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**GEOPHYSICS LTD.
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*Precision
Geophysical Instrumentation and Surveys*

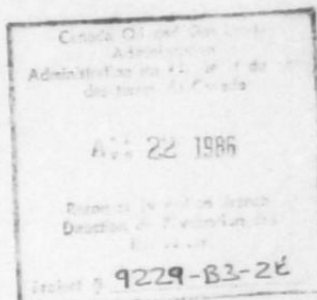
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740 SPADINA AVENUE • TORONTO, ONTARIO, CANADA M5S 2J2

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LOGISTICS REPORT
ON THE
MANITOU LAKE UTEM SURVEY, FT. GOOD HOPE, N.W.T.
FOR
BP MINERALS LTD.
BY
LAMONTAGNE GEOPHYSICS LTD.

MAY 1984



P. McGOWAN

Introduction

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Following the success of the Hume River Pilot Project (report dated July 1983) undertaken by Lamontagne Geophysics Ltd. for BP Minerals in February and March of 1983, a production oriented test survey (Manitou Lake Pilot Project) was proposed to assess the UTEM [®] system sounding capabilities in a production mode. The project was largely planned and supported by Lamontagne Geophysics Ltd. of Toronto and its subcontractors at Explora Geophysics of Val d'Or. The survey was done during February and March of 1984. Two existing seismic lines with a combined length of 42.0 km were read with the original intention of providing 300% coverage using loops measuring 400 x 400 m. The base camp located 30 km west of Fort Good Hope, N.W.T. was centered on the survey area at the intersection of the two seismic lines (see accompanying map sheet).

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Field Survey

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The advance crew, comprised of the subcontractors of Explora Geophysics and locally hired native people, set up the base camp and began the cutting and chaining of transmitter loop lines between February 16 and 23, 1984. The actual survey crew arrived in camp on February 24. Production began only after the arrival of the UTEM system equipment on February 27 and continued through March 25. Five and one half production days were lost during the period due to equipment trouble. Demobilization began on the evening of March 25 and was completed the following day.

The survey was designed to permit 300% coverage over the two lines using 400 x 400 m square transmitter loops with station spacings of 20 and 40 m with the intention of determining the shallow conductivity structure of the area. Thirty line kilometres were read at this level of coverage. Another 12.0 line kilometres, located mainly over less prospective areas, was read at 100% coverage. Two sets of orthogonal 2400 m lines, each centered on a 800 x 800 m loop were read with a station density of 100 and 50 m to investigate the deep conductivity structure.

Considerably more equipment problems were encountered during the course of the survey than during the Hume River survey of the previous year. This was understandable, although not anticipated, as the survey equipment had not completed the required field trials. It was however, the only system that could be made available in the short time between the finalization of the contract and the commencement of the survey. Two faults in the

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UTEM 3 transmitter - a broken semiconductor lead and a malfunction of the precise 5 MHz oscillator - were the major technical hangups.

The survey crew consisted of;

R. Langridge	Geophysicist	Feb 24 - Mar 14
P. McGowan	Geophysicist	Mar 10 - Mar 25
G. Couture*	Technician	Feb 16 - Mar 25
R. Morin*	Field Assistant	Feb 16 - Mar 25
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Data Report

A total of 81 square transmitter loops measuring 400 x 400 m were laid out and read. The loops were centered 400 m apart along the length of the survey line. This permitted the use of two common sides for each loop thus reducing the amount of line cutting and loop moving. The survey lines were read in 1200 m sections centered on each transmitter loop with a station spacing of 40 m except in the neighbourhood (<100 m) of the active transmitter wire where the station spacing was decreased to 20 m to better define the response cross-over. The result of the above procedure was a UTEM profile providing 300% coverage. At each station at least 2048 cycles of the UTEM waveform were averaged. The base frequency used in the survey was 30 Hz since near surface conductive features were of principal interest.

