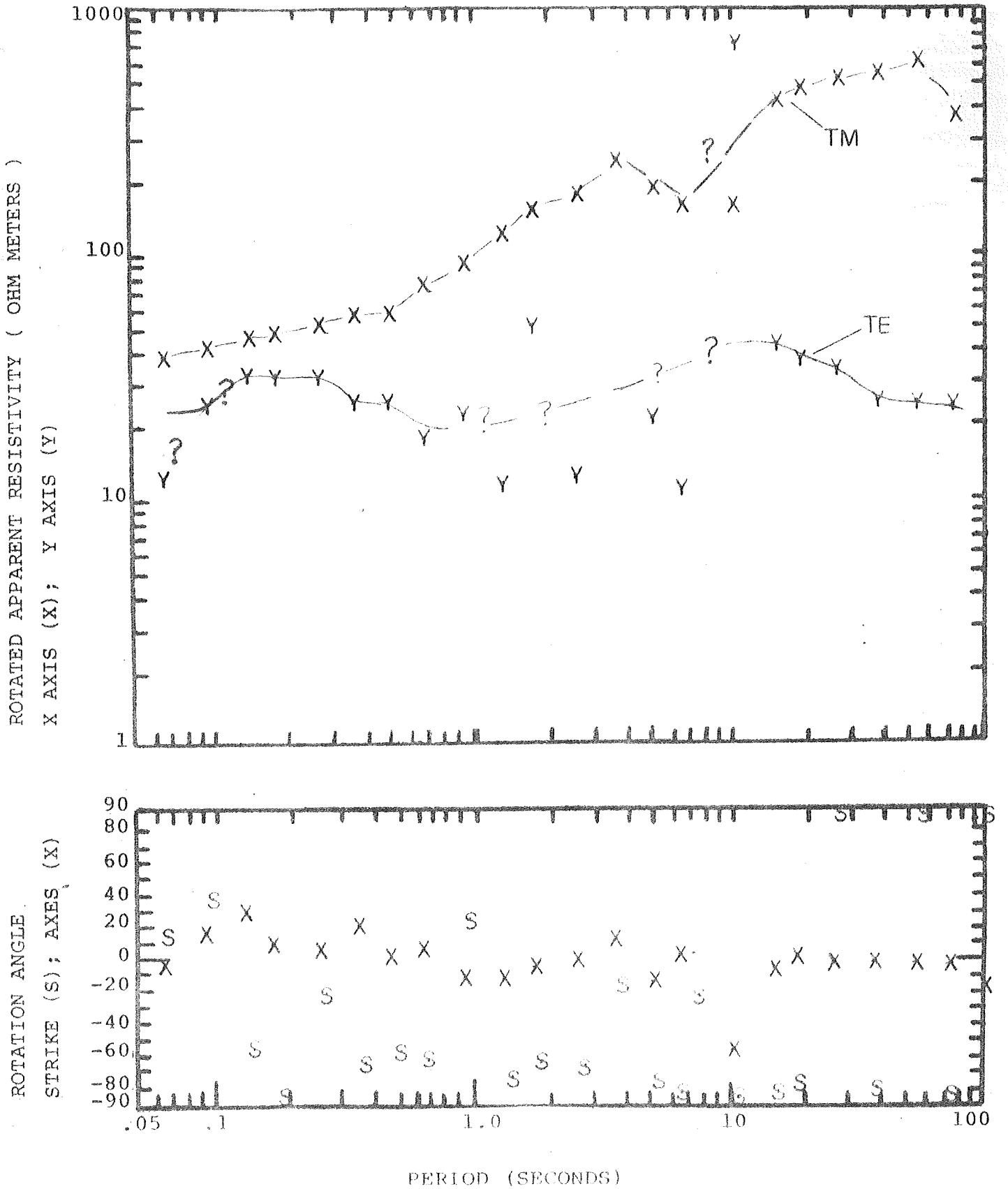
PROSPECT BULLY CREEK, OREGON

STATION 17M



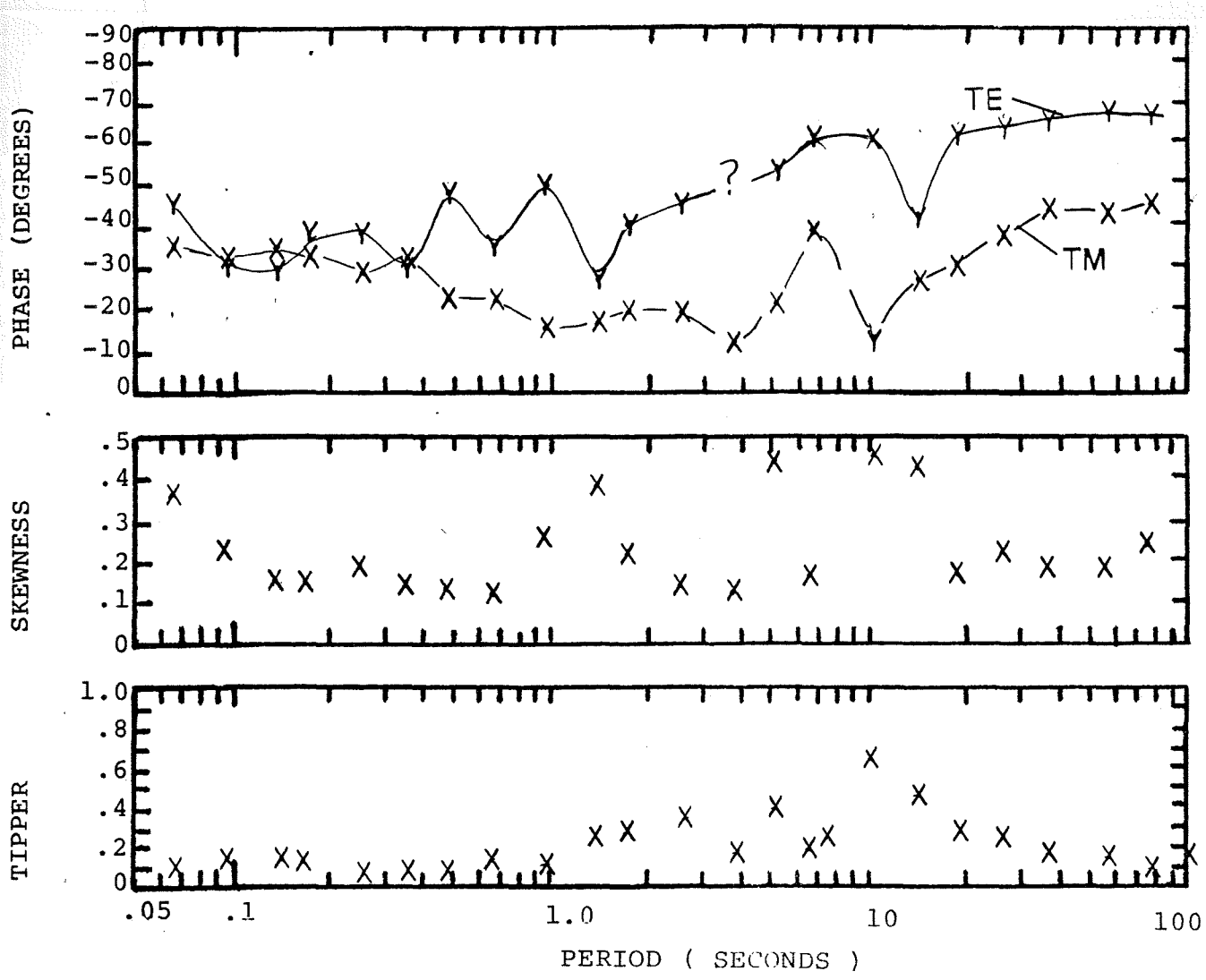
PROSPECT BULLY CREEK, OREGON

STATION 17A



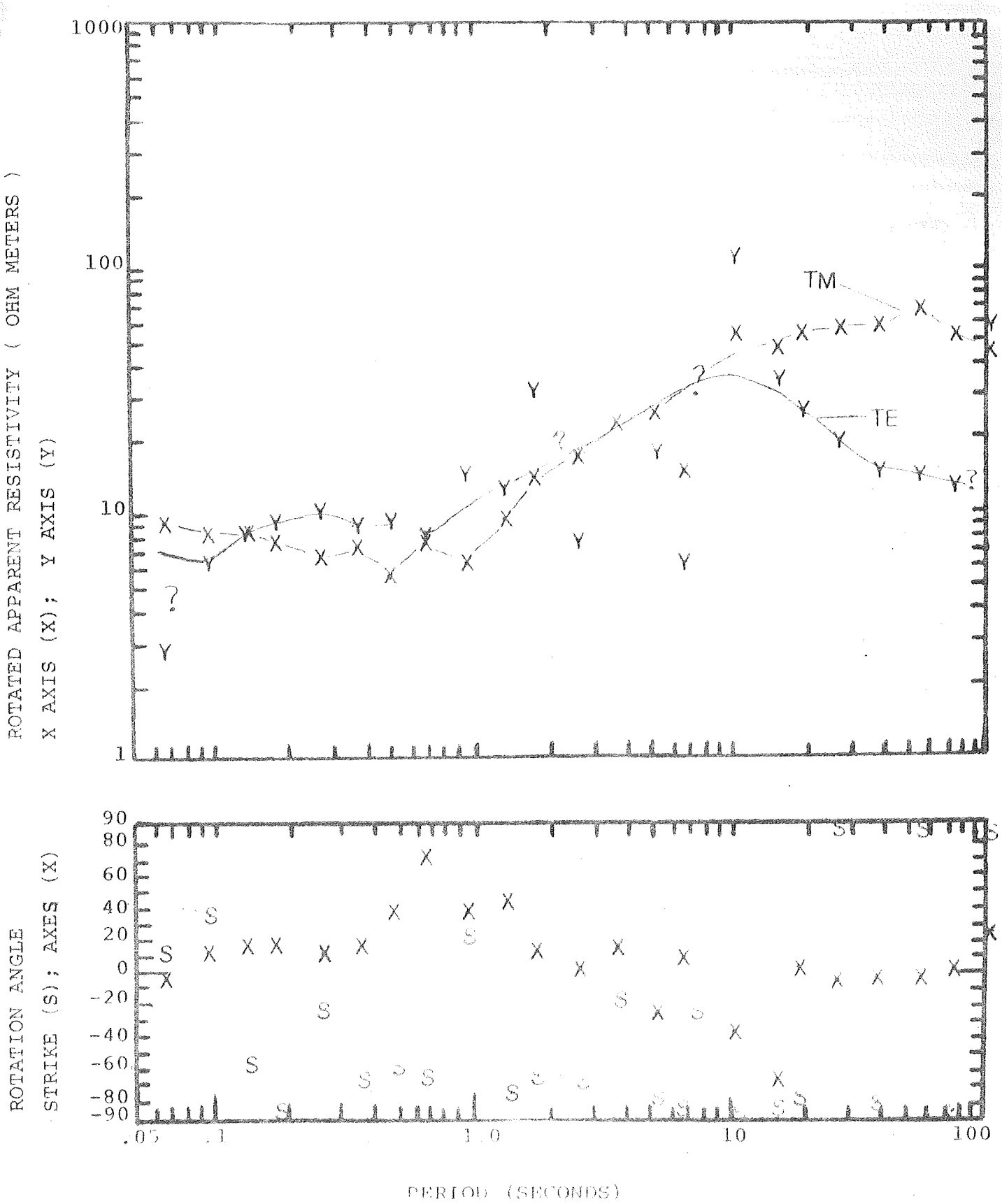
PROSPECT BULLY CREEK, OREGON

STATION 17A



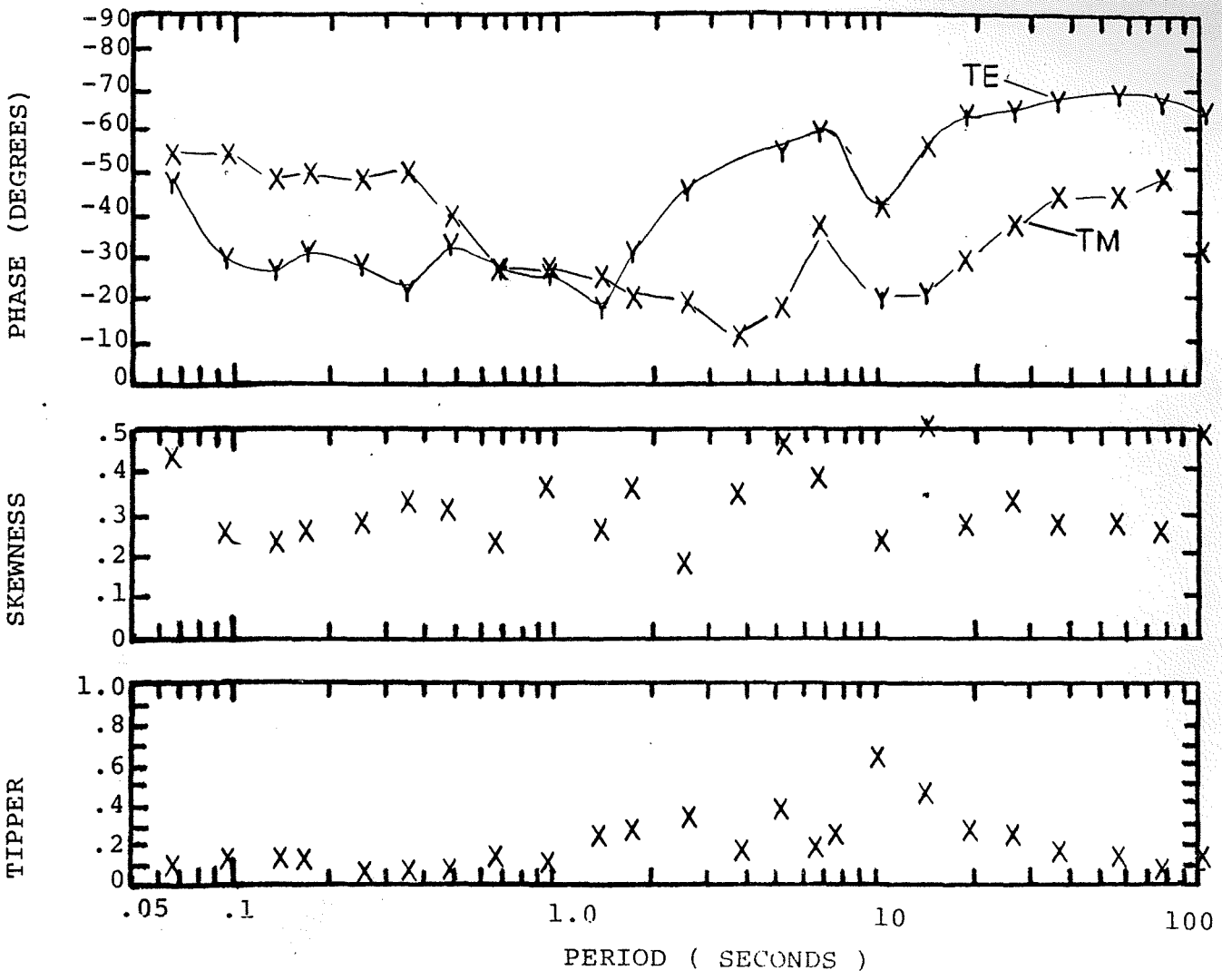
PROSPECT BULLY CREEK, OREGON

