UNITED STATES DEPARTMENT OF INTERIOR

GEOLOGICAL SURVEY

Geophysical measurements in the Beaver Basin, west-central Utah: Part 2--resistivity, IP, and seismic investigations

by

David L. Campbell and Vincent J. Flanigan

Denver, Colorado 80225

Open-File Report 82-420

1982

Geophysical measurements in the Beaver Basin, west-central Utah:

Part 2--resistivity, IP, and seismic investigations

by

David L. Campbell and Vincent J. Flanigan

U.S. Geological Survey, Denver, Colorado 80225

INTRODUCTION

The Beaver Basin lies near the western border of the Tertiary Marysvale volcanic field, in west-central Utah. Many of the low hills to the north, the Tushar range to the east, and the Black Mountains to the south are composed of volcanic rocks, and the granite-cored Mineral Mountains to the west also contain Tertiary intrusive and extrusive rocks. (See Rowley and others, 1979, for a more complete description.) Like other Basin and Range valleys, the Beaver Basin is fault bounded, but its depth is not known. Steven and others, 1980, point out that a valley has existed here since mid-Miocene time, and propose that the basin may have acted as a sump for uranium leached from the surrounding volcanics. Miller and others, 1980, have analyzed well waters from the Beaver Basin, showing that two separate aquifers seem to be present west of Beaver. In the location studied, the shallower aquifer (<100m) has oxidizing waters while the deeper aquifer (>200m) has reducing waters which are supersaturated with uranium. It is possible that uranium roll-fronts or stratigraphic traps may occur in either aquifer, and that there may be an aquitard between them.

This report[1] presents resistivity, spectral induced polarization (IP), and seismic data collected in September, 1980, and September 1981, in the Beaver Basin. The purpose of this work and other geophysical work there reported by Flanigan and Campbell, 1981, was to help resolve questions relating to basin depth, location of border faults, location of possible roll-front and stratigraphic uranium concentrations, and possible existence of aquitards between shallower and deeper groundwater systems.

A. DC Electrical Soundings

Vertical electrical sundings (VES) were made using a USGS-built transmitter, together with a 60 Hz, 1.4 kw gasoline-powered generator. Potentials were measured using a Honeywell "Electronic 195" strip-chart recorder. The Schlumberger electrode configuration was used, with potential electrode spacings MN/2 = 2, 6, 20, 60, 200, and 600 ft (0.61, 1.83, 6.1, 18.3, 61, and 183 m), and current electrode spacings AB/2 = 10, 14, 20, 30, 40, 60, 80, 100, 140..., 10,000, and 14,000 ft (3.1, 4.3, 6.1, 9.1, 12.2, 18.3, 24.4, 30.5, 42.7..., 3,048, and 4,267 m).

VES were made at two locations (large circles on Fig. 1):

(1) VES 1, oriented east-west, and located on Airport Road, southwest of Greenville. Center point was at station 600W on the "Airport Road" Slingram line described by Flanigan and Campbell, 1981.

(2) VES 2, oriented approximately north-south, and made on the median strip of I-15. Center point was 4.0 miles north of the Beaver off-ramp at Route 21.

[1]This work was partly funded by DOE Contract No. DE-A113-78GJ01686

Preliminary interpretation of VES 1 and VES 2 was done using a program written in BASIC language by Robert J. Bisdorf and Adel A. R. Zohdy for the Hewlett-Packard System 45A desktop computer (unpub. program, 1979). Output of the program is shown in Appendices A1 and A2. All resistivities in the tables and figures of Appendices A1 and A2 are in units of ohm-m and all distances are in units of feet.

For each VES, the following are given:

(a) original field data,

(b) table of AB/2 versus digitized resistivity, indicating the computer-shifted, -smoothed and -digitized "field" curve which the program interprets,

(c) table of "thickness-depth-resistivity", giving the layer model chosen by the program which fits the input curve within preset tolerances,

(d) table of "AB/2-calculated VES-smoothed VES", giving apparent resistivity values calculated for the chosen layer model and comparing them with values from the corresponding (smoothed) field curve,

(e) plot showing input field curve, "best-fit" layer model, and apparent resistivity points calculated for that model.

The layer models shown in Appendices A1 and A2 are idealized constructs. Unlike nature, they have perfectly horizontal layers with uniform thicknesses, and constant resistivity, and infinite extent. Further, the particular model chosen by the program is only one of many which fit the observed data. (The range of acceptable models may be analyzed using the "Dar Zarrouk" technique of Zohdy, 1974.) Therefore, the precise parameters of each layer model (number of layers, exact depths to top or bottom of a layer, resistivity of a layer) are not necessarily significant; only the general features are. Clearly there is a very thick, conducting (about 4 ohm-m) substratum present below approximately 140 ft (43 m) depth in the southern part of the Beaver Basin (VES 1). North of Beaver (VES 2) there is a conducting substratum which is shallower (about 50 ft = 15 m) and more resistant, about 15 ohm-m. Both resistivity values might represent sediments containing brackish waters. These conducting substrata extend downward to a relatively electrically resistant horizon that could represent crystalline basement, present at about 5200 ft (1580 m) at VES 1, and at about 6000 ft (1830 m) at VES 2. The basement-depth estimate at VES 1 is tentative due to the big error envelopes of the VES 1 signal at large electrode distances AB/2. The VES 2 signal quality was good at all distances, so that all depth estimates at the VES 2 site should be correct within ±20 percent.

B. Spectral IP work

Multi-frequency induced polarization (IP) measurements were made using a ZERO geophysical data processor (GDP) together with a Geotronics EMT-5000 transmitter and a 10 kw gasoline-powered Onan generator. The GDP was used with its standard IP programs, transmitting square-wave signals of frequencies indicated by thumb-dial settings 0 (128 sec/cycle), 1 (64 sec/cycle), 2 (32 sec/cycle), 3 (16 sec/cycle), 4 (8 sec/cycle), 5 (4 sec/cycle), 6 (2 sec/cycle, 7 (1 sec/cycle), 8 (2 cycle/sec), 9 (4 cycle/sec), 10 (8 cycle/sec), 11 (16 cycle/sec), 12 (32 cycle/sec), 13 (64 cycle/sec), 14 (128 cycle/sec), and 15 (256 cycle/sec). Measurements were made at three locations (squares in Fig. 1):

(1) Airport Road, 200 S. This dipole-dipole sounding was located along the "Airport Road, 200 S" slingram line described by Flanigan and Campbell, 1981. Two hundred-foot (61-m) dipoles were used, with electrode 0 located at station 200E and electrode 10 at station 1800W. IP measurements were made at frequency settings 1, 4, and 7. Pseudo-sections of measured phases and apparent resistivities are given in Appendix B1.

(2) Airport Road, south. This dipole-dipole sounding was located along the "Airport Road, south" slingram line described by Flanigan and Campbell, 1981. Two hundred-foot (61-m) dipoles were used, with electrode 1 at station 400W and electrode 10 at station 2200W. IP phase measurements were made at frequency settings 0, 1, 2, 3, 4, and 7. Pseudo-sections of measured phases and apparent resistivities are given in Appendix B2.

(3) Big John caldera. IP spectra were measured on two outcrops of a conglomerate beneath the Joe Lott Tuff Member of the Mount Belknap volcanics in the Big John caldera (Fig. 1). Steven and others (1979) speculate that this relatively-porous conglomerate may contain roll-front uranium deposits with the uranium leached from the tuff immediately above it. The two exposures of the conglomerate occur along Highway 153 about 4 miles (6.4 km) apart. At the NE exposure the conglomerate was red in color (oxidized) and at the SW exposure it was brown (reduced). The purpose of the experiment was to test for possible IP spectral differences between the oxidized and reduced ground. Set-up was identical at both sites, involving 50-foot (15.2-

m) dipoles arranged at the n=1 dipole-dipole configuration. The conglomerate at each site is at least 15 m thick (its bottom is not exposed), and the unit appears to dip to the north. Electrodes were embedded in the outcrop along Highway 153 and approximately in the center of its apparent width.

Plots of the resulting IP spectra are shown in Appendix B3. No particular differences in the spectra are apparent, so we conclude that spectral IP cannot distinguish oxidized and reduced ground here. This does not mean that IP cannot be used to find uranium roll-fronts, however; Smith and others, 1976, document cases where IP does this well. Apparently the IP responds to disseminated sulfides or other minerals associated with the roll front, but not to oxidized and reduced ground as such.

C. Magnetic and Resistivity Measurements at the Big John caldera IP Sites

There were minor resistivity differences between the NE and SW sites at the Big John caldera. Resistivity of the reduced facies (SW outcrop) was 27.1 ohm-m, of the oxidized facies (NE outcrop) 19.7 ohm-m, as measured at GDP frequency setting 0. Corresponding resistivities measured at VLF frequency 18.6 KHz using a Geonics EM16 with R100 attachment were about 28 ohm-m and about 5 ohm-m, respectively, with phase angles of 52^{o} at both sites. At a stream crossing of the SW exposure, VLF resistivity dipped to a low of 10 ohm-m. The VLF resistivity of the Joe Lott Tuff Member overlying the conglomerate was 50 ohm-m, and that of the Osiris Tuff, which lies just south of the NE site across the topographic wall of the Big John caldera, was 38 ohm-m.

The Joe Lott Tuff Member is somewhat more magnetic than the conglomerate. A Geometrics model 826A magnetometer was used to make total field magnetic measurements at the SW site along Highway 153, so that the profile crossed the tuff-conglomerate contact at a very gentle angle. Over tuff, the magnetics were spikey with a noise envelope of approximately 200 nT. Upon crossing the contact, the measured field dropped by some 200 nT from the average value over tuff and became smooth, continuing to drop at a uniform rate of about 1 nT every 8-9 ft (1 nT/2.5 m) as we proceeded southwesterly away from the contact. The experiment was then repeated at the NE site with very similar results; even the magnitudes of the fields were comparable. We conclude that there is no practical difference between susceptiblities of oxidized and reduced conglomerate, and that the overlying Joe Lott Tuff Member has sufficiently erratic magnetization to mask even quite large magnetic signatures which might exist due to possible redox cells in the conglomerate below.

D. Seismic reflection and refraction

A Bison model 1580 seismograph was used to record waves generated by dropping a 500-pound (227-kg) weight on an identical 500-pound anvil from heights up to 2 meters. An inertia switch started the seismometer clock at impact. Waveforms were detected using standard Mark IV vertical-component geophones and were recorded on strip-charts using a Bison model 1480 strip-chart recorder.

Preliminary refraction work was done (only) at seismic locations 1 and 3 (figure 1), and showed similar near-surface structures at both locations. Appendix C shows data from these locations. Interpretation was done using a hand-calculator program by Campbell, 1981. At location 1 there is an 11-m thick surficial layer having velocity 380 m/s, underlain by a unit of velocity 1560 m/s. The interface between the two layers is horizontal (0° apparent dip along the east-west line of the geophones, as shown by reversing the shots). At location 3 there is a 1-m to 4-m thick surficial layer having velocity 375 m/s, underlain by a 12-m to 6-m thick layer of 900 m/s material, underlain by material of velocity 1620 m/s. Sketches of the interpreted seismic structure are given in Appendix C.

At location 3, the interface between 375 m/s and 900 m/s material may represent the water table, for the nearby fields are irrigated at that site. By contrast, seismic location 1 is in dry sagebrush land, and here the 900 m/s unit was not detected. Velocities of 1560 m/s or 1620 m/s are also typical of sediments, moist or dry, but are too low to represent any but the most fractured or weathered of volcanic flows or limestone units. At seismic location 1, resistivity values increase at the approximate depth of the 1560 m/s interface (Appendix A1), so it is unlikely that this interface represents water table there. The most likely interpretation is, therefore, that the 1560 m/s and 1620 m/s layers represent sedimentary units different from those at the surface. These units are each estimated to be at least 24 m thick: an assumed 3000 m/s layer at 35 m depth would lead to breaks in the observed refraction curves between 90 and 100 m distance in both cases, and a single (but not definitive) early arrival which may indicate such a break was observed at one 100-m geophone at each site.

Reflection records were made at five places in the Beaver Basin, indicated by X's on Figure 1. In each case, seismic arrivals were recorded for a total of three seconds after the source impulse. (Each of the six seismometer channels recorded for 500 msec. Delay times were set so that channel 1 recorded from 0 to 500 msec, channel 2 from 500 to 1000 msec, etc.) The experiment tried to detect reflections from horizons which might represent aquitards in the sedimentary (or volcanic?) fill of the Beaver Basin, or the crystalline basement below. Strip-charts of the resulting signals are shown in Appendix D.

At location 1, there were a number of arrivals which were relatively evenly spaced and which had similar waveforms. These arrivals may represent multiple P-wave reflections from a strong reflector below. The character of the seismic traces changes systematically as one moves north and east from location 1. At location 2, there are arrivals to 3 seconds, but they are not the clear bursts of energy which may represent multiple reflections at location 1. At location 3, there are no strong arrivals after about 1.5 seconds. At location 4, there are no strong arrivals after about 0.8 seconds, and at location 5 there are no strong arrivals after about 0.4 seconds. At all these locations, the data-taking procedures were comparable. We conclude that the possible strong reflector at location 1 becomes ill-defined or absent as one moves to the north, and that the sedimentary fill is too thick at sites 4 and 5 (at least) for a basement reflection to be recorded using our particular instruments and weight drop-system. (Presumably the wave becomes scattered and absorbed while traveling through the thick basin sediments.)

We have the following advice for others who may try similar seismic reflection work:

(1) Movement of nearby vehicles, animals, and crew members during any particular 3-second recording period is very likely to add spurious

arrivals to the record. Such spurious waves often are so large they swamp out the weak reflected arrivals you want. Therefore,

(a) Don't use the "stacking" capability of the instrument, by which new signals are added to old as the weight is dropped again and again. If you do, the record will end up being a composite showing every high-amplitude accident that happened over all 3-second recording periods.

(b) Always record at least twice at a site, and reject any wave which doesn't arrive each time.

(2) Arrange it so the hammer strikes the anvil without tumbling off. Multiple sources are hard to sort out!

(3) You can get as big a signal hitting the anvil with an 8-lb sledge hammer as you can dropping the weight from about 2 ft (0.6 m), and the frequency content of the signal is about the same (probably due to the natural modes of vibration of the anvil). High frequencies damp rapidly in the material filling the Beaver Basin, so that only lower frequency reflections(?) are seen after approximately 500 msec. The lower frequencies imparted by the large anvil are therefore appropriate to this work. Dropping the 500-lb weight from 6 ft (1.8 m) doesn't even double the signal amplitude of the post-500 msec reflections which may be produced by sledge hammer. It would be interesting to compare dynamite sources with weight-drop sources for this kind of reflection work.

References

Campbell, D. L., 1981, Four or fewer dipping seismic refractors: interpretation, Program SEIS 13C in Ballantyne and others, eds., Manual of Geophysical Hand-calculator Programs: Society of Exploration Geophysicists, Tulsa.

Flanigan, V. J., and Campbell, D. L., 1981, Geophysical studies in the Beaver Basin, west-central Utah: part 1--slingram, magnetic, and spontaneous polarization profiles: U.S. Geological Survey Open-File Report 81-199, 5 p., 11 figs.

Miller, W. R., McHugh, J. B., and Ficklin, W. H., 1980, Possible uranium mineralization, Beaver Basin, Utah: U.S. Geological Survey Open-File Report 80-508, 35 p.

Rowley, P. D., Steven, T. A., Anderson, J. A., and Cunningham, C. G., 1979, Cenozoic stratigraphic and structural framework of southwestern Utah: U.S. Geological Survey Professional Paper 1149, 22 p.

Smith, B. D., Cady, J. W., Campbell, D. L., Daniels, J. J., and Flanigan, V. J., 1976, A case for "other" geophysical methods in exploration for uranium deposits: International Atomic Energy Agency, Proceedings, International Symposium on Exploration for Uranium Ore Deposits, Vienna, Austria, p. 337-351.

Steven, T. A., Cunningham, C. G., and Anderson, J. J., 1979, Uranium potential of the Big John caldera, Beaver County, Utah: U.S. Geological Survey Open-File Report 79-527, 16 p.

Steven, T. A., Cunningham, C. G., and Machette, M. N., 1980, Integrated uranium systems in the Marysvale volcanic field, west-central Utah: U.S. Geological Survey Open File Report 80-524, 39 p.

Zohdy, A. D. R., 1974, Use of Dar Zarrouk curves in the interpretation of vertical electric sounding data: U.S. Geologial Survey Bulletin 1313-D, 41 p., 1 pl.