Line A (the NE trending seismic line) was read at 300% coverage along its entire length (loops 1-42). It required 13 days (including 1 1/2 down days) to complete this phase of the survey. The first 7.2 km of Line B (the NW trending seismic line) was read at 300% coverage (loops 43-59) in 7 days (including 4 down days). Following consultation with G. Mitchell of BP Minerals, it was decided that the rest of Line B up 24400W would be read initially at 100% coverage. Upon inspection of the 100% coverage data, selected sections would then be read at 300% coverage, thus limiting the sparse data coverage to the least prospective

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areas. The reading of Line B was completed at 100% coverage in the 4 days ending March 22 (loops 60-73). The section from 14000W to 19200W was filled-in to 300% during the 2 following days (loops 74-81) to better define a local resistive feature.

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Table I is a brief production log summarizing the survey period.

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DATES	LOOPS READ	COMMENTS
Feb 27 - Mar 5	1 - 22	1/2 day lost Mar 3
Mar 6	none	intermittent Tx problems
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Mar 19 - Mar 24(noon)	59 - 81	double shift each day
Mar 24(n) - Mar 25	82 - 85	800 x 800 m loops read

At the end of each field day the data tapes were dumped to disk back at camp. The data were then reduced, usually the same day. Loop co-ordinates were carefully surveyed, as results from the Hume River Project indicated that strict geometrical control was required to obtain meaningful information from this type of sounding survey. The exact loop co-ordinates and station locations were used in the in field data reduction. An interfacing and AC power problem did not permit the production of in field hard copy plots until March 13. The data could, however, be inspected daily using the video screen graphics option of the field computer. Preliminary stripping of the data (as was done during the Hume River Survey) was not possible during the course of the survey due to the unavailability of time caused by the equipment problems.

A preliminary inspection of the data* from line A indicated that there was little horizontal variation in the conductivity along the line. The data* from Line B indicated a definite pattern of resistivity variation along the length of the line. In general the resistivity tended to decrease along the section from 0W to 7600W with the greatest gradients at 4000W and 6600W. A local resistive feature at 1200W was also noted. The resistivity remained consistently low out to about 19000W except for a distinct resistive zone between 14000W and 16200W. Beyond 19000W the resistivity increased steadily.

* The preliminary interpretation involved an inspection of the character of the response of the later time channel (numbers 3-5). This represents mean delay times of 0.8 to 3.2 msec and typical depths of 200 to 400 m.