STATION 17B



PROSPECT BULLY CREEK, OREGON

STATION 17B



R 42 E

R 43 E

T 16 S

T 17 S

T 18 S

MT SURVEY PLATE 1 LOCATION MAP

APPROXIMATE DIRECTIONS 10-50 SECOND BAND
TIPPER STRIKE
TE MODE ROTATED AXIS

SCALE 1:24,000

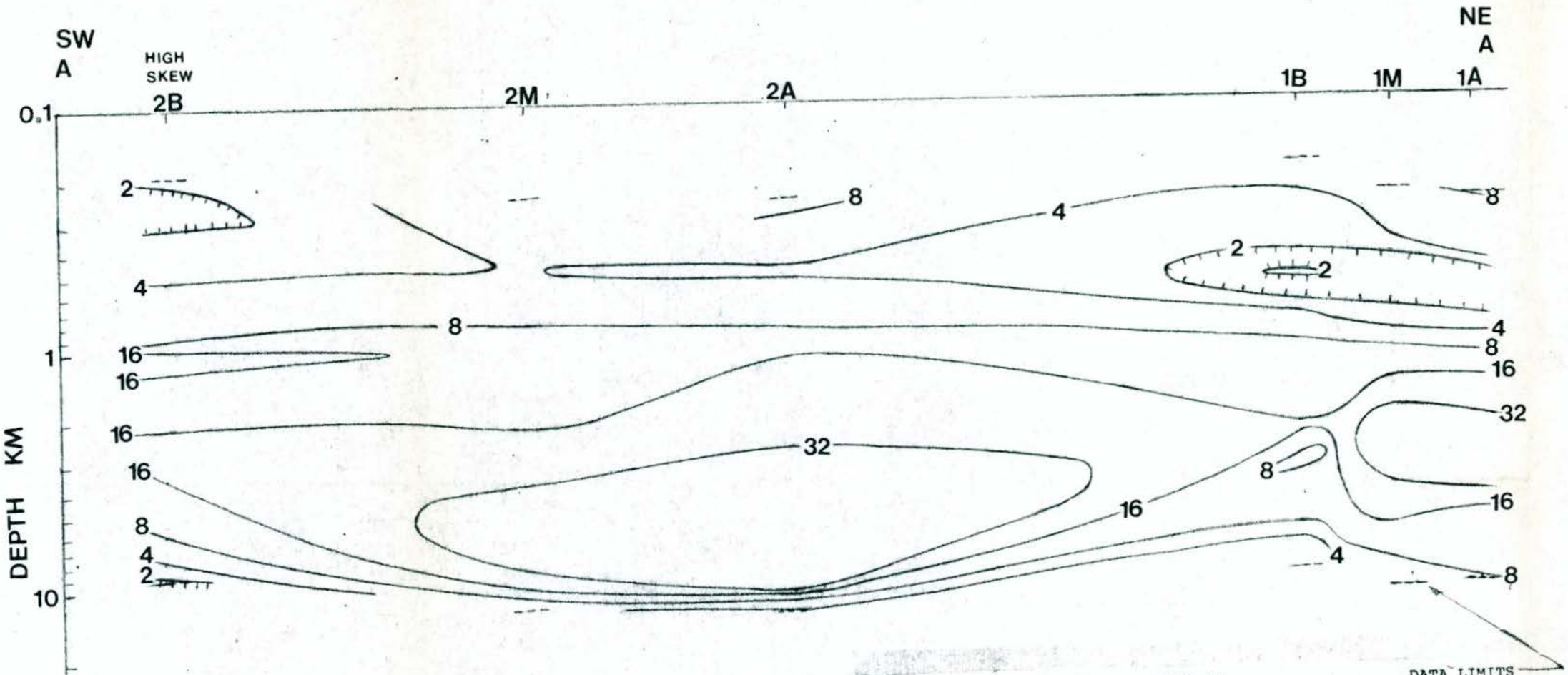
MILE
FEET
KILOMETER

NORTH
MN
18½

AMAX EXPLORATION, INC.