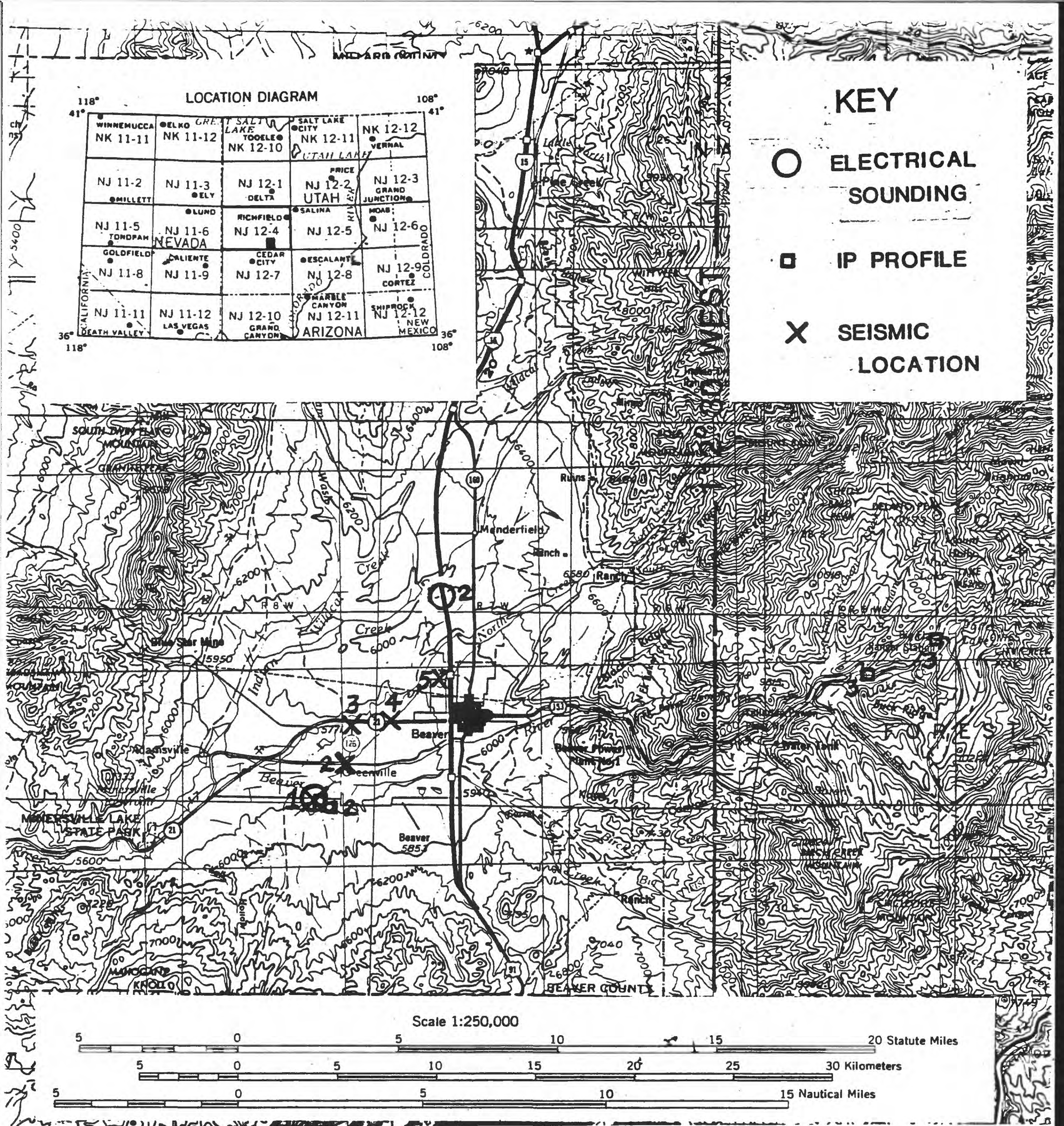
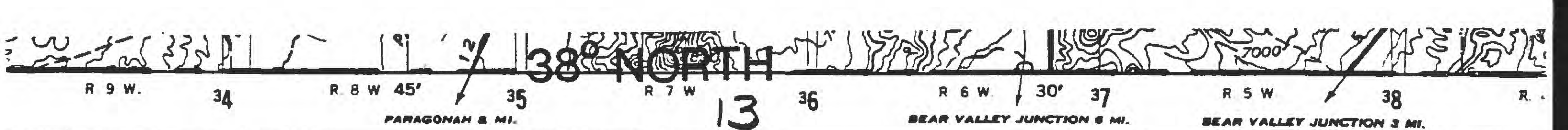
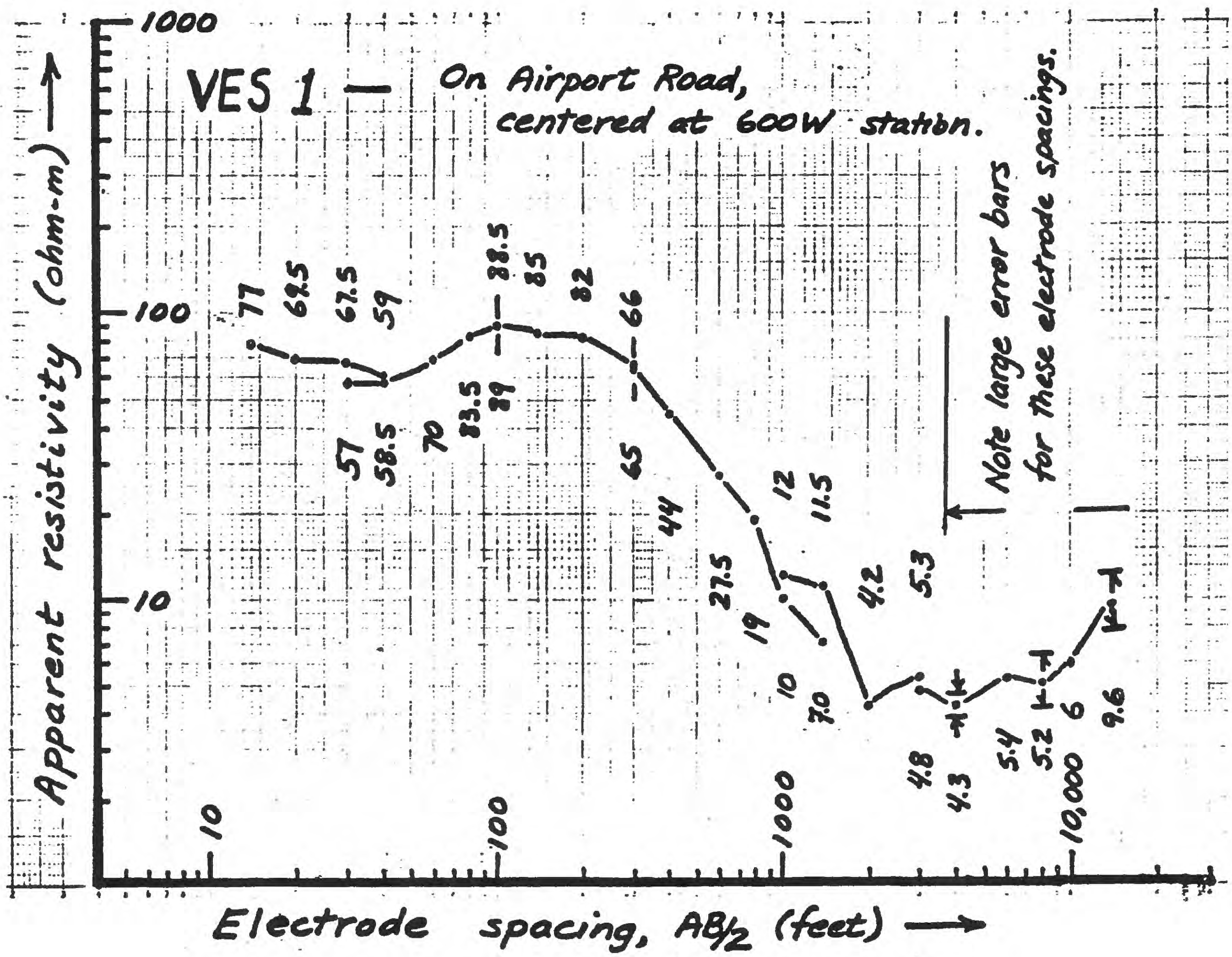


Figure 1.—A portion of the Richfield, UT, 2° sheet, showing approximate locations of geophysical investigations described in this report.





VES 1

IFORCE =1

AB/2	DIGITIZED RESISTIVITY
20.54919	73.21519
30.16209	71.08028
44.27189	62.56716
64.98224	78.74323
95.38089	94.16766
140.00000	90.97770
205.49190	87.33864
301.62086	70.23040
442.71887	41.65068
649.82244	27.93553
953.80890	12.37570
1400.00000	6.33962
2054.91897	3.78240
3016.20856	4.80232
4427.18872	4.42245
6498.22436	5.39788
9538.08896	5.73650
13999.99999	9.00000

NUMBER OF ITERATIONS = 18.00000

SUM OF SQUARED RESIDUALS = .02223

SOLUTION TO SMOOTHED VES CURVE FOLLOWS

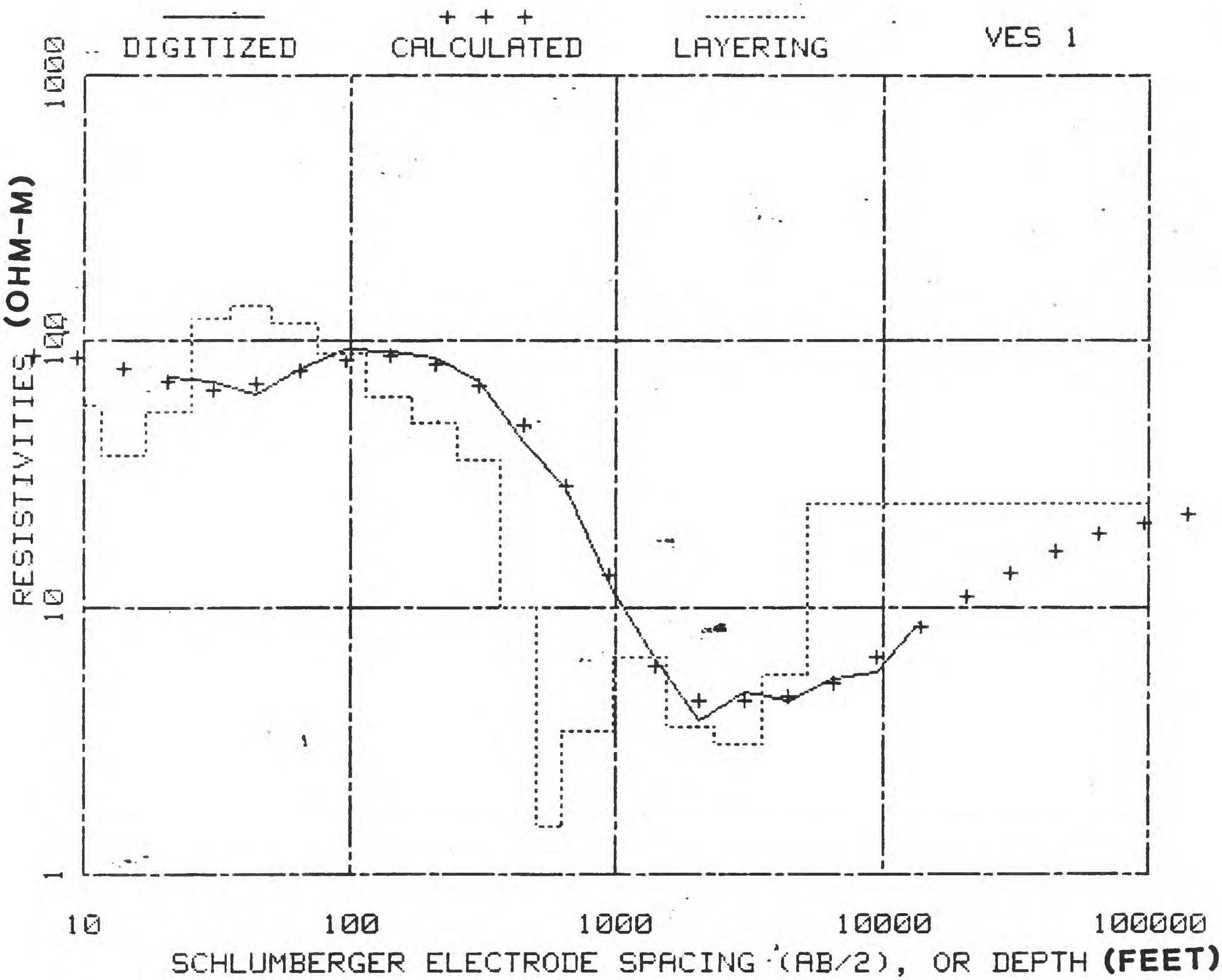
FITTING TOLERANCE= .00100 IS SATISFIED

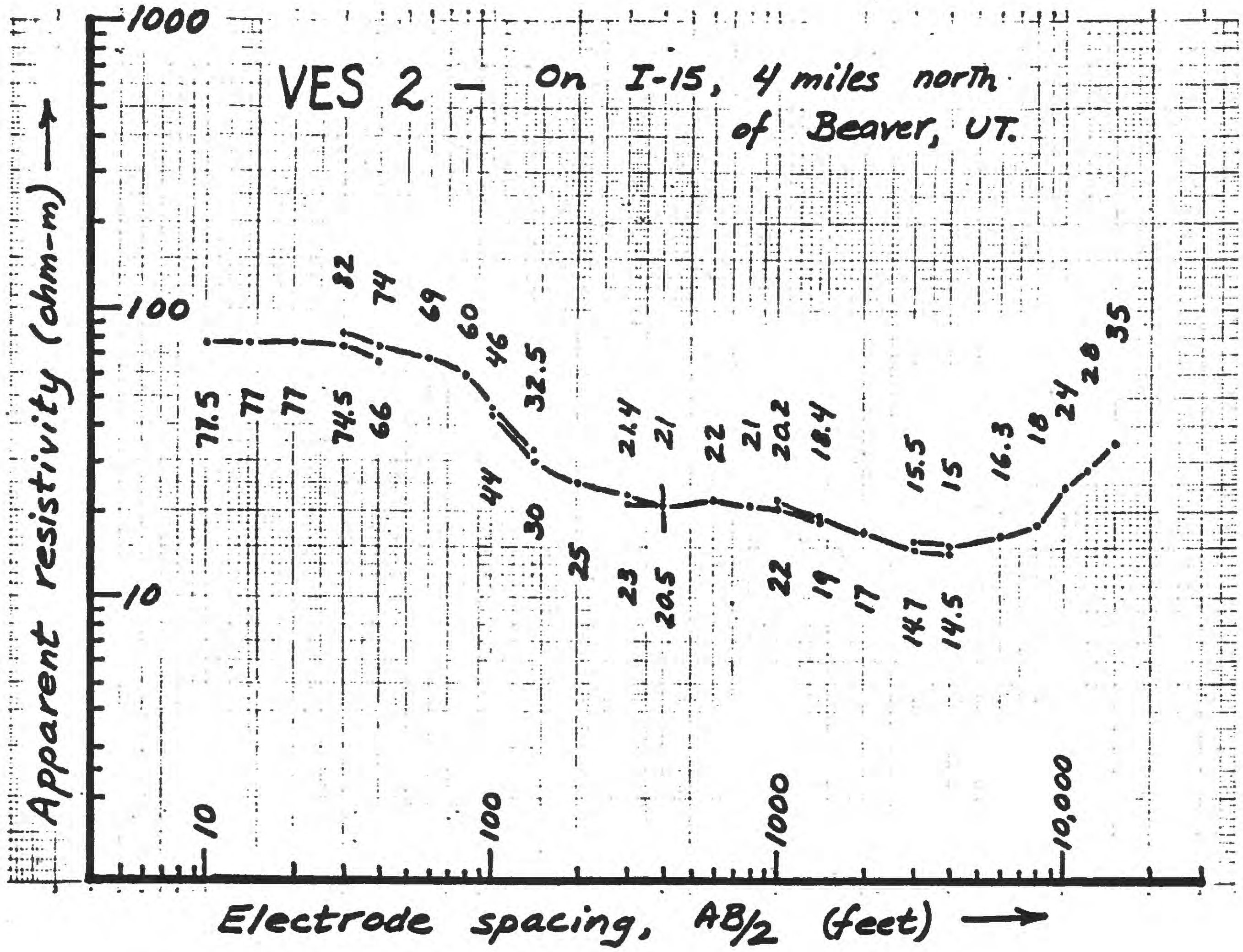
NUMBER OF ITERATIONS = 14.00000

SUM OF SQUARED RESIDUALS = .00097

THICKNESS	DEPTH	RESISTIVITY
1.18553	1.18553	90.55873
.55454	1.74007	88.21234
.81395	2.55402	87.39086
1.19459	3.74861	91.19380
1.74758	5.49619	99.32720
2.57415	8.07034	91.73780
3.69857	11.76890	57.64861
5.26080	17.02971	37.20677
8.13161	25.16132	54.24906
9.90645	35.06777	122.02939
15.31048	50.37824	135.13257
24.98340	75.36164	116.15939
37.76802	113.12966	89.54297
54.58866	167.71832	62.00515
79.47403	247.19235	49.00516
115.03831	362.23066	36.07132
136.04923	498.27989	9.95042
129.23394	627.51383	1.48715
356.33561	983.84945	3.43213
550.33632	1534.18576	6.51935
794.90909	2329.09485	3.57777
1168.52804	3497.62289	3.04734
1702.76089	5200.38378	5.58484
999999.00000	1005199.38378	24.44643