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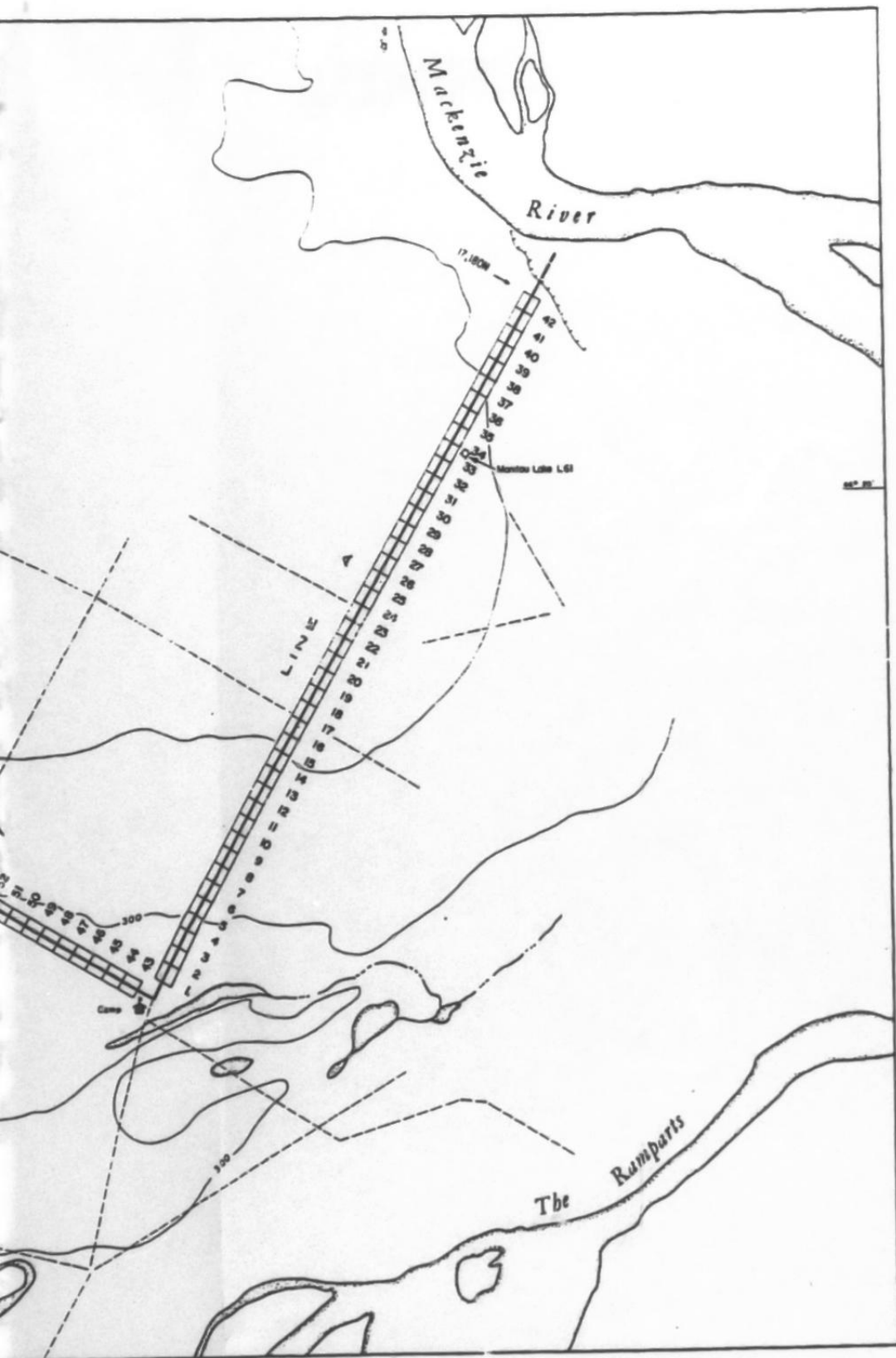
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Page 8
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LEGEND

————	UTEM Survey Line
————	Existing Gravel Line
□	UTEM Traversal Line
—♦—	DOT
—♦—	DOE

0 1 2 3 4 5 km

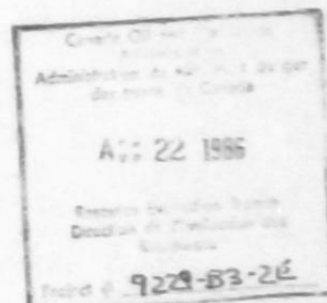
BP EXPLORATION CANADA LTD.

MANITOU LAKE PROJECT
UTEM SURVEY LOCATION MAP

STUDY AREA - F 100	AUTHOR -	DATE - May 1994	DRAWN BY -
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REPORT ON UTEM SURVEY AT
MANITOU LAKE, N.W.T.
FOR
BP EXPLORATION
BY
LAMONTAGNE GEOPHYSICS LTD.