A SUBSIDIARY OF AMAX INC. 7100 WEST 44TH AVENUE, WHEAT RIDGE, COLORADO 80033
GEOTHERMAL BRANCH

BULLY CREEK, OREGON

BY
TERRAPHYSICS 6/81



RESISTIVITY VALUES IN
OHM METERS

PLATE 2 LINE A A'

TE MODE ONE DIMENSIONAL INVERSIONS

BULLY CREEK PROSPECT, OREGON

FOR

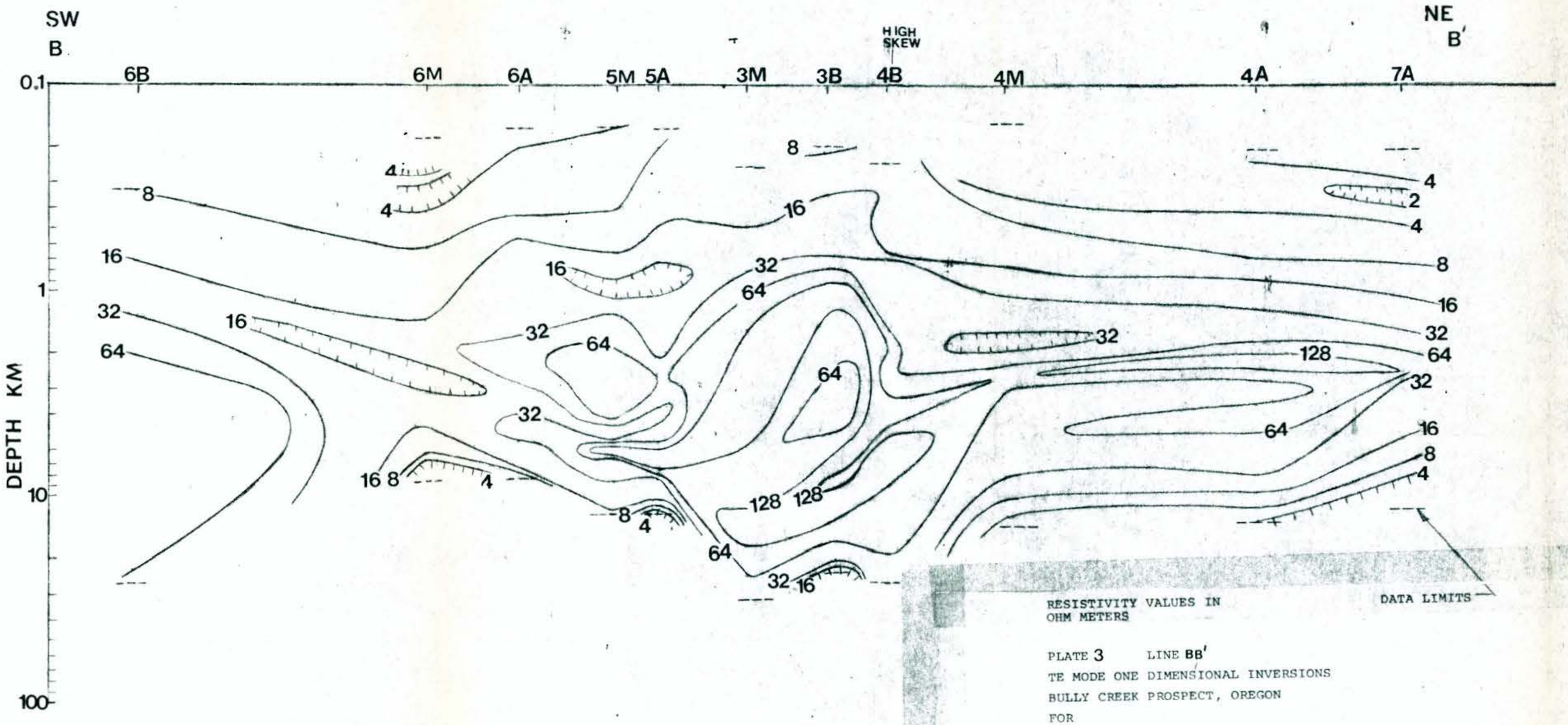
AMAX EXPLORATION INC. /

CHEVRON RESOURCES CO.