AB/2	CALC VES	SMOOTHED VES
2.05492	89.98473	90.87811
3.01621	89.65558	90.74716
4.42719	89.38599	90.35049
6.49822	88.67893	89.22094
9.53809	85.90985	86.35561
14.00000	79.47399	80.45472
20.54919	70.90050	72.01438
30.16209	65.85181	66.15835
44.27189	68.78872	68.82747
64.98224	77.43254	77.98751
95.38089	85.59572	86.37311
140.00000	88.15923	88.99721
205.49190	82.30809	83.06209
301.62086	68.19225	68.50200
442.71887	48.83420	49.15586
649.82244	28.71744	29.27264
953.80890	13.23953	13.30195
1400.00000	5.99124	5.62913
2054.91897	4.47894	4.19248
3016.20856	4.44370	4.33370
4427.18872	4.61432	4.62119
6498.22436	5.21923	5.24167
9538.08896	6.52104	6.49820
13999.99999	8.47359	8.46773
20549.18973	10.87925	10.99575
30162.08564	13.54651	0.00000
44271.88720	16.25417	0.00000
64982.24361	18.74472	0.00000
95380.88958	20.79562	0.00000
139999.99987	22.29628	0.00000


DIGITIZED
+ + +
CALCULATED
LAYERING
VES 1
1000
100
10
1
RESISTIVITIES (OHM-M)
10
100
1000
10000
100000
SCHLUMBERGER ELECTRODE SPACING (AB/2), OR DEPTH (FEET)



VES 2

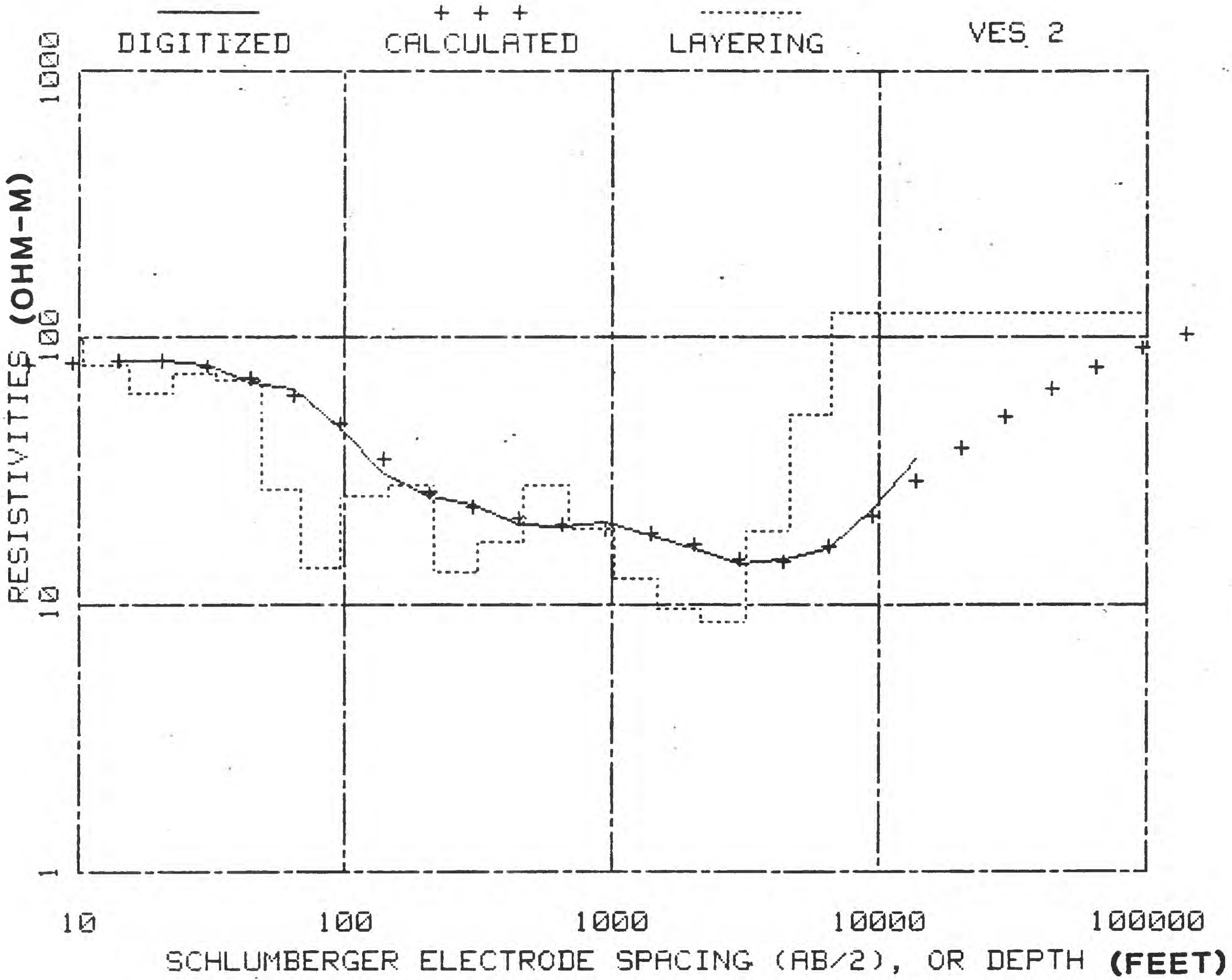
IFORCE =1

AB/2	DIGITIZED RESISTIVITY
14.00000	81.48813
20.54919	81.54230
30.16209	78.70242
44.27189	67.99762
64.98224	63.87634
95.38089	46.11871
140.00000	30.67603
205.49190	25.38103
301.62086	23.48181
442.71887	20.01416
649.82244	19.46052
953.80890	20.45650
1400.00000	18.36667
2054.91897	16.25541
3016.20856	14.19863
4427.18872	14.93355
6498.22436	16.40171
9538.08896	22.68837
13999.99999	35.00000

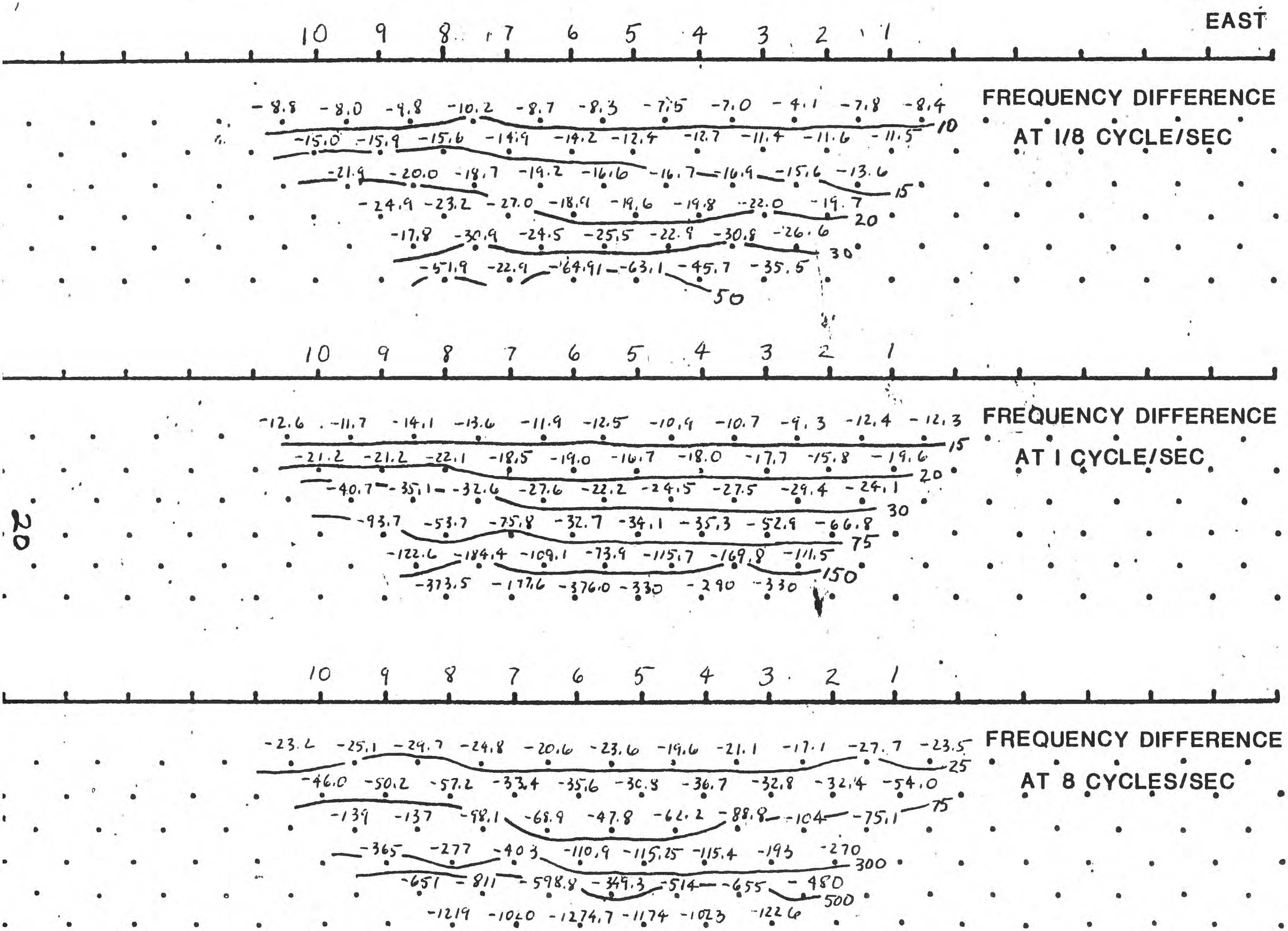
NUMBER OF ITERATIONS = 31.00000
SUM OF SQUARED RESIDUALS = .00779
SOLUTION TO SMOOTHED VES CURVE FOLLOWS
FITTING TOLERANCE= .00100 IS SATISFIED
NUMBER OF ITERATIONS = 7.00000
SUM OF SQUARED RESIDUALS = .00066

THICKNESS	DEPTH	RESISTIVITY
1.05000	1.05000	76.01746
.49113	1.54113	75.97188
.72096	2.26209	75.40510
1.05821	3.32030	75.00673
1.55243	4.87273	78.64504
2.25667	7.12939	91.02310
3.29789	10.42728	99.47104
4.90566	15.33294	79.47855
7.11895	22.45189	62.10833
10.58055	33.03245	73.67091
15.51057	48.54301	68.87305
20.03079	68.57380	27.28451
26.75729	95.33109	13.82431
48.84983	144.18092	25.77585
72.05183	216.23275	27.80708
97.36581	313.59857	13.16209
154.08448	467.68304	17.13953
219.89451	687.57756	27.89938
333.33699	1020.91455	19.25999
472.13425	1493.04880	12.45316
684.35640	2177.40520	9.55233
1020.75356	3198.15876	8.54303
1443.75464	4641.91340	18.98563
2069.11736	6711.03076	50.90237
999999.00000	1006710.03076	123.15260

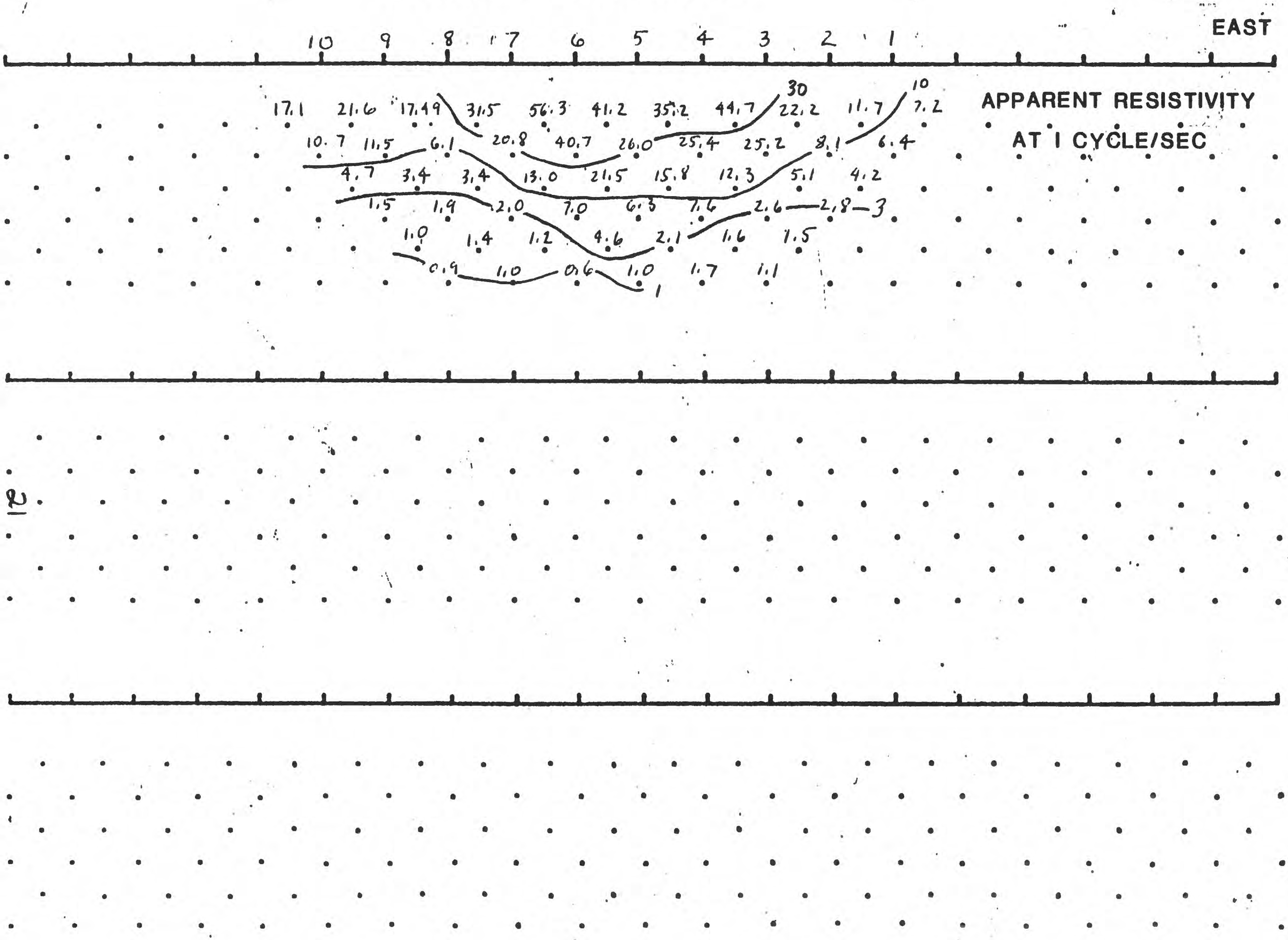
AB/2	CALC VES	SMOOTHED VES
1.40000	76.02254	76.08419
2.05492	76.06588	76.15680
3.01621	76.26705	76.37216
4.42719	76.91403	76.95616
6.49822	78.36999	78.31208
9.53809	80.53392	80.61867
14.00000	82.17954	82.59112
20.54919	81.38308	81.45220
30.16209	77.23737	76.64656
44.27189	70.31771	70.40416
64.98224	60.65120	61.33913
95.38089	47.82587	47.25821
140.00000	34.83830	33.73631
205.49190	26.57570	26.56090
301.62086	23.08359	23.22424
442.71887	21.15679	20.67216
649.82244	19.84232	19.54572
953.80890	19.25778	19.36716
1400.00000	18.50152	18.50625
2054.91897	16.83106	16.73278
3016.20856	14.94155	14.95401
4427.18872	14.46477	14.39809
6498.22436	16.66067	16.50845
9538.08896	21.69834	22.08344
13999.99999	29.21041	30.84219
20549.18973	38.95406	42.72095
30162.08563	50.70724	16.25417
44271.88720	63.95237	18.74472
64982.24361	77.73917	20.79562
95380.88958	90.80389	22.29628
139999.99986	101.92430	23.27231


DIGITIZED
+ + +
CALCULATED
LAYERING
VES 2
RESISTIVITIES (OHM-M)
1000
100
10
1
10
100
1000
10000
100000
SCHLUMBERGER ELECTRODE SPACING (AB/2), OR DEPTH (FEET)