NOVEMBER 1984

P.D. MCGOWAN AND J.C. MACNAE

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TABLE OF CONTENTS

INTRODUCTION.....	1
FIELD SURVEY.....	2
DATA REPORT	
ACQUISITION.....	5
FIELD REDUCTION.....	
DATA PRECISION.....	8
PRESENTATION.....	9
Conventional UTEM Plots.....	9
Depth Image Processed (DIP) UTEM Plots.....	10
Slowness Transform Apparent Resistivity (STAR) Plots.....	11
INTERPRETATION REPORT.....	12
LINE A.....	13
Overburden.....	14
Unit 1.....	14
Unit 2, Unit 3, Units 4 and 5.....	15
Unit Ca.....	16
Unit Br.....	17
LINE B.....	18
Overburden, Unit 1.....	19
Unit 2, Unit 3, Unit 4.....	20
Large Loop Data.....	21
CONCLUSIONS.....	23
REFERENCES.....	26
APPENDIX A: DEPTH IMAGE PROCESSING (DIP) METHOD	
APPENDIX B: APPARENT SOURCE DEPTH (ASD) AND FLATTENED APPARENT SOURCE DEPTH (FASD) SECTIONS	
APPENDIX C: SLOWNESS TRANSFORM APPARENT RESISTIVITY (STAR) SECTIONS	
APPENDIX D: CONVENTIONALLY PRESENTED UTEM DATA	

INTRODUCTION

Following the success of the Hume River Pilot Project (report dated July 1983) undertaken by Lamontagne Geophysics Ltd. for BP Minerals in February and March of 1983, a production oriented test survey (Manitou Lake Pilot Project) was proposed to assess the UTEM 3 system sounding capabilities in a production mode. The project was largely planned and supported by Lamontagne Geophysics Ltd. of Toronto and its subcontractors at Explora Geophysics of Val d'Or. The survey was done during February and March of 1984. Two existing seismic lines with a combined length of 42.0 km were read with the original intention of providing 300% coverage using loops measuring 400 x 400 m. This size of loop was considered optimal for the investigation of shallow structures such as permafrost - the main target of the investigation. The base camp located 30 km west of Fort Good Hope, N.W.T. was centered on the survey area at the intersection of the two seismic lines (see Figure 1 and accompanying map sheet).

This report contains a summary of the survey logistics and data collection, as contained in the Manitou Lake Logistics Report (McGowan, April, 1984), as well as a full interpretation report, conclusions and recommendations. Appendices to the report include the UTEM 3 field data plotted in standard and "depth image" processed form. A brief discussion of the depth image processing (DIP) technique is included for easy reference. However the

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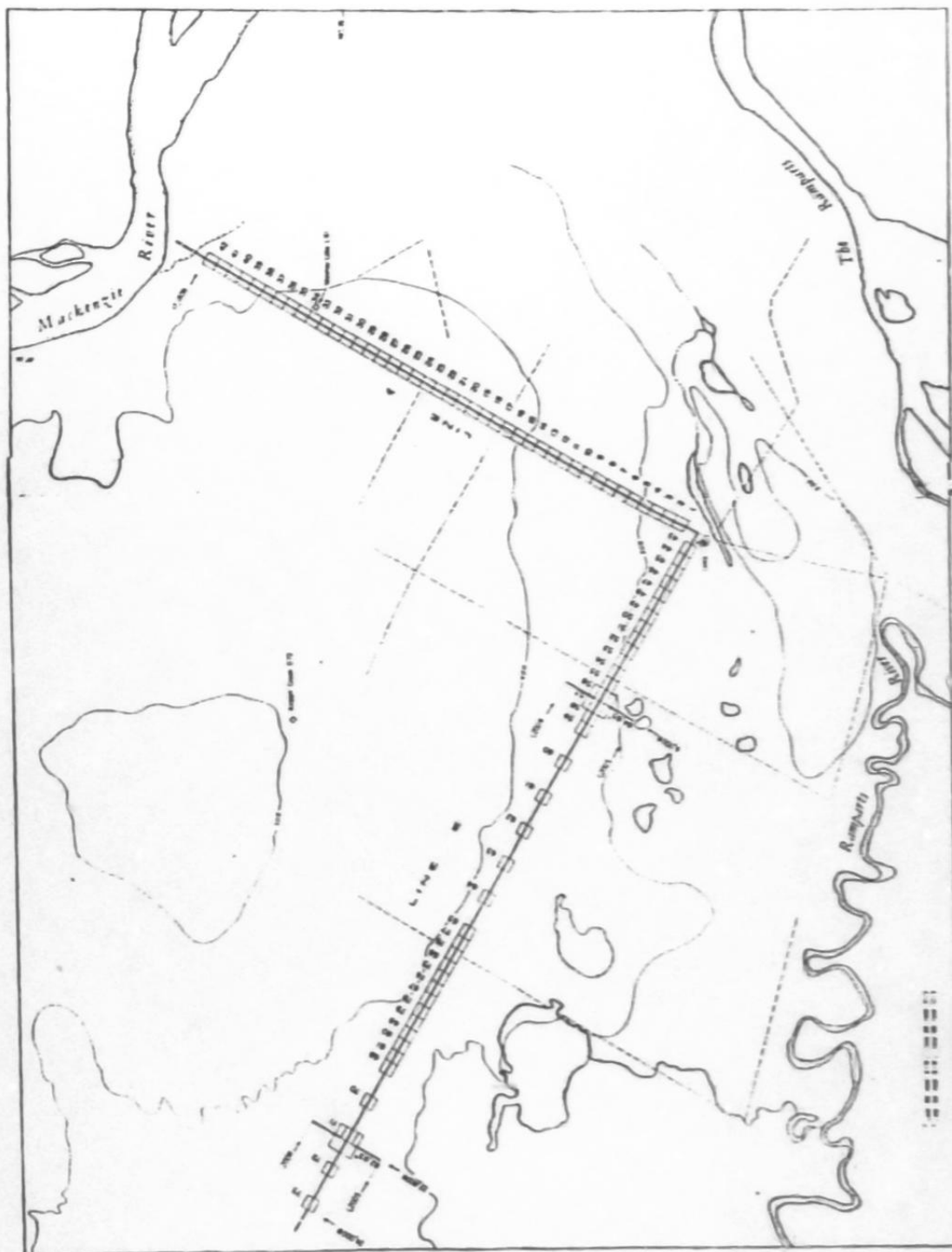