SCALE 1:24,000

BY

TERRAPHYSICS 6/81



RESISTIVITY VALUES IN OHM METERS

PLATE 3 LINE BB'

TE MODE ONE DIMENSIONAL INVERSIONS

BULLY CREEK PROSPECT, OREGON

FOR

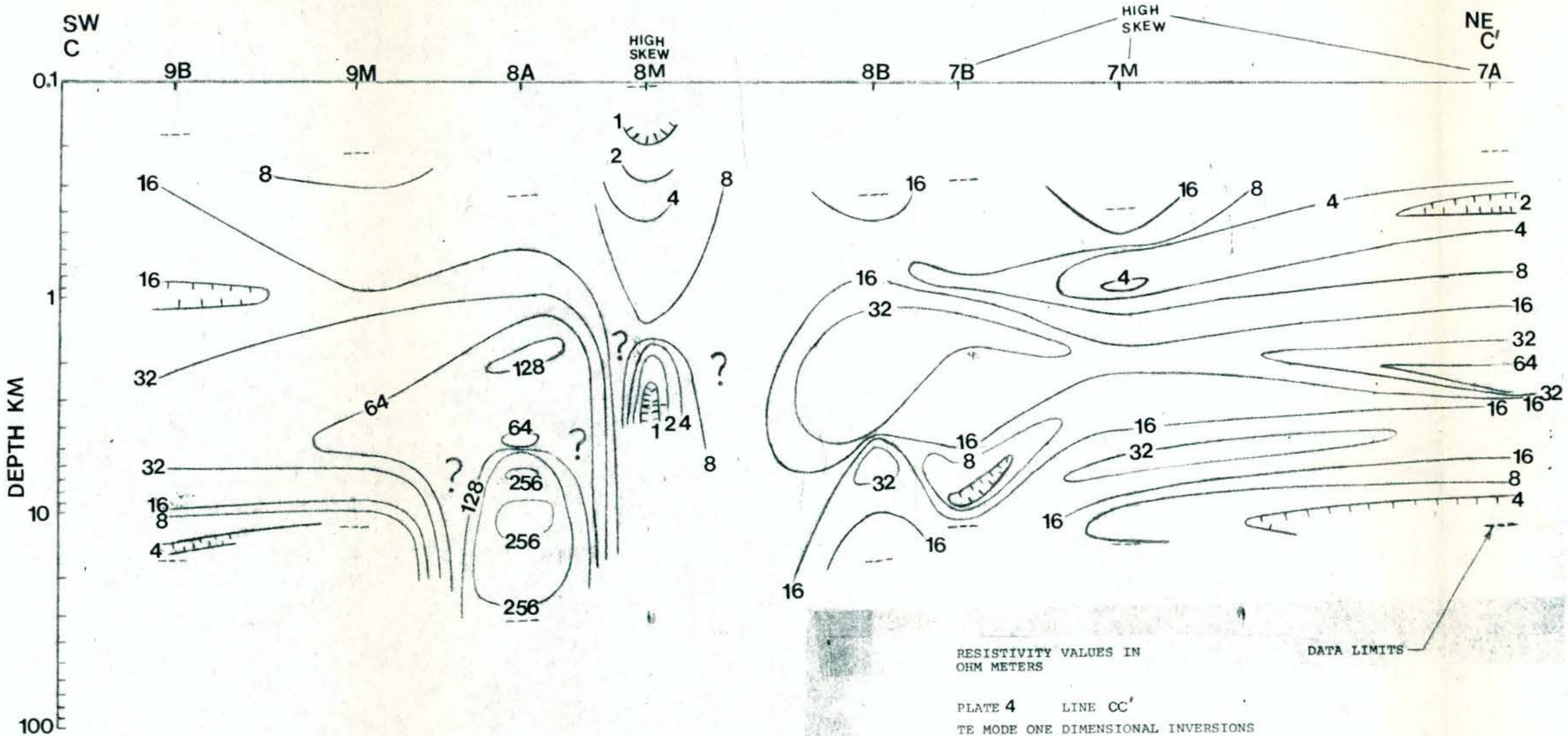
AMAX EXPLORATION INC. /

CHEVRON RESOURCES CO.

SCALE 1:24,000

BY

TERRAPHYSICS 6/81



RESISTIVITY VALUES IN
OHM METERS

PLATE 4 LINE CC'

TE MODE ONE DIMENSIONAL INVERSIONS

BULLY CREEK PROSPECT, OREGON

FOR

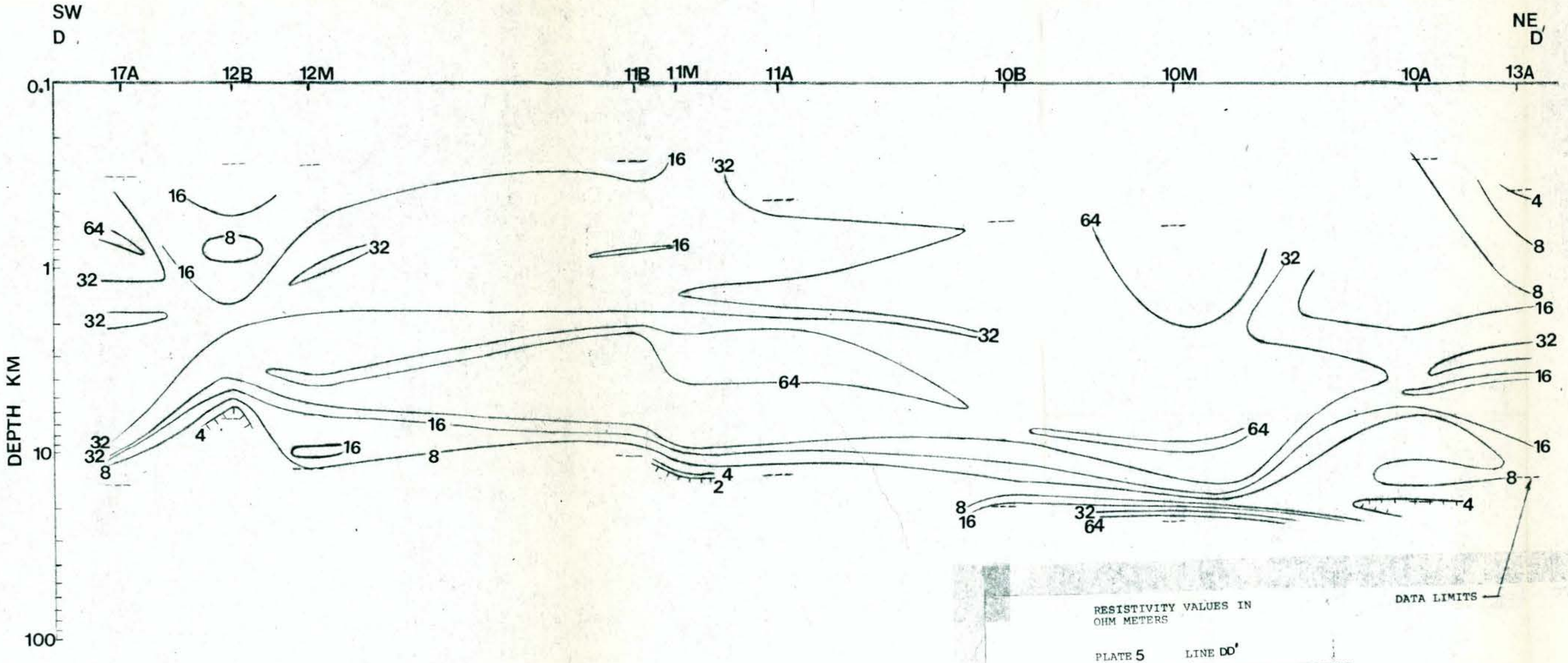
AMAX EXPLORATION INC. /

CHEVRON RESOURCES CO.