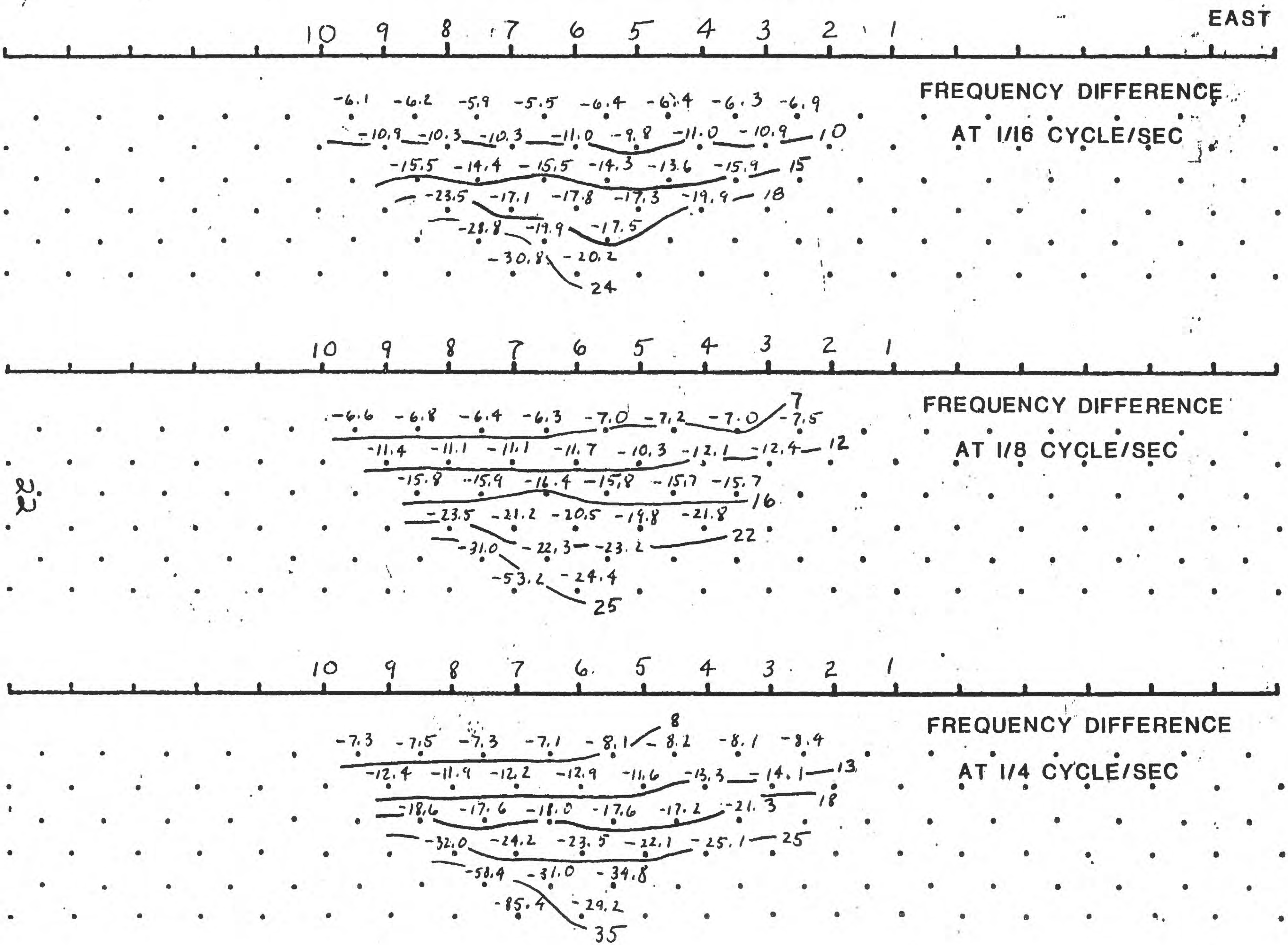
APPENDIX BI - AIRPORT ROAD



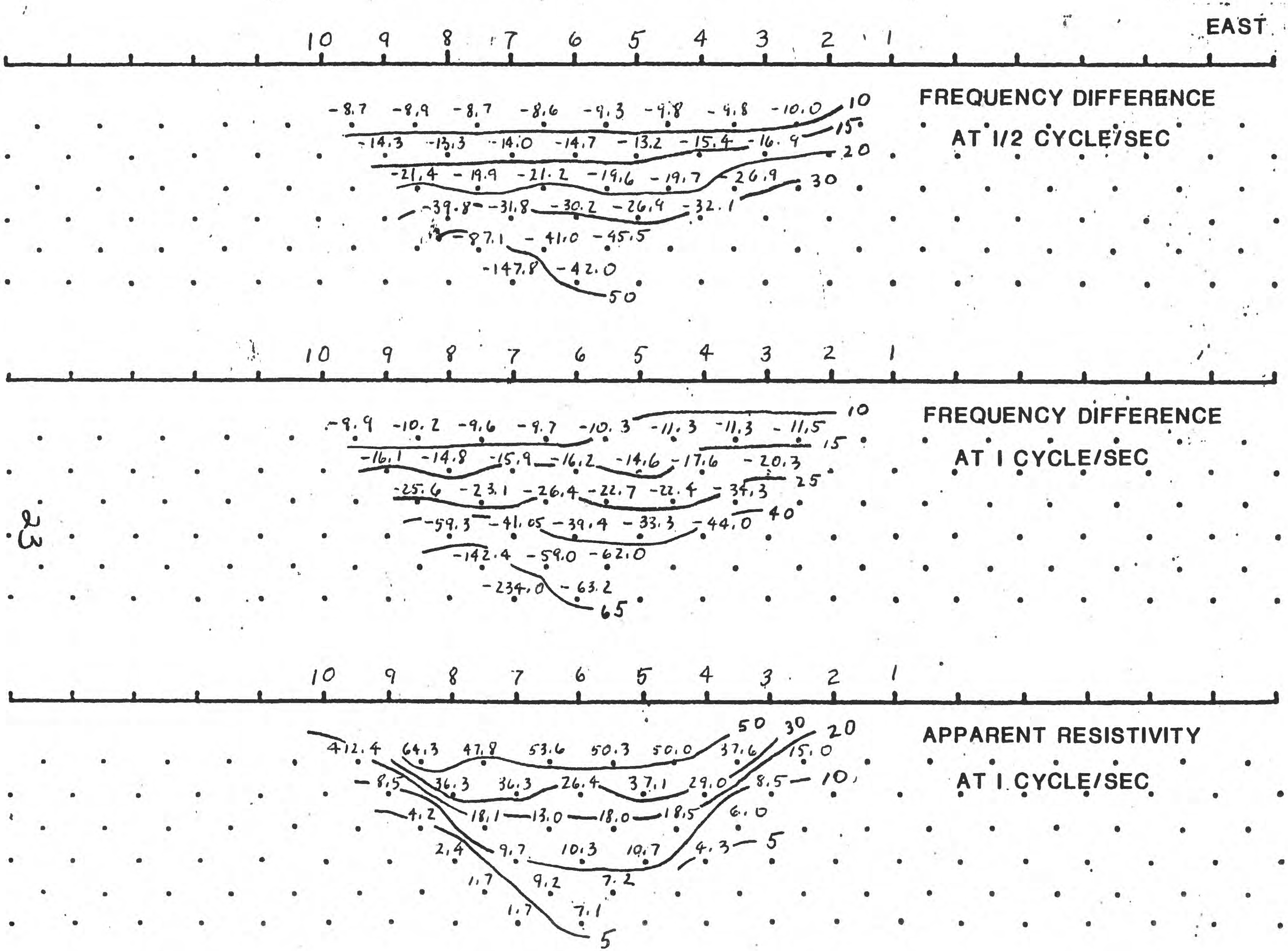
APPENDIX BI - AIRPORT ROAD



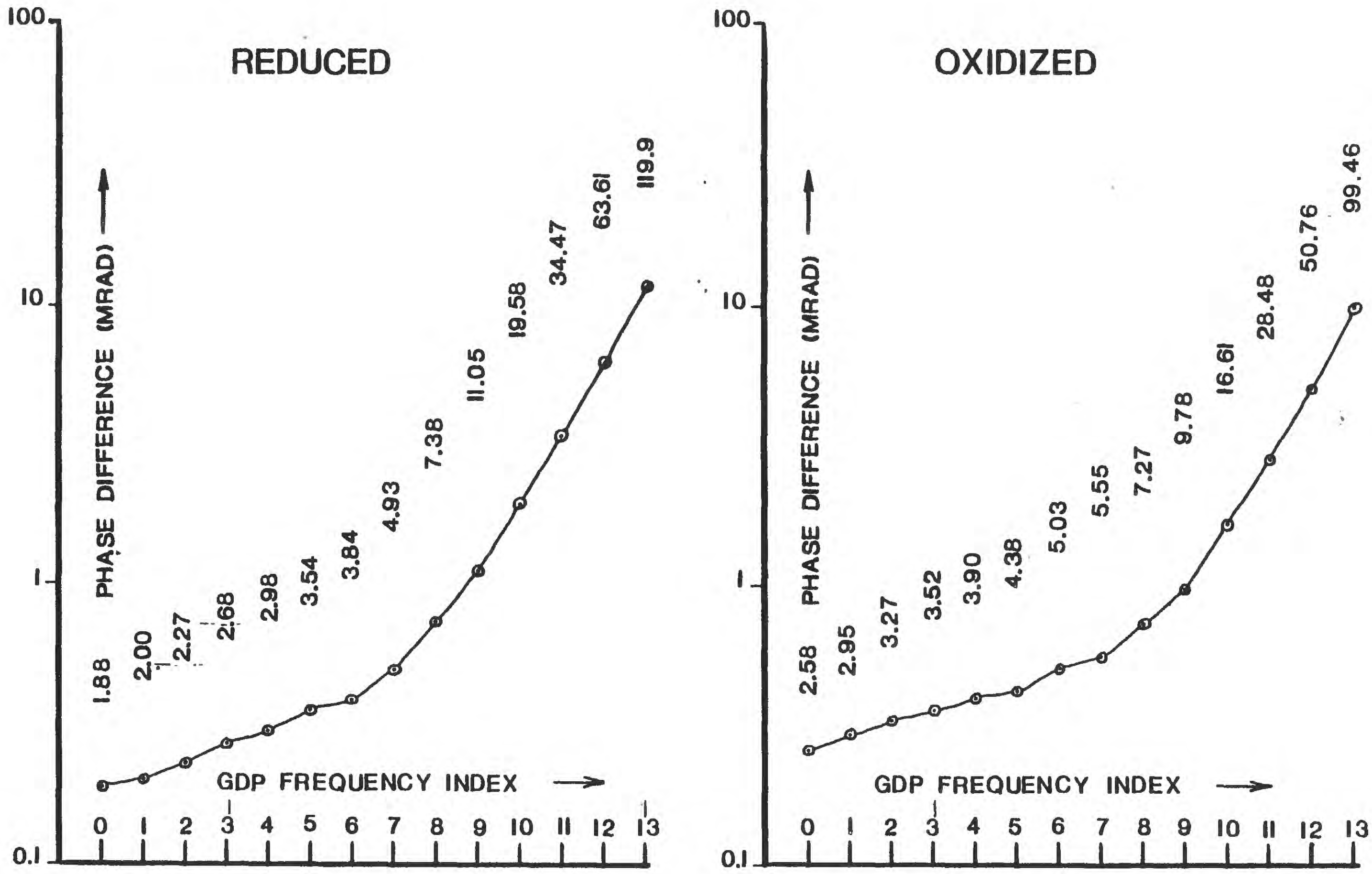
APPENDIX B2 - AIRPORT ROAD SOUTH



APPENDIX B2 - AIRPORT ROAD SOUTH



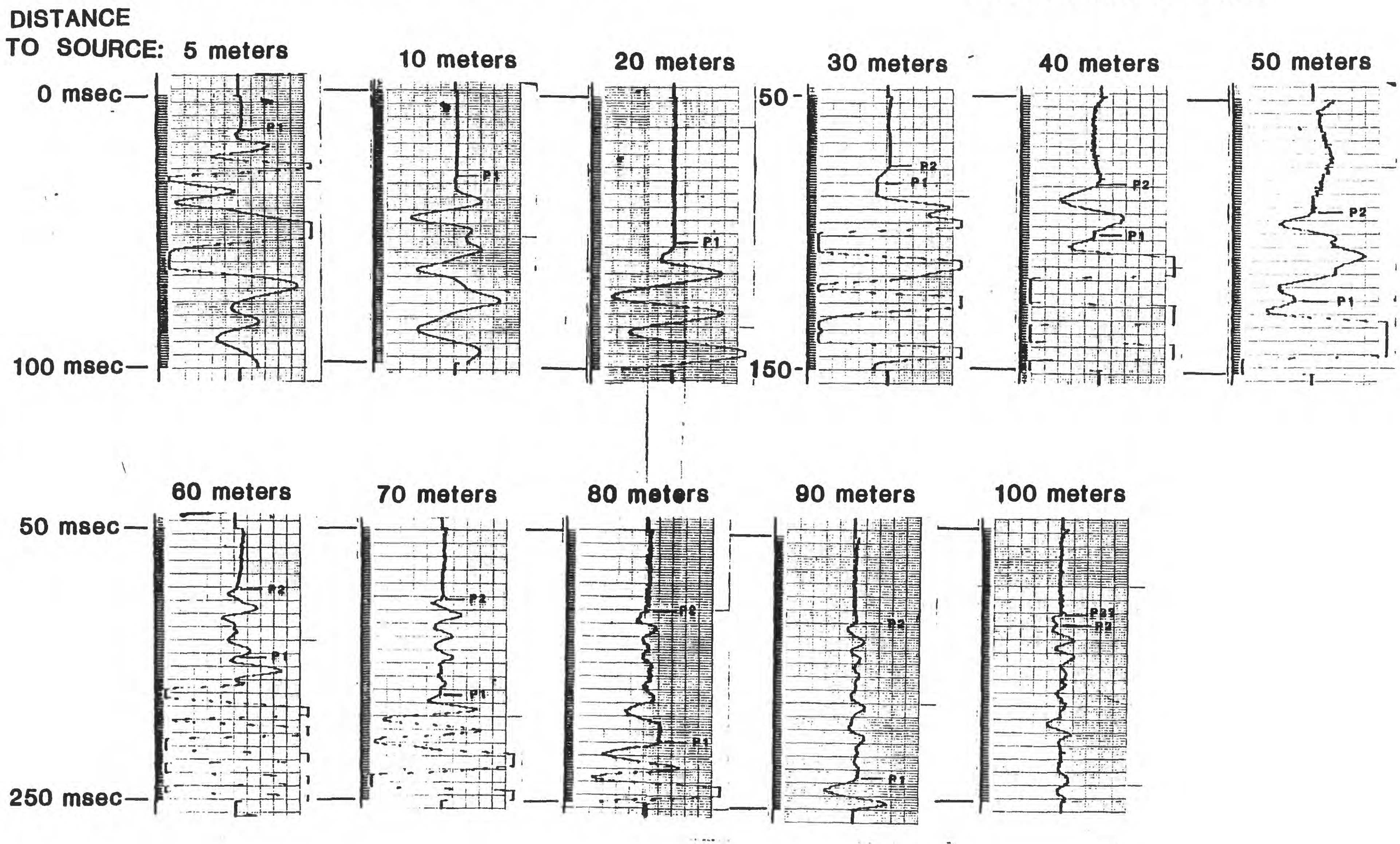
APPENDIX B3: COMPLEX RESISTIVITY SPECTRA



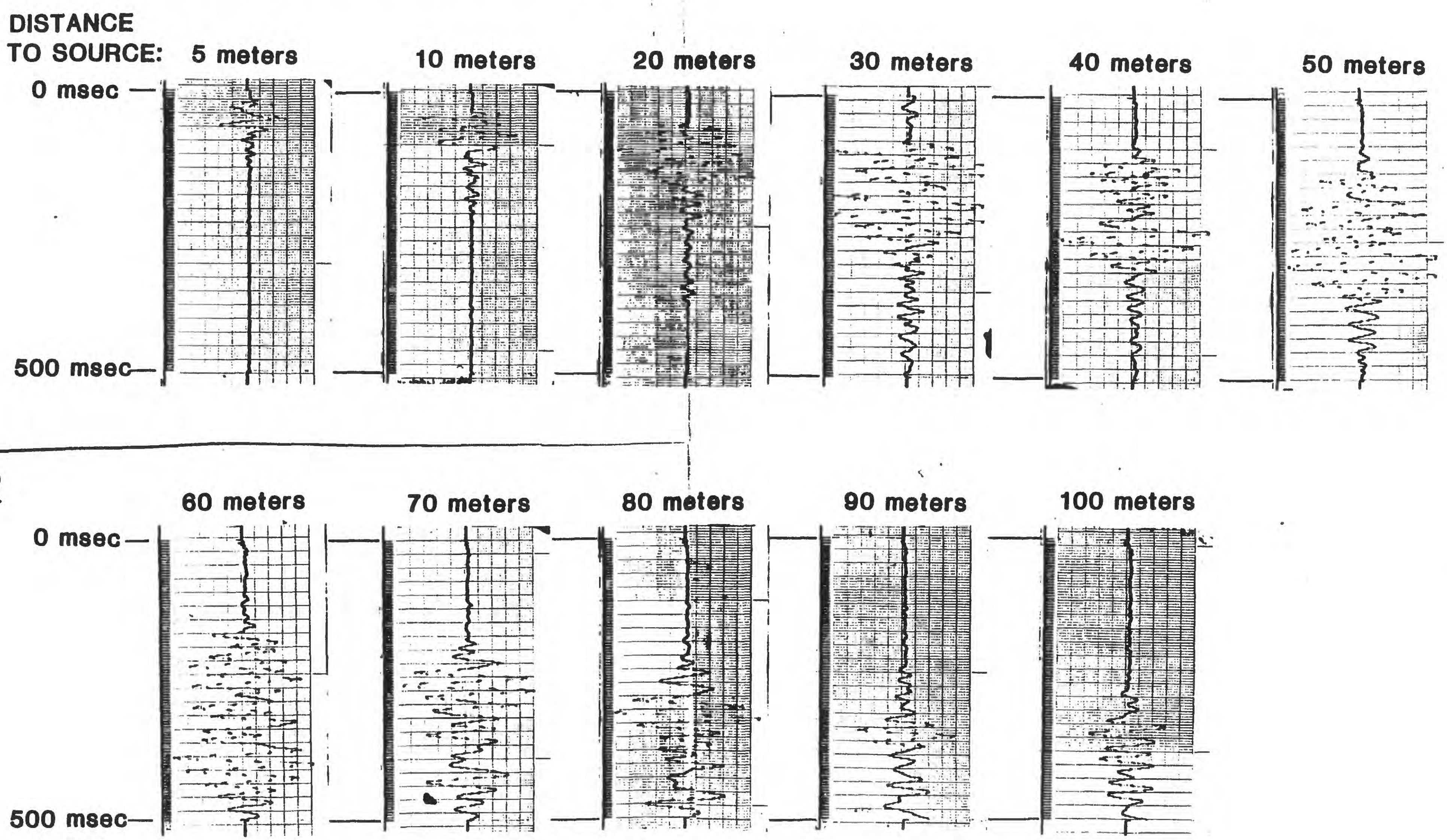
APPENDIX C

SEISMIC SITE 1: AIRPORT ROAD, SHOT ON WEST END

EARLY ARRIVALS ONLY.