Figure 1; Manitou Lake Survey Location Map (including loop positions).

²
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detailed description of the processing is contained in the DIP report by Macnae (October, 1984).

Considerable time elapsed between the completion of data acquisition and completion of this report, as the DIP software was only in a rudimentary state of development upon completion of the Manitou Lake Survey. As is the case with most new data processing techniques, the development of the software took more time than anticipated. Because the DIP technique was designed explicitly to aid in the interpretation of UTEM 3 sounding data (a procedure usually not easy to perform without considerable experience), much thought was devoted to the final presentation of the data. The results have been very encouraging.

FIELD SURVEY

The advance crew, comprised of the subcontractors of Explora Geophysics and locally hired native people, set up the base camp and began the cutting and chaining of transmitter loop lines between February 16 and 23, 1934. The actual survey crew arrived in camp on February 24. Production began only after the arrival of the UTEM system equipment on February 27 and continued through March 25. Five and one half production days were lost during the period due to equipment trouble. Demobilization began on the evening of March 25 and was completed the following day.

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Two faults in the UTEM 3 transmitter - a broken semiconductor lead and a malfunction of the precise 5 MHz oscillator - resulted in the loss of five production days and may have added a degree of uncertainty to data collected on several of the earlier days of the survey.

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DATA PRECISION

At each station an average of 3072 repeat cycles were stacked, taking approximately 2 minutes reading time at the 30 Hz base frequency used for the 400 x 400 metre loops and 4 minutes reading time at the 15 Hz base frequency used to survey the 800 x 800 metre loops. Statistical estimates of reading repeatability expressed in percent of primary field are presented in Table II.