SCALE 1:24,000

BY

TERRAPHYSICS 6/81



RESISTIVITY VALUES IN
OHM METERS

PLATE 5 LINE DD'

TE MODE ONE DIMENSIONAL INVERSIONS

BULLY CREEK PROSPECT, OREGON

FOR

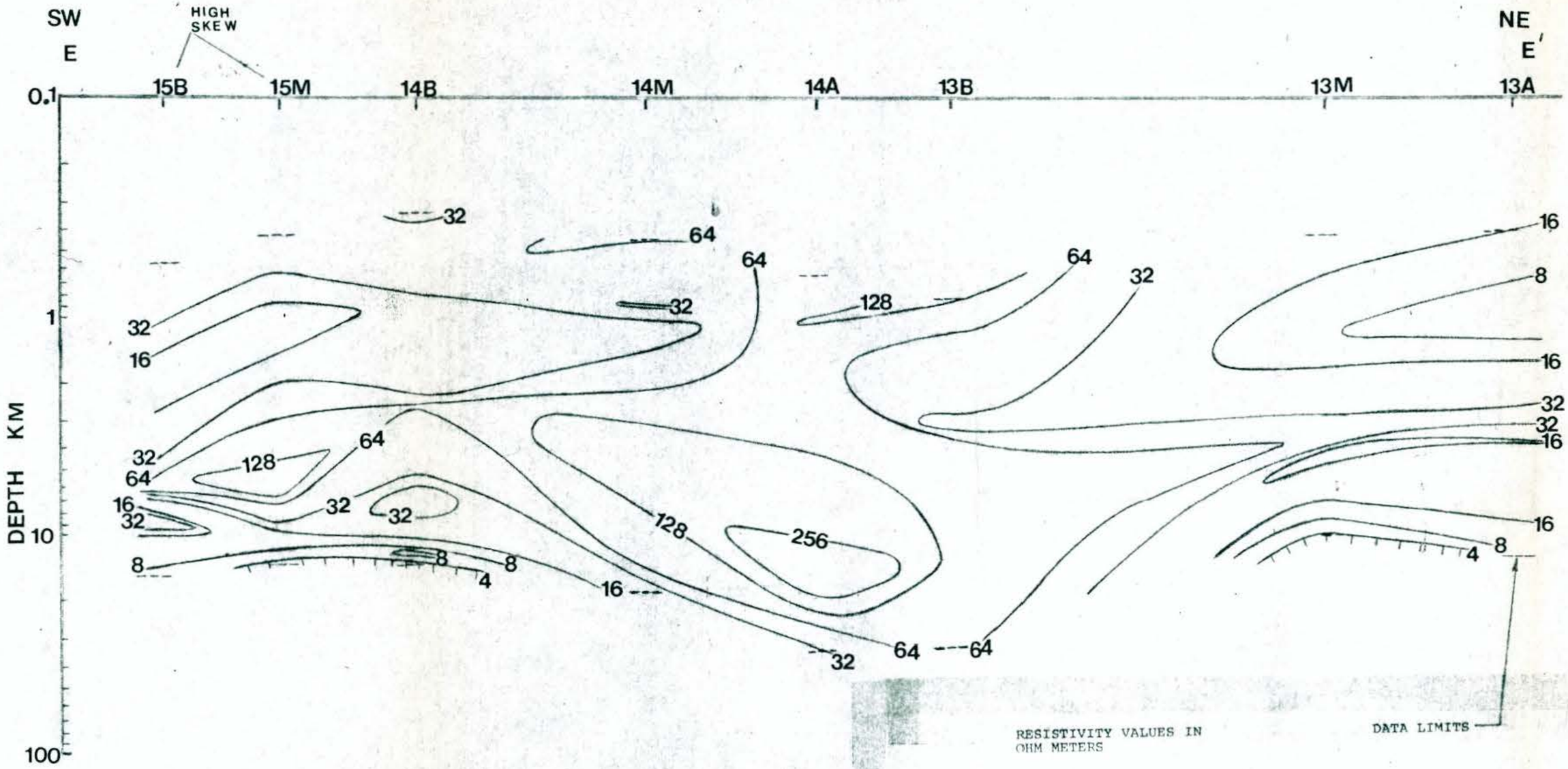
AMAX EXPLORATION INC. /

CHEVRON RESOURCES CO.

SCALE 1:24,000

BY

TERRAPHYSICS 6/81



RESISTIVITY VALUES IN
OHM METERS

PLATE 6 LINE EE'

TE MODE ONE DIMENSIONAL INVERSIONS

BULLY CREEK PROSPECT, OREGON

FOR

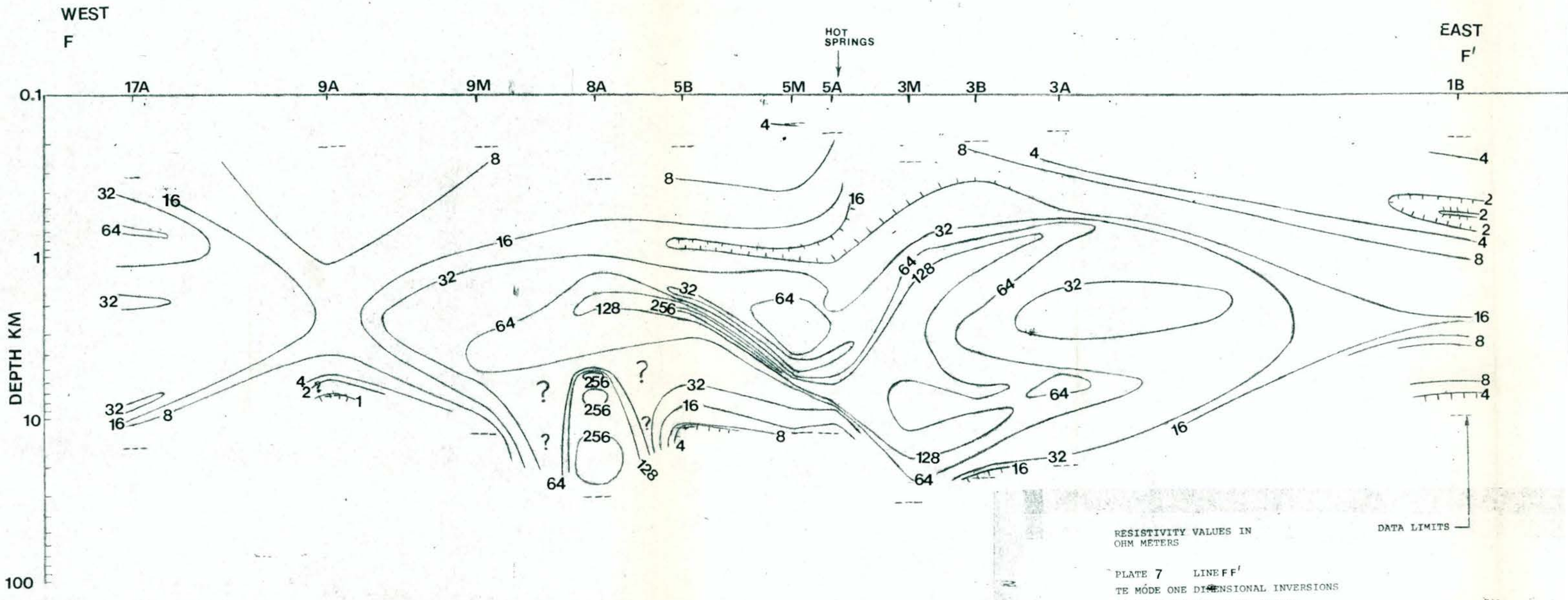
AMAX EXPLORATION INC. /

CHEVRON RESOURCES CO.