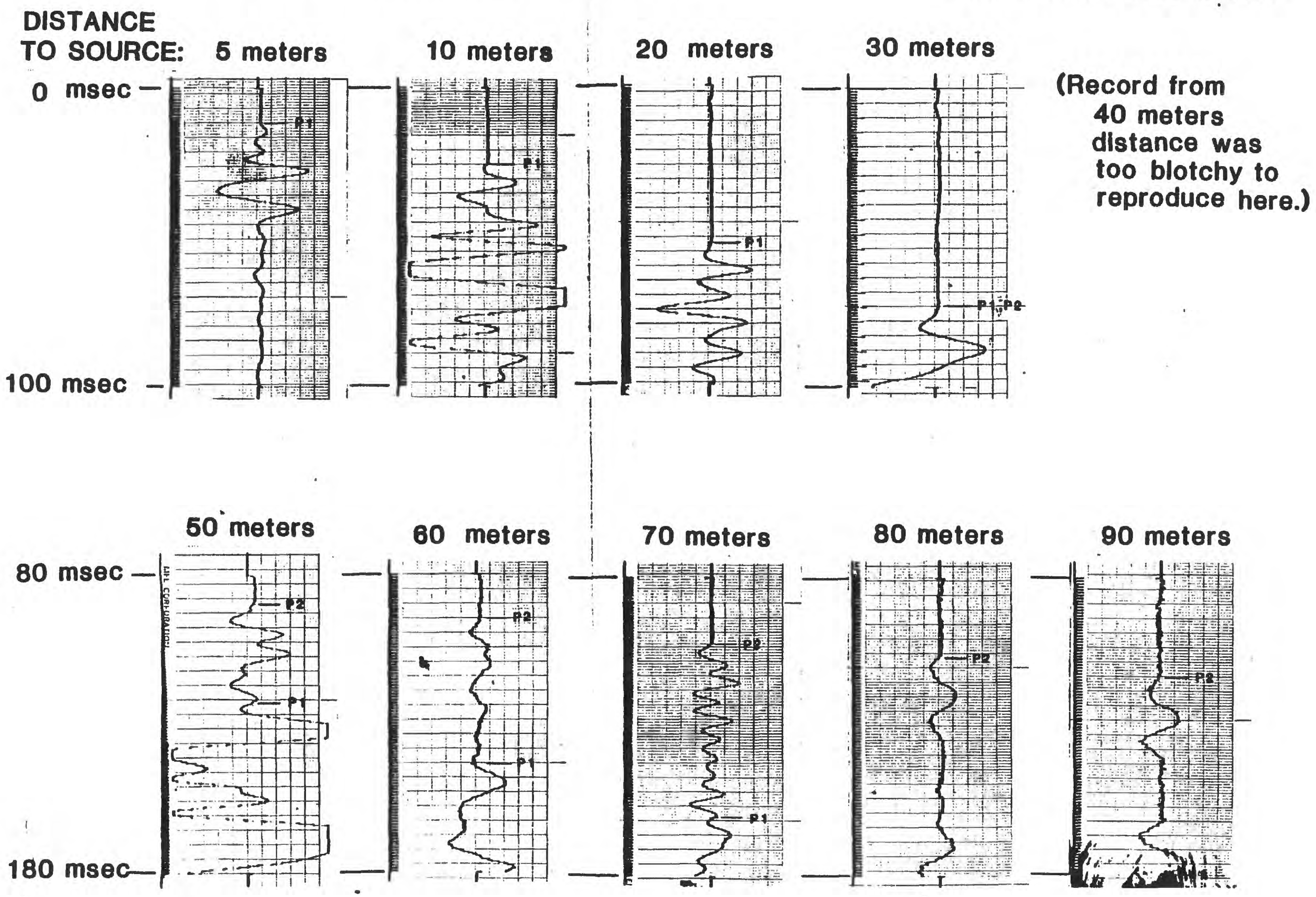


SEISMIC SITE 1: AIRPORT ROAD, SHOT ON WEST END

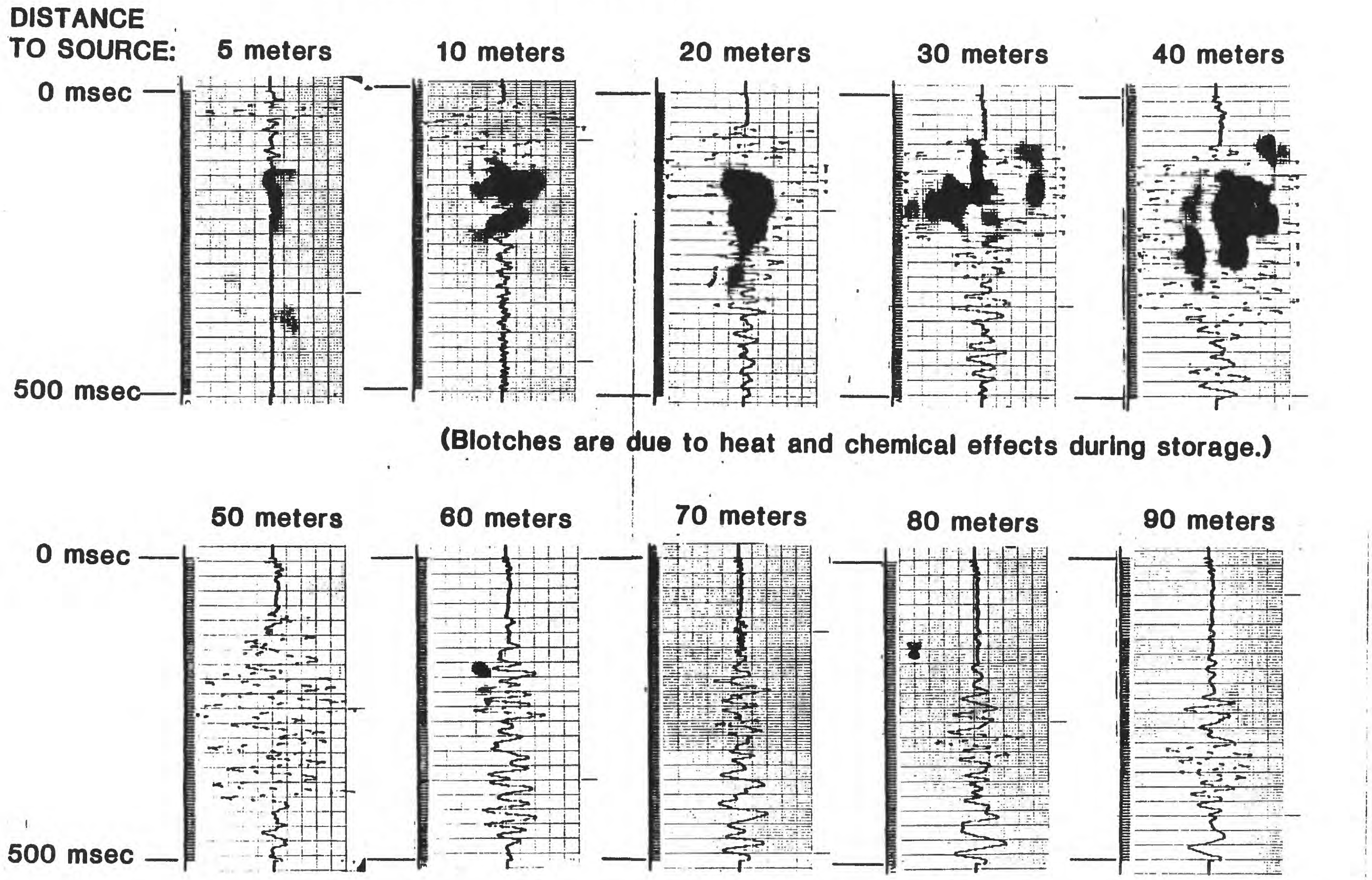


SEISMIC SITE 1: AIRPORT ROAD, SHOT ON EAST END

EARLY ARRIVALS ONLY.

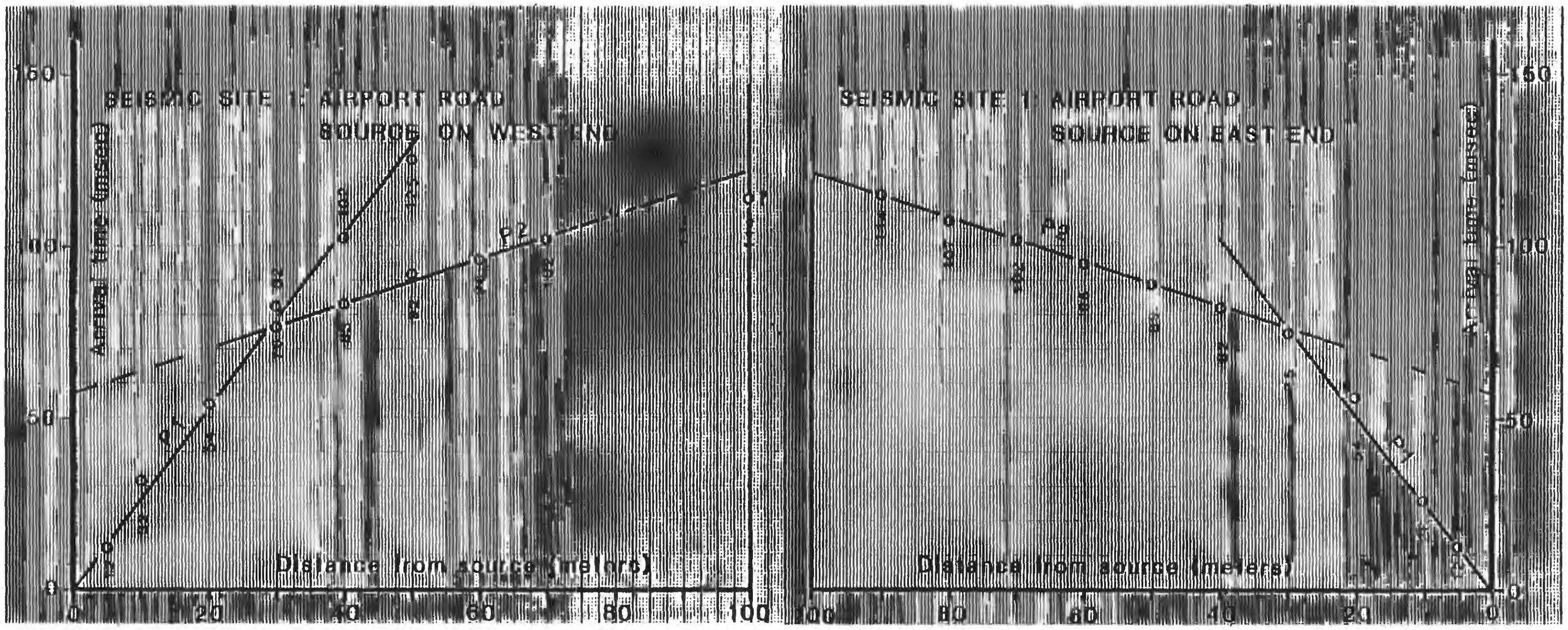


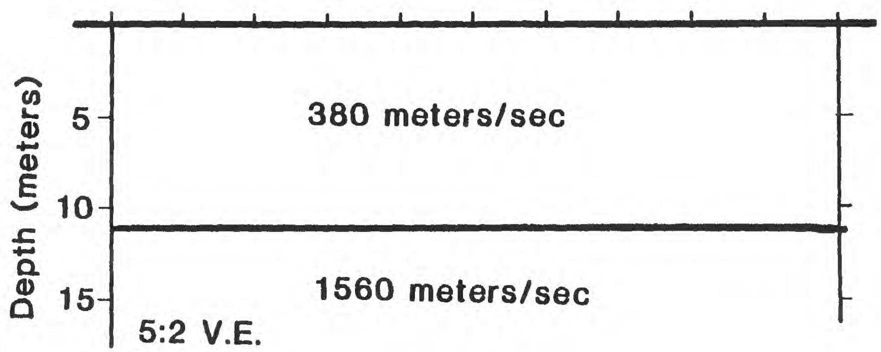
SEISMIC SITE 1: AIRPORT ROAD, SHOT ON EAST END



(Blotches are due to heat and chemical effects during storage.)