Table II - Reading Repeatability (small loops)

Channel	Mean Delay Time (msec)	Inside Loop	Outside loop at distance		
			0-150m	150-350m	>350m
10	0.023	0.5%	1.0%	5.0%	10.0%
9	0.046	0.2%	0.5%	2.0%	5.0%
8	0.092	0.2%	0.2%	1.0%	2.0%
7	0.184	0.1%	0.1%	0.5%	1.0%
6	0.368	0.1%	0.1%	0.2%	0.5%
5	0.737	0.1%	0.1%	0.2%	0.5%
4	1.47	0.1%	0.1%	0.1%	0.2%
3	2.9	0.1%	0.1%	0.1%	0.2%
2	5.9	0.1%	0.1%	0.1%	0.1%
1	11.8	0.1%	0.1%	0.1%	0.1%

MEASURED
VERTICAL MAGNETIC
FIELD

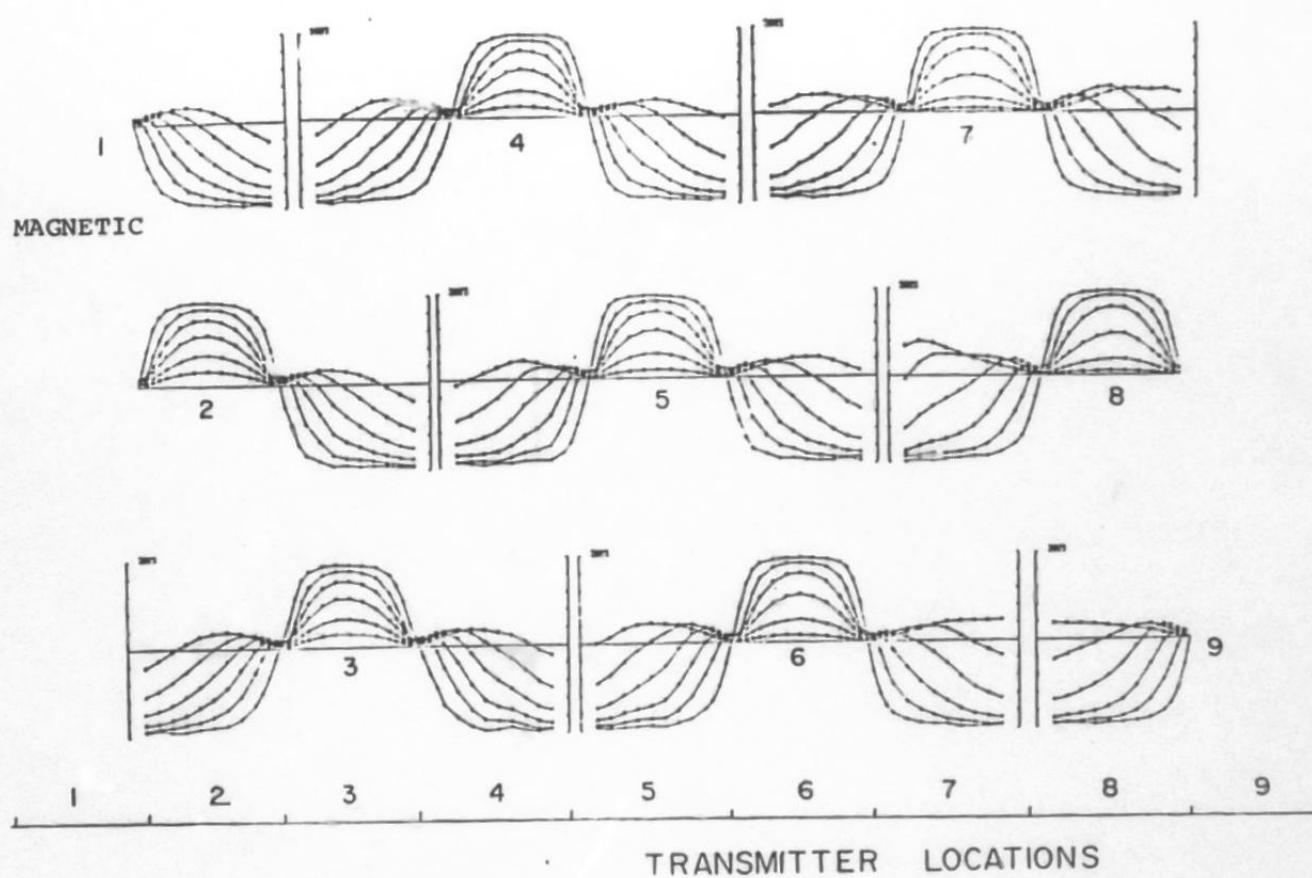


Figure 2: Early delay time data measured along a 3km profile. Each receiver station was occupied three times and data read from different transmitter loops as shown. The form of the vertical component UTEM response consists of a central positive over the transmitter loop, and a characteristic pattern of migrating crossovers outside the loop.