SCALE 1:24,000

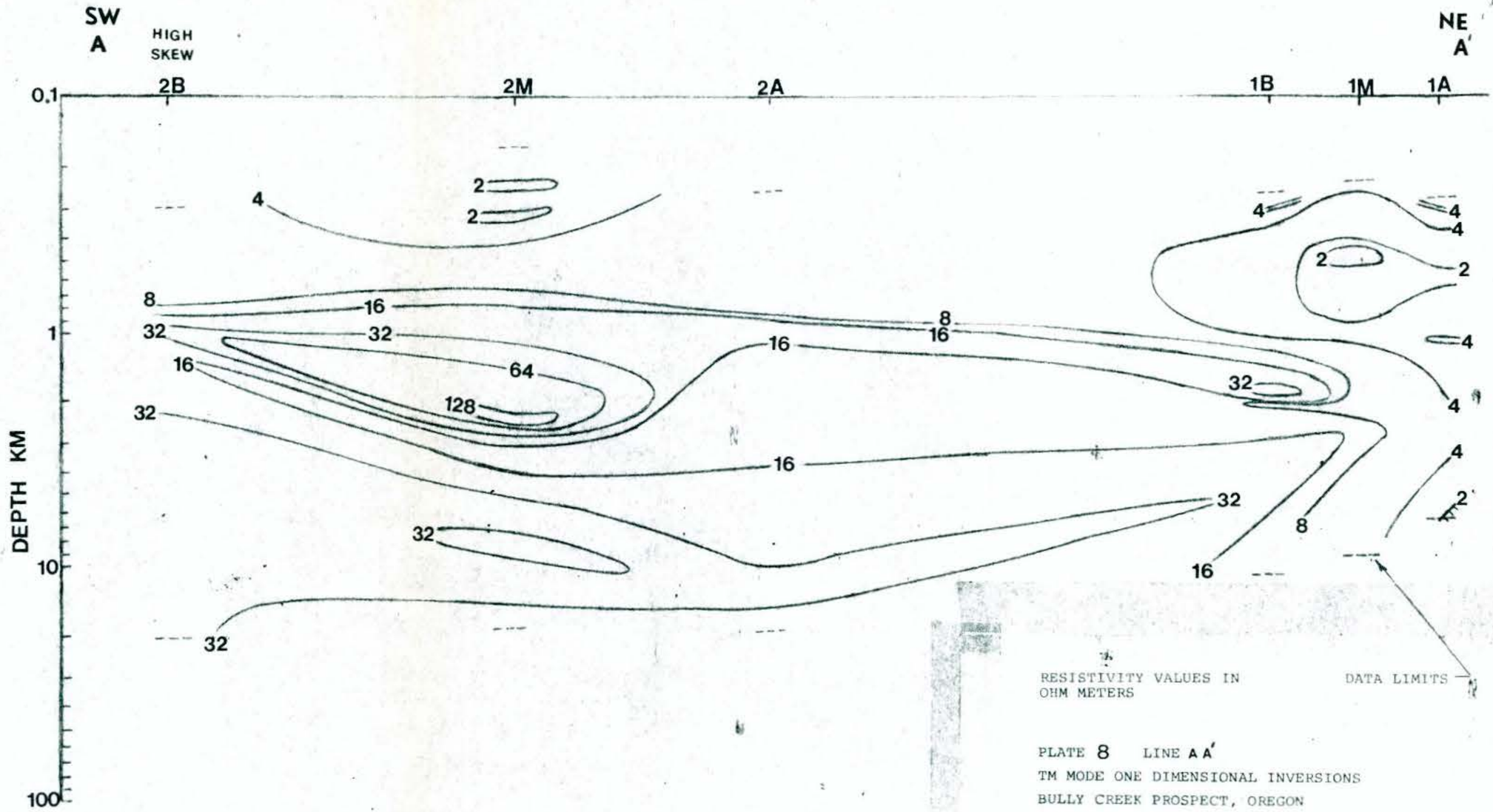
BY

TERRAPHYSICS 6/81



RESISTIVITY VALUES IN
OHM METERS

PLATE 7 LINE F F'
TE MODE ONE DIMENSIONAL INVERSIONS
BULLY CREEK PROSPECT, OREGON
FOR
AMAX EXPLORATION INC. /
CHEVRON RESOURCES CO.
SCALE 1:24,000
BY
TERRAPHYSICS 6/81



RESISTIVITY VALUES IN OHM METERS

DATA LIMITS

PLATE 8 LINE A A'

TM MODE ONE DIMENSIONAL INVERSIONS

BULLY CREEK PROSPECT, OREGON

FOR

AMAX EXPLORATION INC./

CHEVRON RESOURCES CO.

SCALE 1:24,000

BY

TERRAPHYSICS 6/81

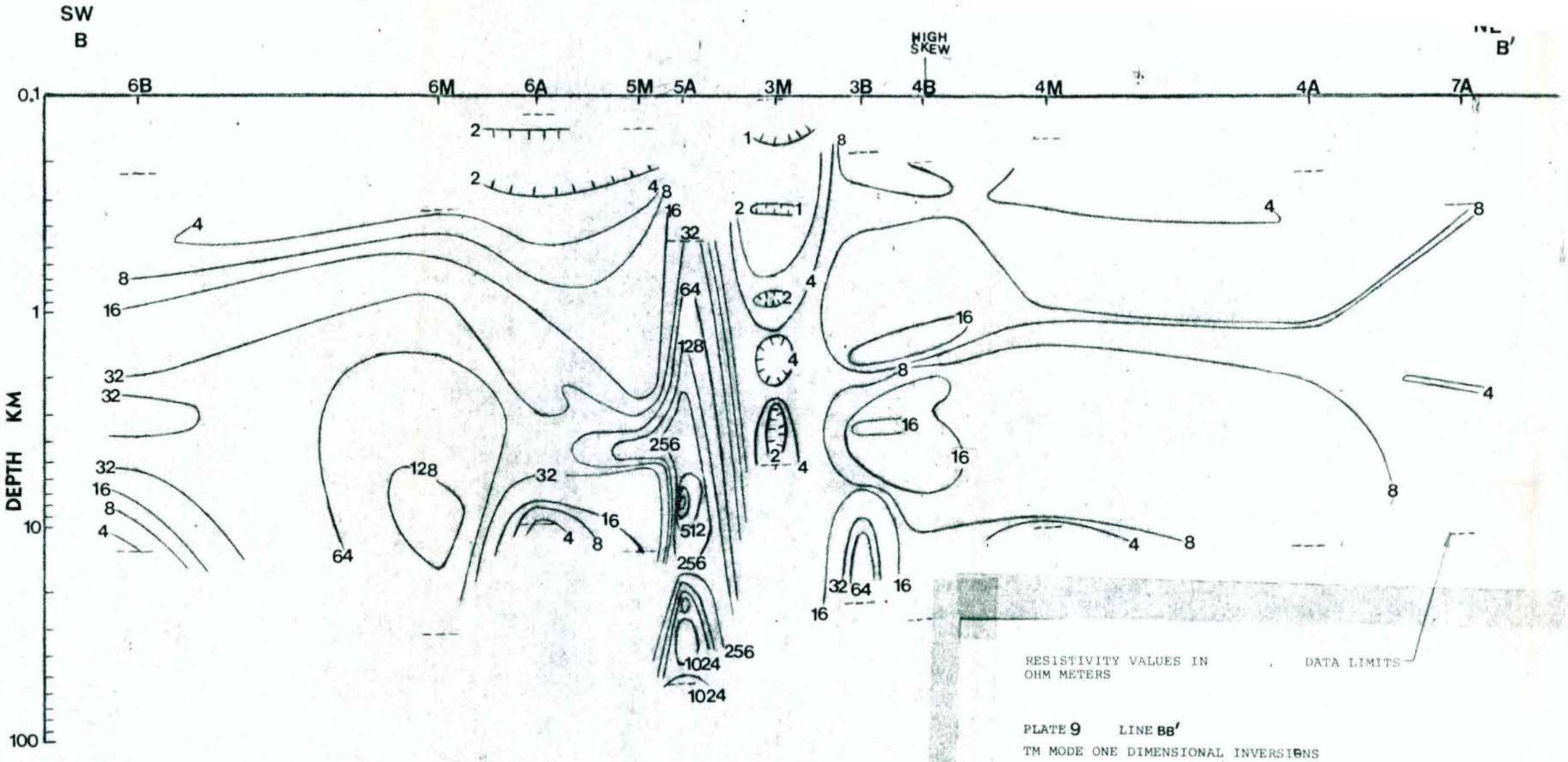


PLATE 9 LINE BB'

TM MODE ONE DIMENSIONAL INVERSIONS

BULLY CREEK PROSPECT, OREGON

FOR

AMAX EXPLORATION INC./

CHEVRON RESOURCES CO.