INTERPRETATION

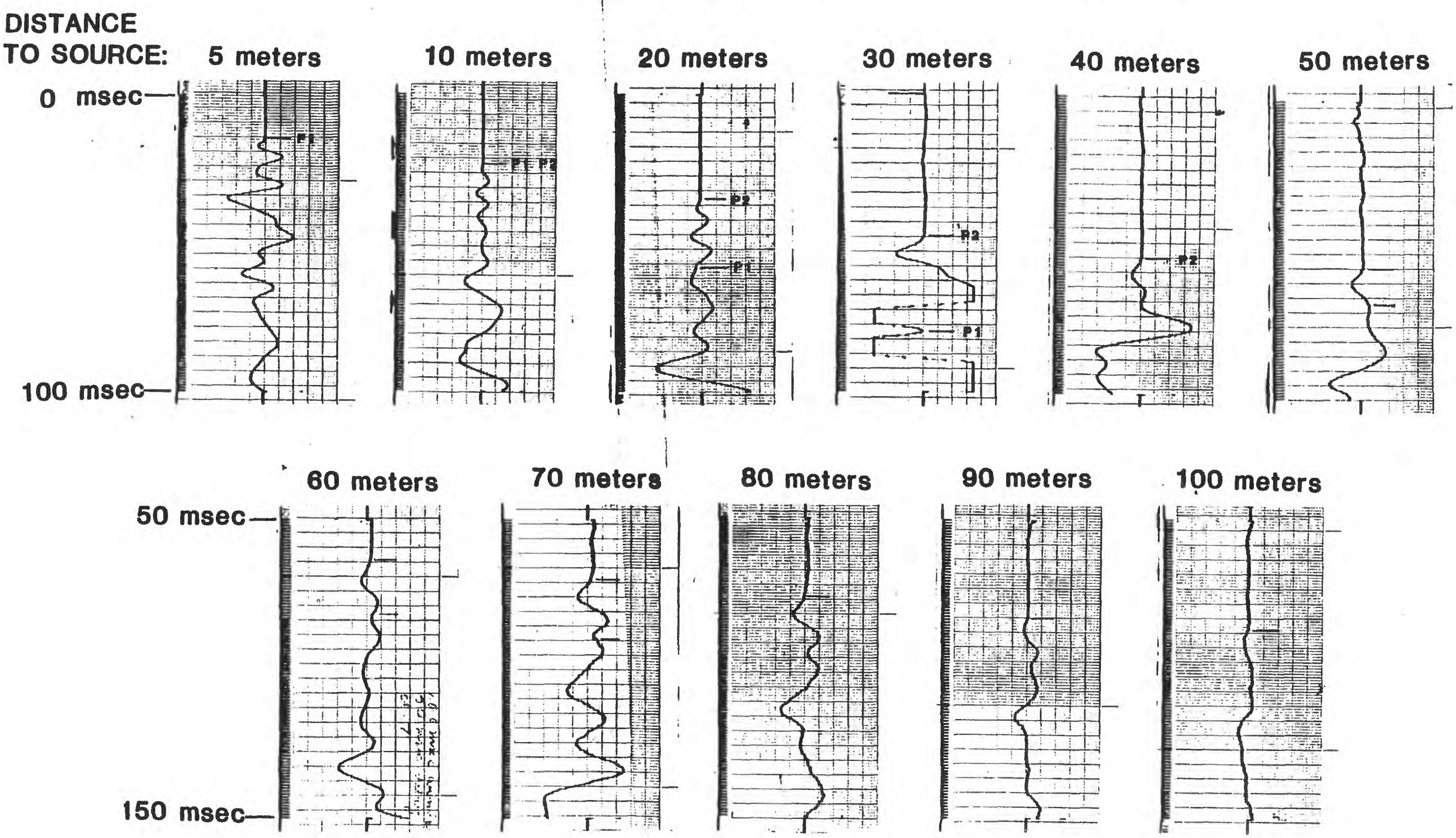




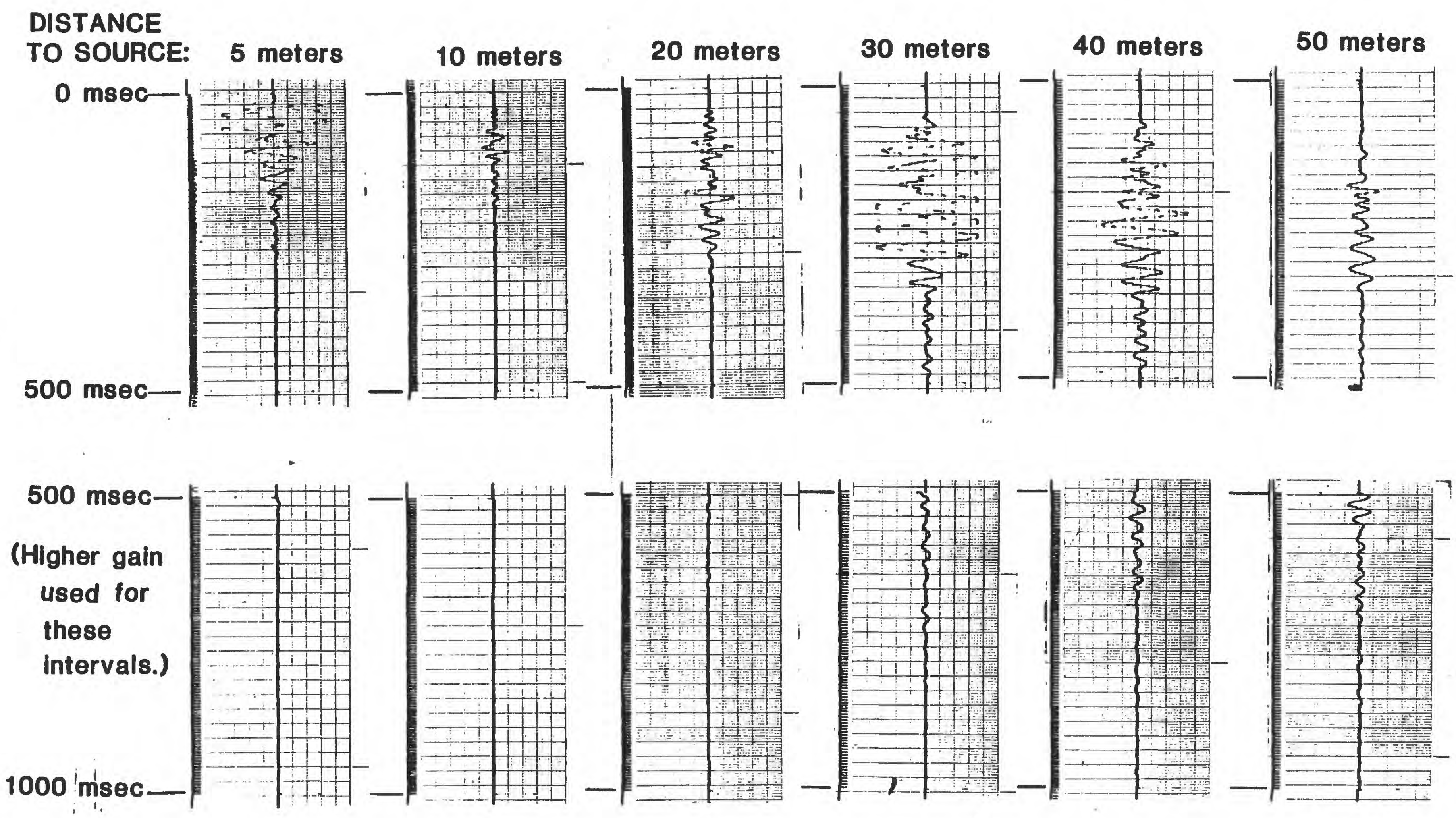

```
LAYER    1
     380.00    VLOC
       0.00    DIP

LAYER    2
    1562.50    VLOC
       0.00    DIP
      11.17    DPTH
```

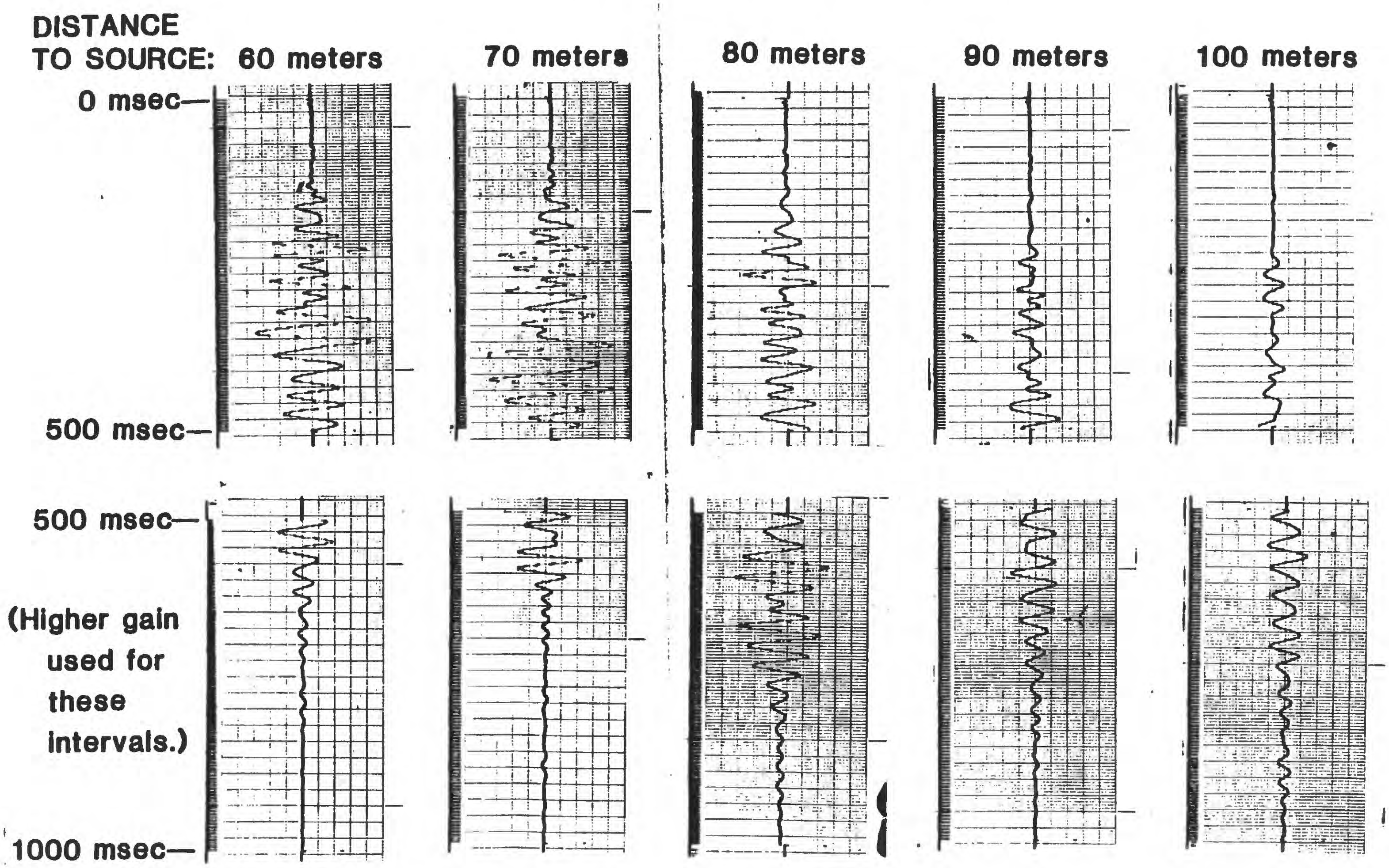
SEISMIC SITE 3: GREENVILLE TURNOFF (SHOT ON NORTH END)   EARLY ARRIVALS ONLY



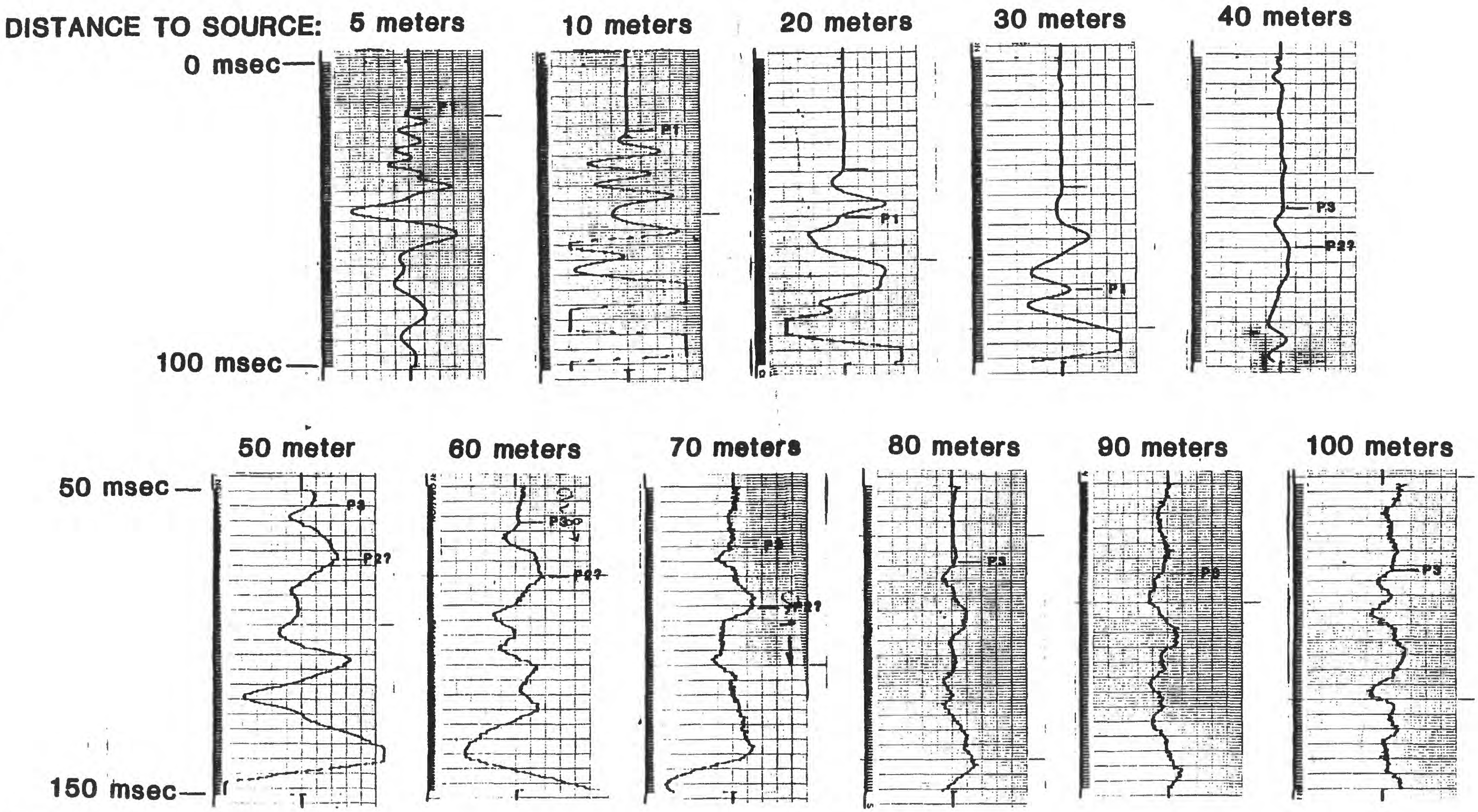
SEISMIC SITE 3: GREENVILLE TURNOFF (SHOT ON NORTH END)



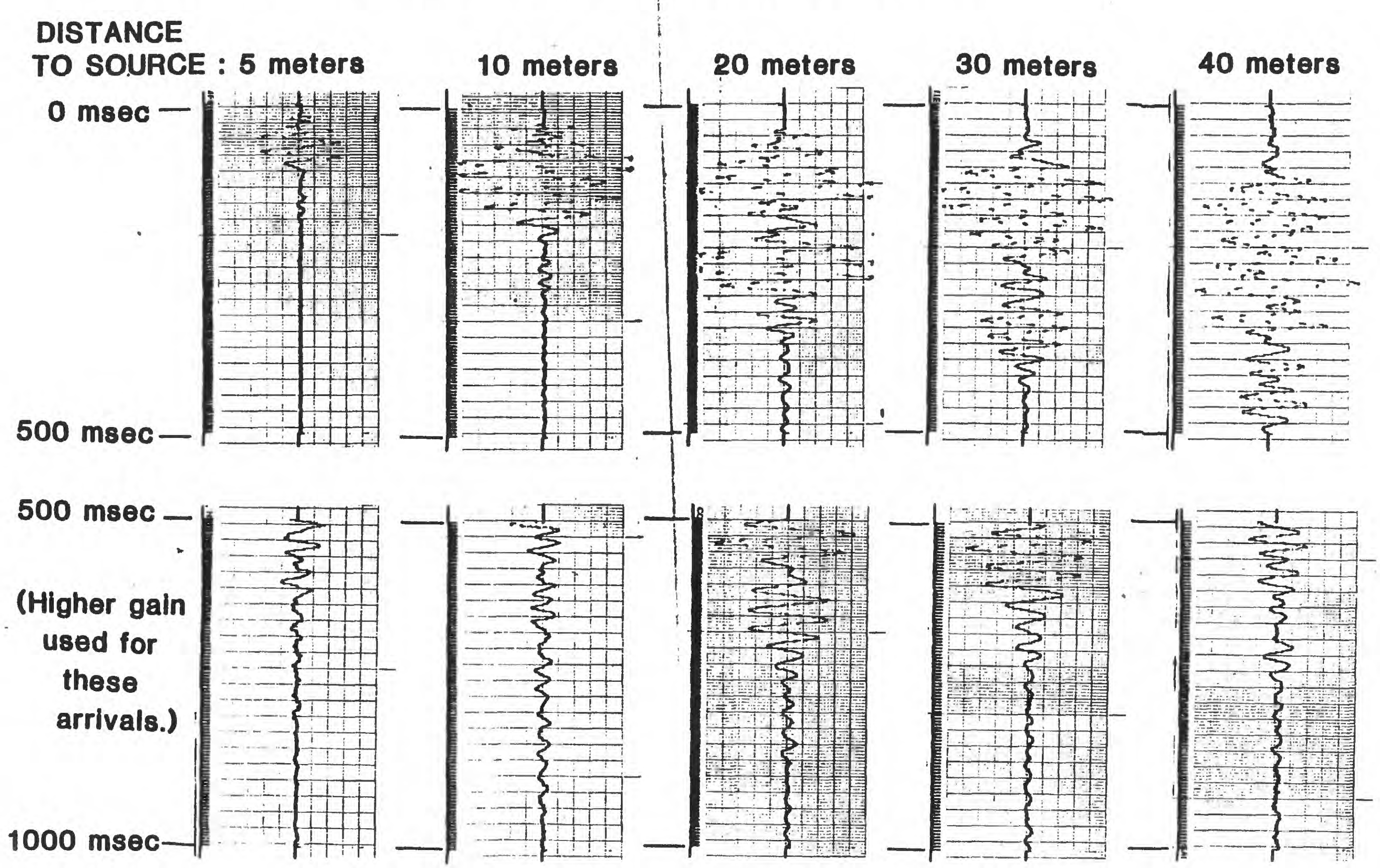
SEISMIC SITE 3: GREENVILLE TURNOFF (SHOT ON NORTH END)



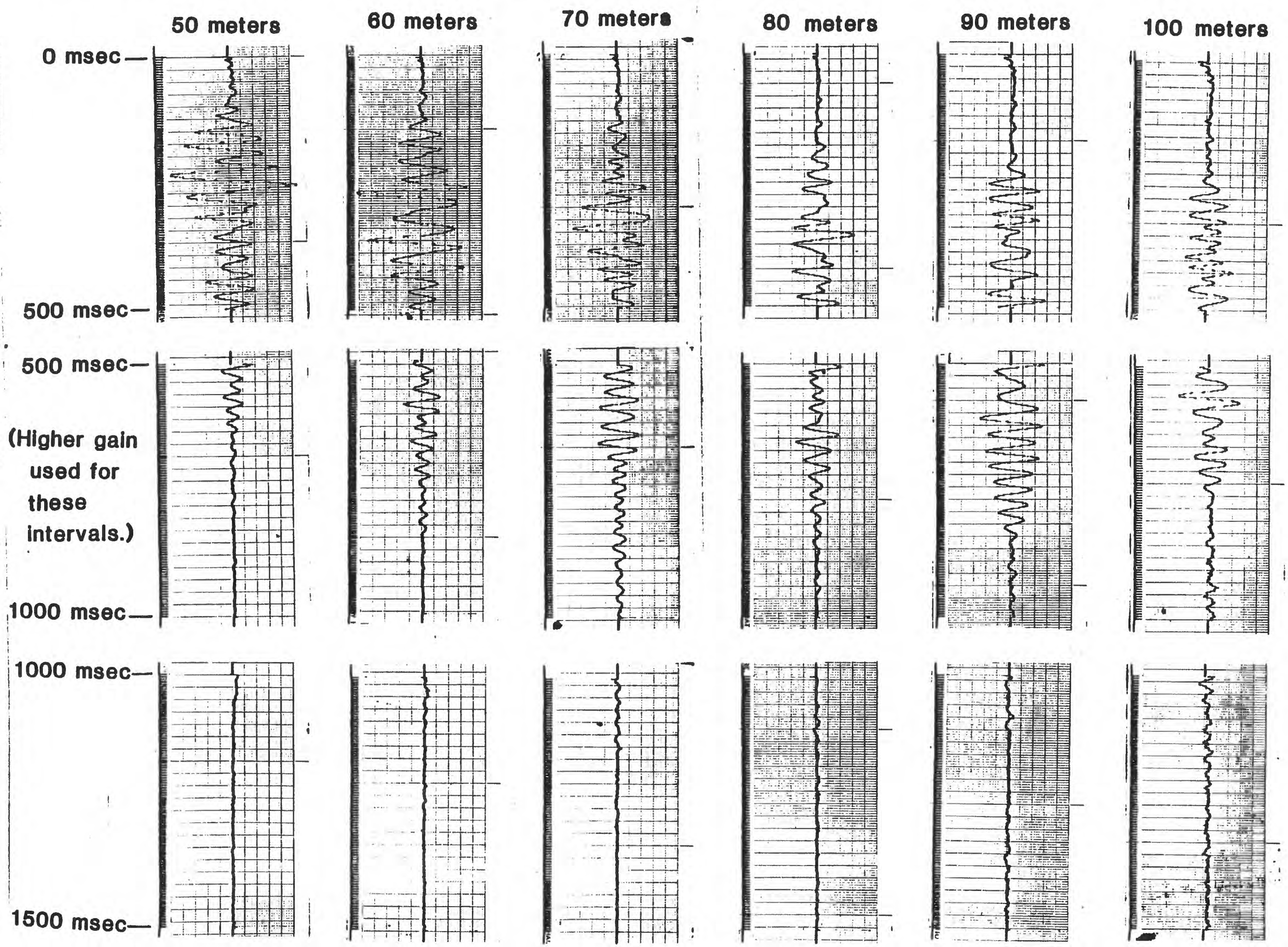
SEISMIC SITE 3: GREENVILLE TURNOFF (SHOT ON SOUTH END). EARLY ARRIVALS ONLY.