PRESENTATION

UTEM data from the Manitou Lake Survey are presented in three forms. The conventionally presented UTEM data (spider plots) appear in Appendix D. Depth image processed (DIP) data are presented as sections in Appendix B. Slowness transform apparent resistivity (STAR) plots are presented in Appendix C. Coverage on each of the two seismic lines was for the most part 300% (i.e. each station was read from three different overlapping Tx loop positions). This relationship is illustrated in Figure 2.

Conventional UTEM Plots

Standard UTEM profiles for each loop surveyed may be found in Appendix D. The data is plotted on three axes. On the bottom axis, channel 1 (latest time) alone is plotted reduced to calculated primary field (H_p) i.e. $(Ch1-H_p)/H_p \times 100\%$. In resistive areas $Ch1$ may be assumed to be essentially the primary field so all other channels are reduced to measured channel 1 as $(Chn-Ch1)/Ch1 \times 100\%$. This reduction method corrects for chainage errors. The intermediate to late time channels (channels 5 through 2) are plotted on the middle axis. The early time channels (channels 10 through 6) and a repetition of channel 5 for scale comparison are plotted on the upper axis at a reduced scale. The loop wire is located at the two points where all channels are near zero.

Depth Image Processed (DIP) UTEM Plots

The UTEM data from each of the two seismic lines and the two deep sounding (800 x 800 m) loops are presented in Appendix B. The data are presented with and without channel 8 "flattening". The DIP technique is described briefly in Appendix A.

For each section, the horizontal scale is linear and the vertical scale is logarithmic. This results in a varying degree of vertical exaggeration (greatest in shallow data) as the axis labels clearly show. Transmitter loop positions are indicated on the horizontal axis.

The apparent source depths (ASD's) are plotted for each of the 10 UTEM delay times together with a flat reference depth (Figure 3a). The reference depth is an arithmetic mean of the ASD's for that delay time. To accentuate the relative resistive and conductive parts of the section, the area between the ASD and reference depth has been shaded - dark shading where the ASD is greater and light shading where the ASD is less than the reference depth. The apparent time zero depth (DO), which usually represents the depth to bottom of a resistive overburden, is also plotted.

To suppress the effect of shallow features on the ASD plots, a selected ASD may be "flattened". The ASD's at each station are shifted so that the ASD of the selected delay time is at the reference depth determined as in the