SCALE 1:24,000

BY

TERRAPHYSICS 6/81

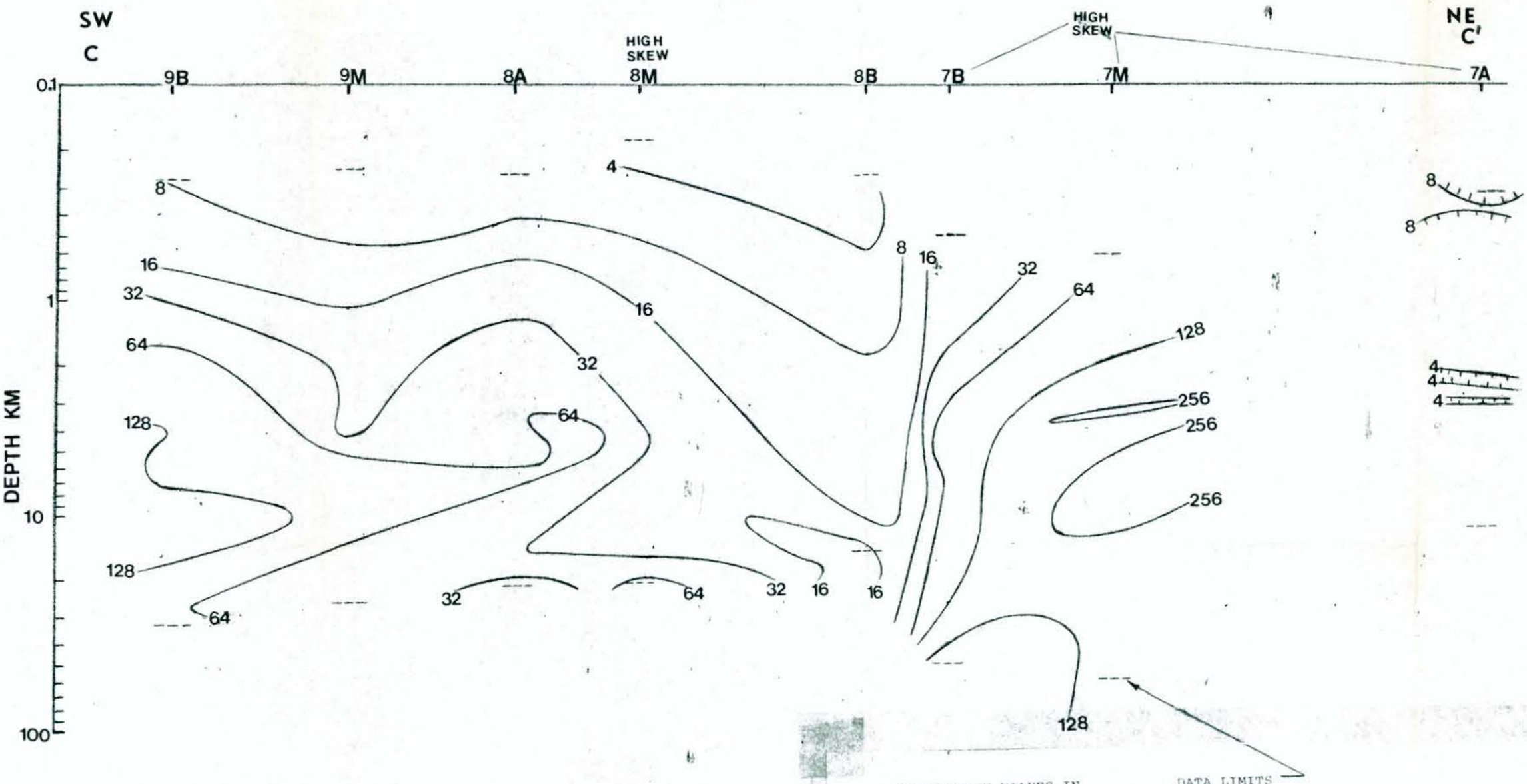


PLATE 10 LINE CC'

TM MODE ONE DIMENSIONAL INVERSIONS

BULLY CREEK PROSPECT, OREGON

FOR

AMAX EXPLORATION INC./

CHEVRON RESOURCES CO.

SCALE 1:24,000

BY

TERRAPHYSICS 6/81

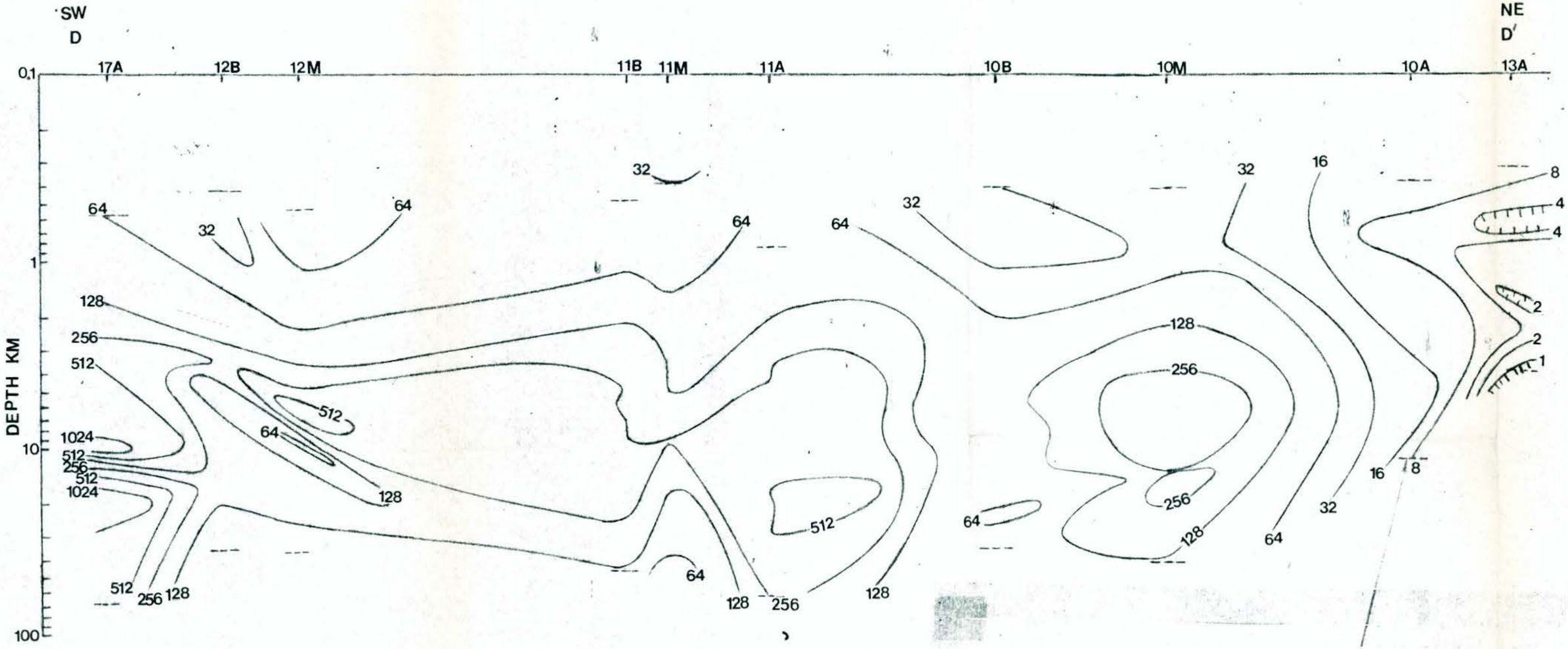


PLATE 11 LINE DD'