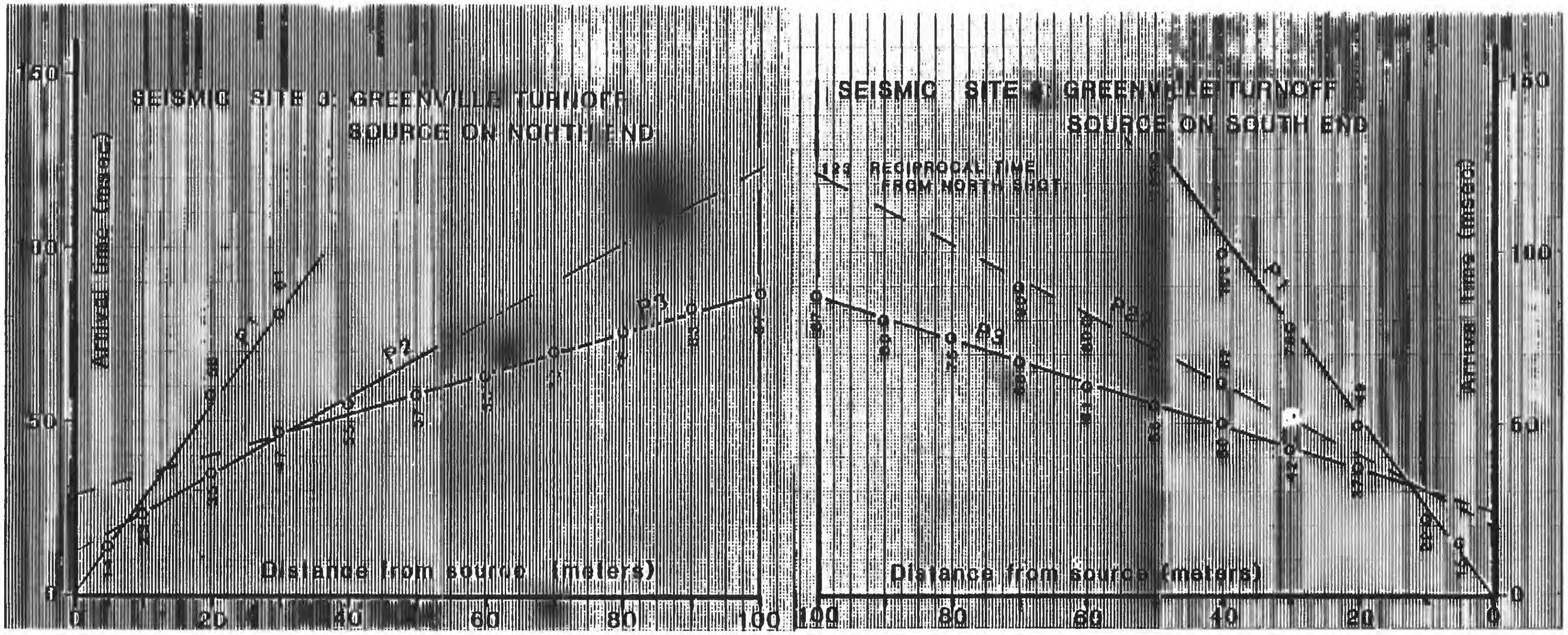
SEISMIC SITE 3: GREENVILLE TURNOFF (SHOT ON SOUTH END)

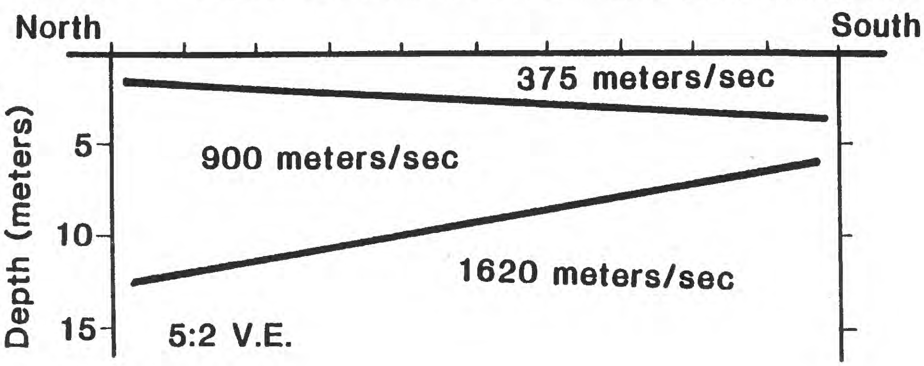


SEISMIC SITE 3: GREENVILLE TURNOFF (SHOT ON SOUTH END)



INTERPRETATION





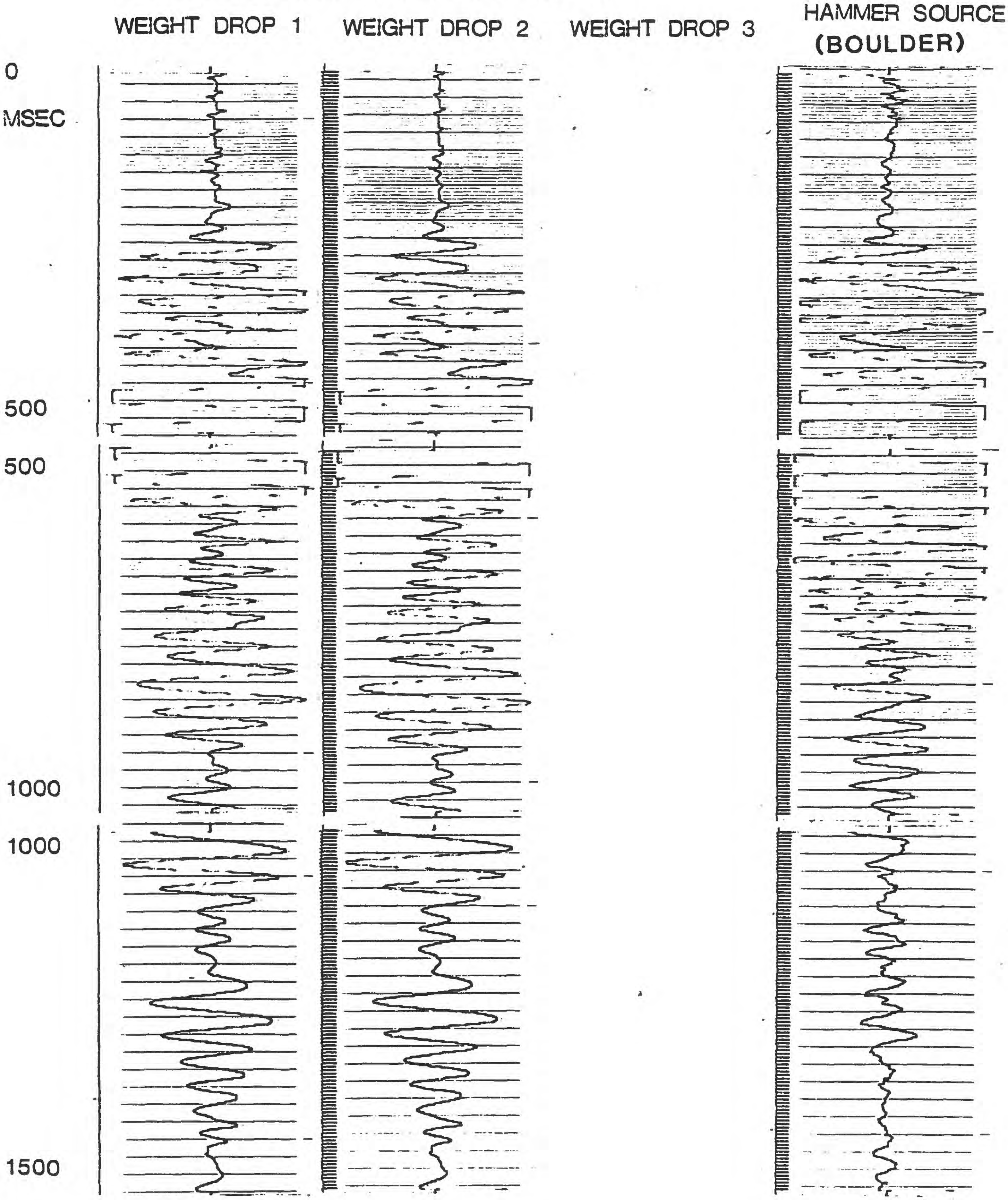
LAYER 1
375.00 VLOC
0.00 DIP

LAYER 2
904.54 VLOC
1.29 DIP
1.44 DPTH

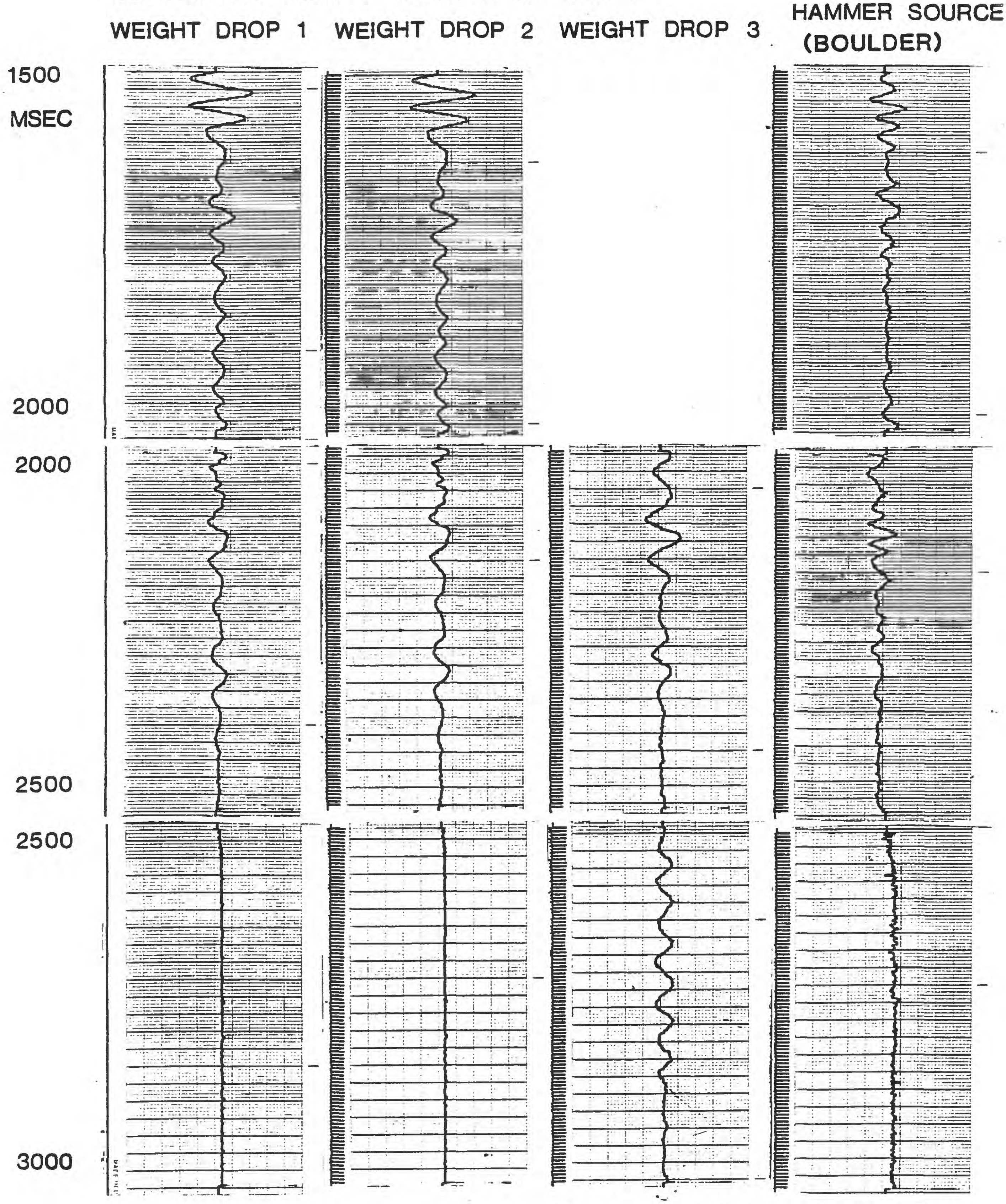
LAYER 3
1619.76 VLOC
-3.94 DIP
12.65 DPTH

APPENDIX D

SEISMIC LOCATION 1 (CENTER OF VES 1)

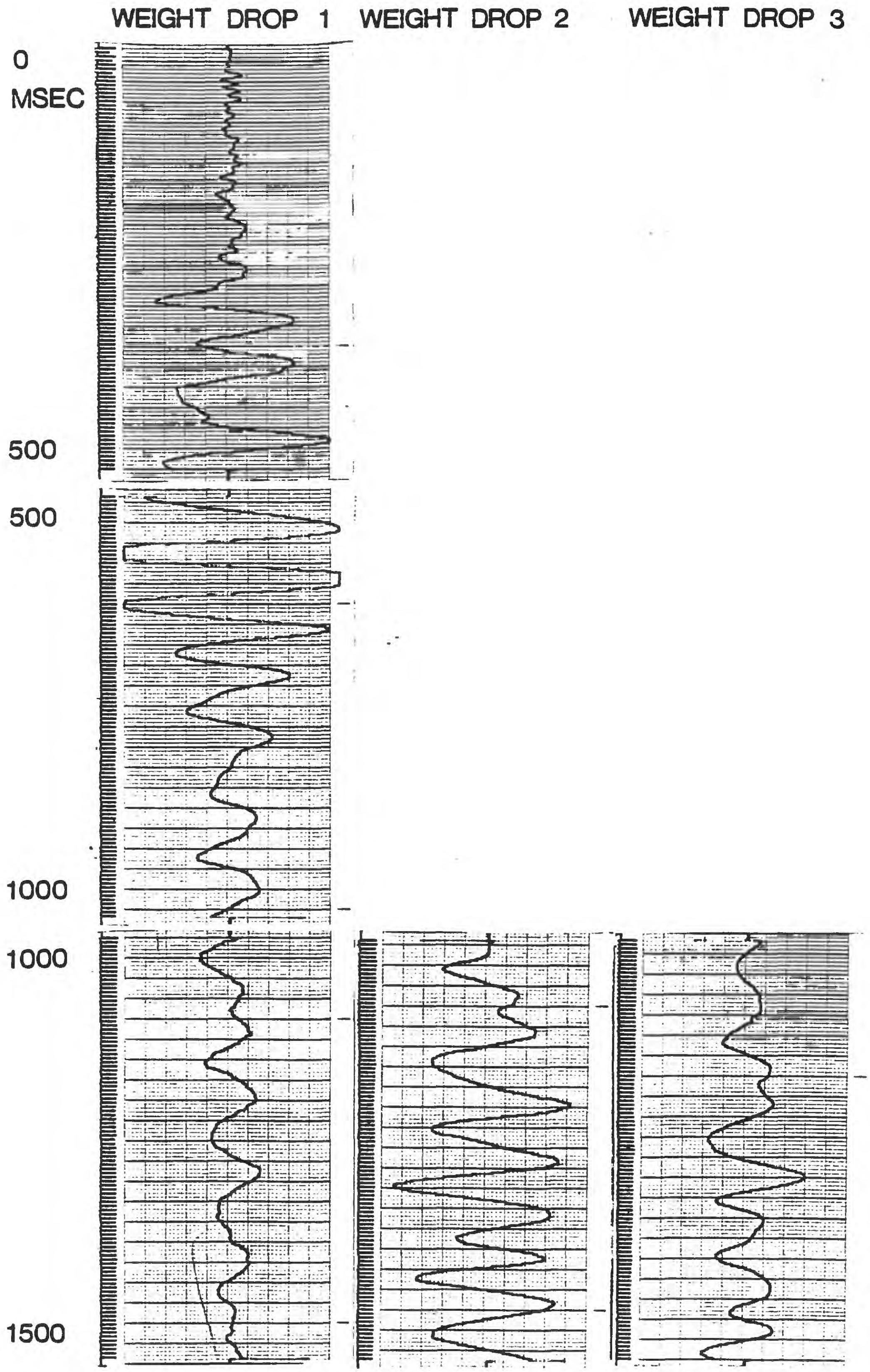


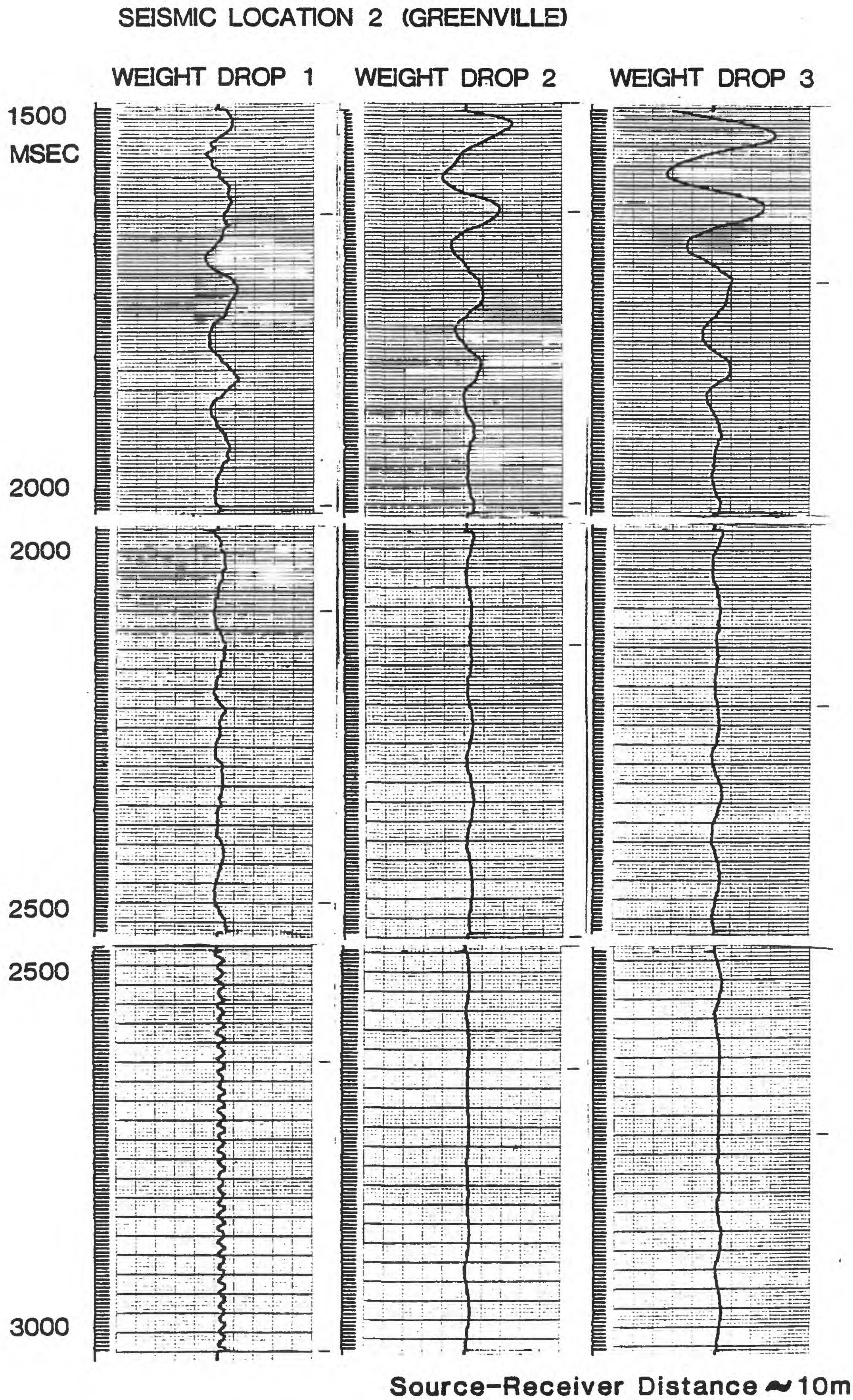
SEISMIC LOCATION 1 (CENTER OF VES 1)



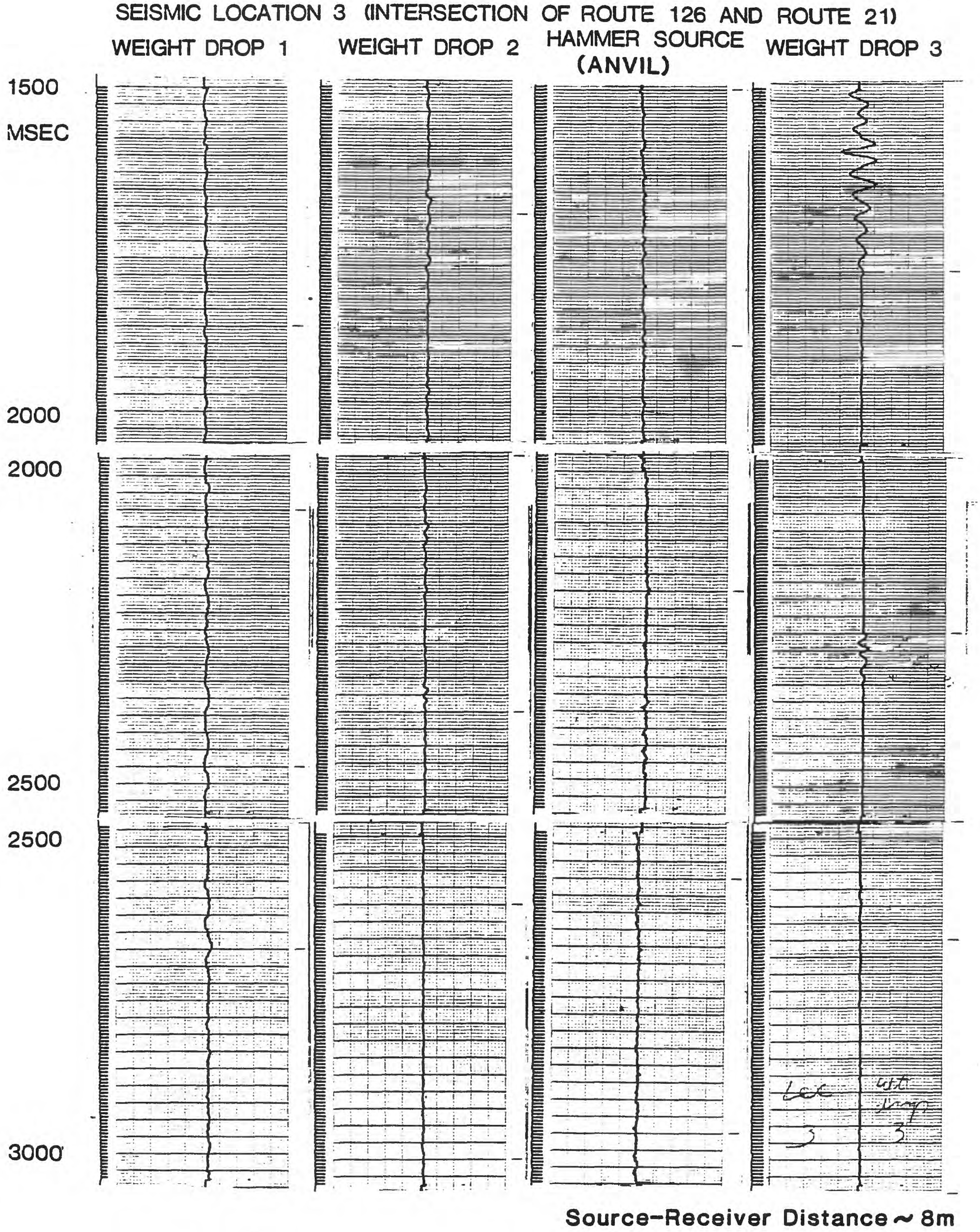
Source–Receiver Distance = 83m

SEISMIC LOCATION 2 (GREENVILLE)



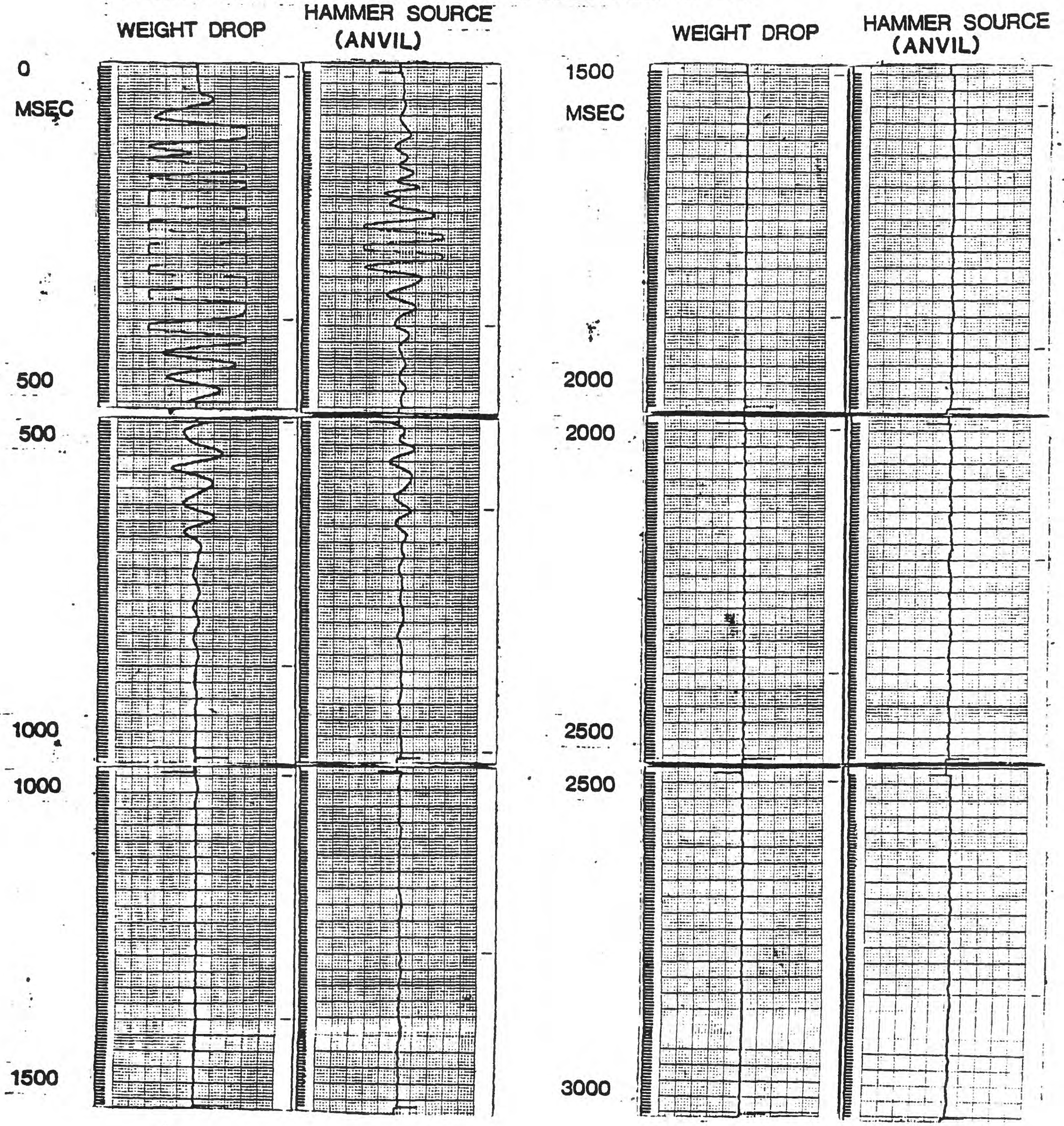


SEISMIC LOCATION 2 (GREENVILLE)
WEIGHT DROP 1
WEIGHT DROP 2
WEIGHT DROP 3
1500
MSEC
2000
2000
2500
2500
3000
Source-Receiver Distance ~ 10m

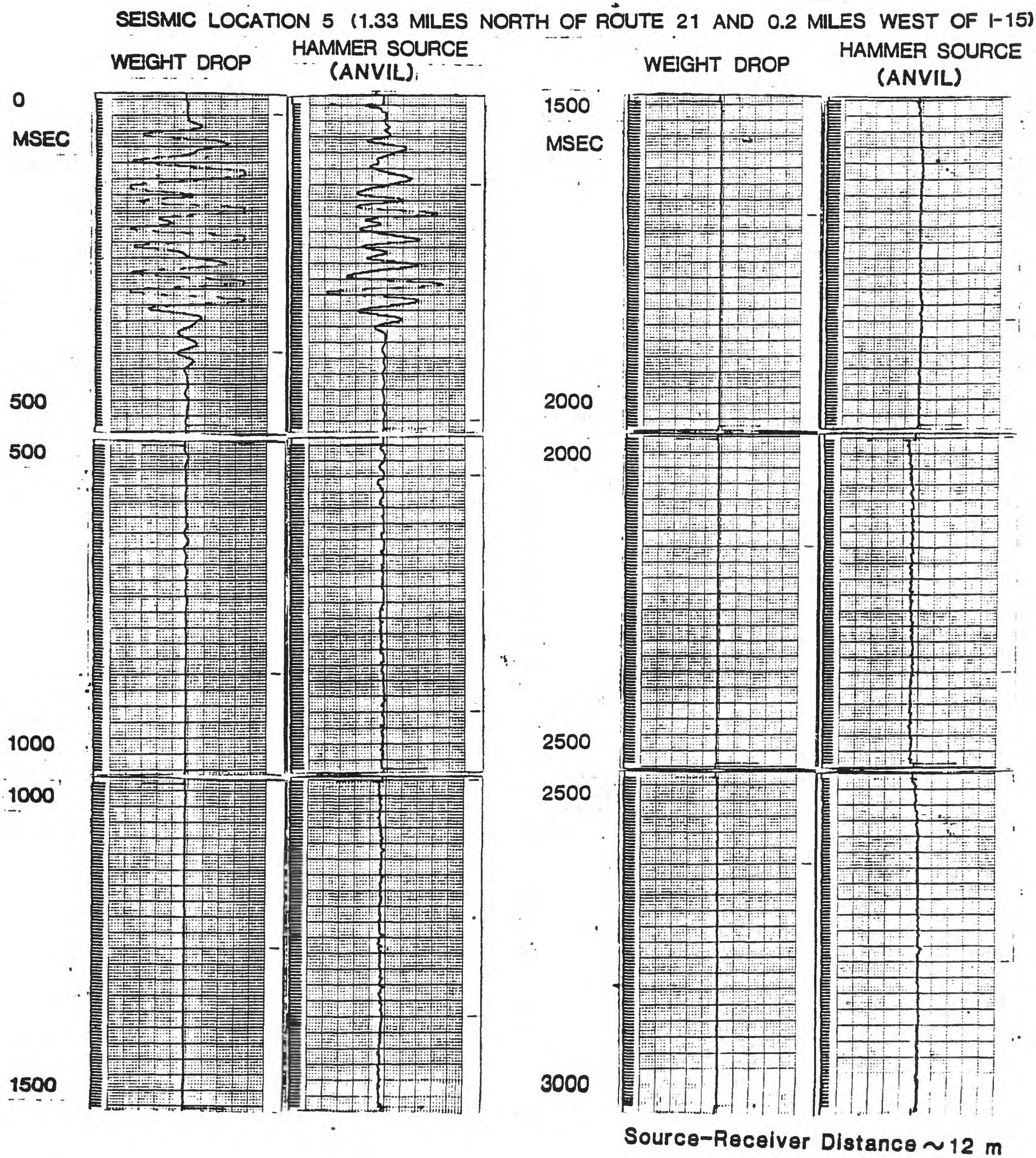


SEISMIC LOCATION 3 (INTERSECTION OF ROUTE 126 AND ROUTE 21)
WEIGHT DROP 1
WEIGHT DROP 2
HAMMER SOURCE (ANVIL)
WEIGHT DROP 3
1500
MSEC
2000
2000
2500
2500
3000
Source-Receiver Distance ~ 8m

SEISMIC LOCATION 4 (ON ROUTE 21 2 MILES WEST OF I-15)



Source–Receiver Distance ~15m



SEISMIC LOCATION 5 (1.33 MILES NORTH OF ROUTE 21 AND 0.2 MILES WEST OF I-15)
WEIGHT DROP
HAMMER SOURCE (ANVIL)
WEIGHT DROP
HAMMER SOURCE (ANVIL)
0 MSEC
500
500
1000
1000
1500
1500 MSEC
2000
2000
2500
2500
3000
Source-Receiver Distance ~ 12 m