TM MODE ONE DIMENSIONAL INVERSIONS

BULLY CREEK PROSPECT, OREGON

FOR

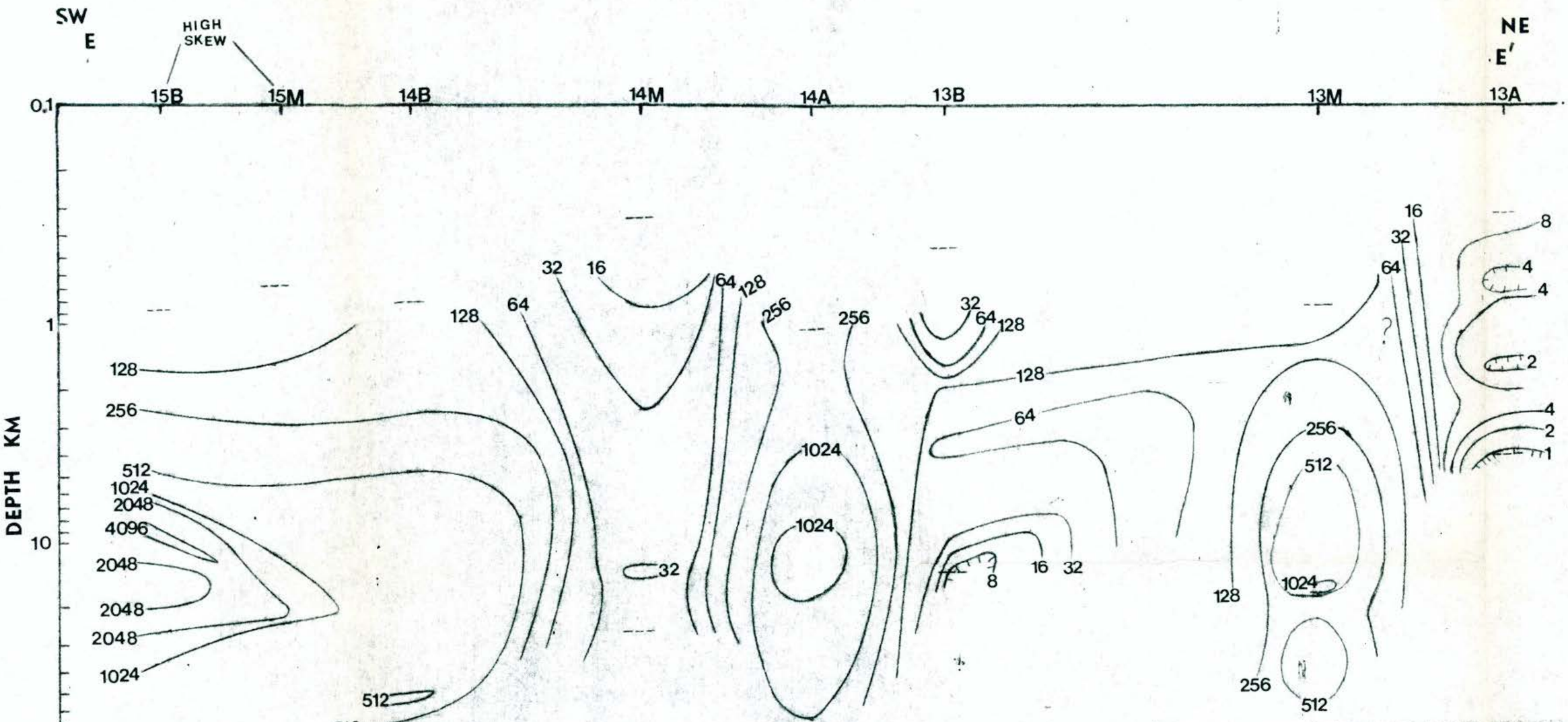
AMAX EXPLORATION INC./

CHEVRON RESOURCES CO.

SCALE 1:24,000

BY

TERRAPHYSICS 6/81



RESISTIVITY VALUES IN
OHM METERS

PLATE 12 LINE E E'
TM MODE ONE DIMENSIONAL INVERSIONS
BULLY CREEK PROSPECT, OREGON
FOR
AMAX EXPLORATION INC./
CHEVRON RESOURCES CO.
SCALE 1:24,000
BY
TERRAPHYSICS 6/81

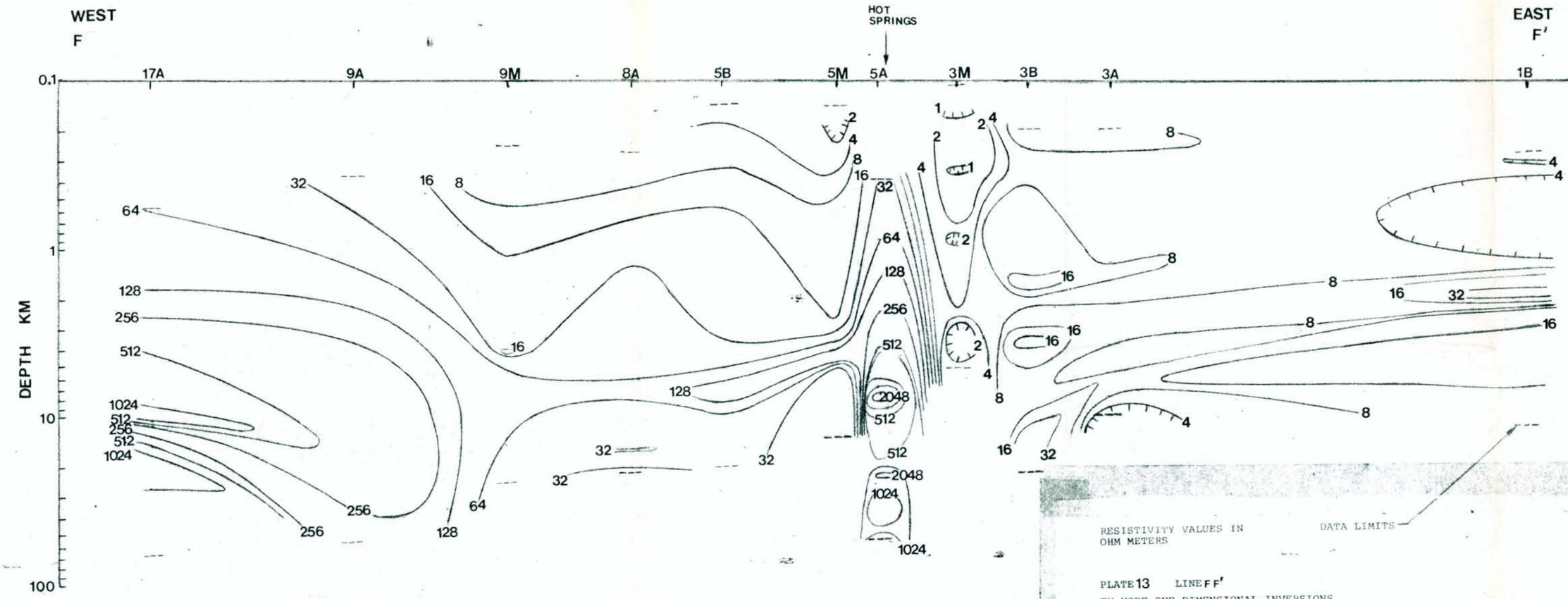


PLATE 13 LINE F F'
TM MODE ONE DIMENSIONAL INVERSIONS
BULLY CREEK PROSPECT, OREGON
FOR
AMAX EXPLORATION INC./
CHEVRON RESOURCES CO.
SCALE 1:24,000
BY
TERRAPHYSICS 6/81