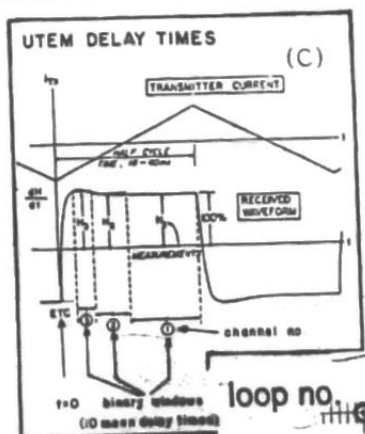
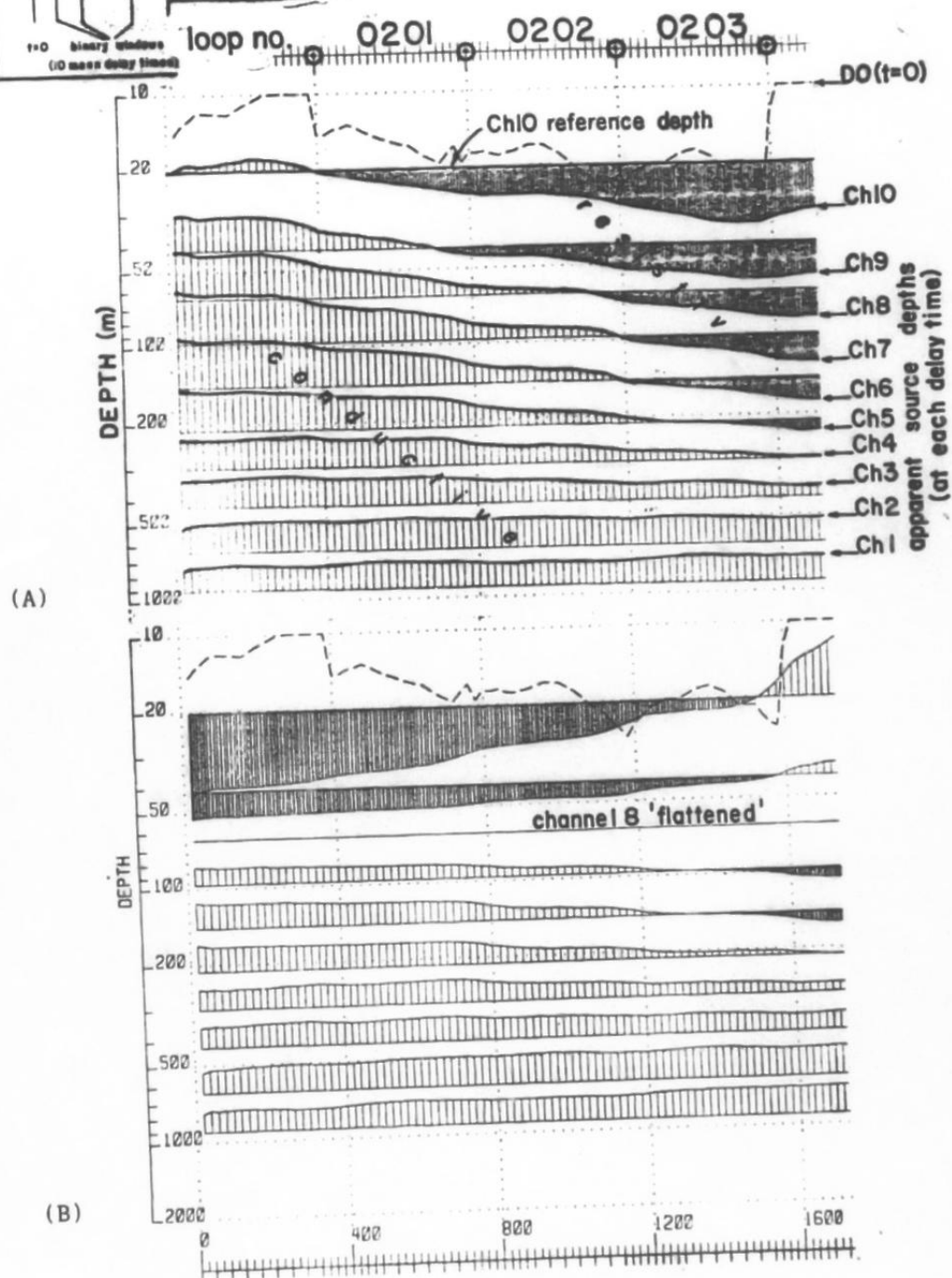


Figure 3: Presentation of Apparent Source Depth (ASD) data. (A) normal (B) flattened. (C) UTEM delay times.



normal ASD plots (Figure 3b).

Slowness Transform Apparent Resistivity (STAR) Plots

The resistivity as a function of depth below each station has been calculated from the DIP UTEM data and is presented in Appendix C. The scales of the axes are once again logarithmic in depth and linear in horizontal (station) position (Figure 5). Below each station, a log(depth) vs log(resistivity) plot is presented. A vertical line drawn below each station represents the 30 ohm-m level which was found to be convenient datum for the section. Where the estimated resistivity exceeds this level, the difference is heavily shaded and where it is less, it is lightly shaded.

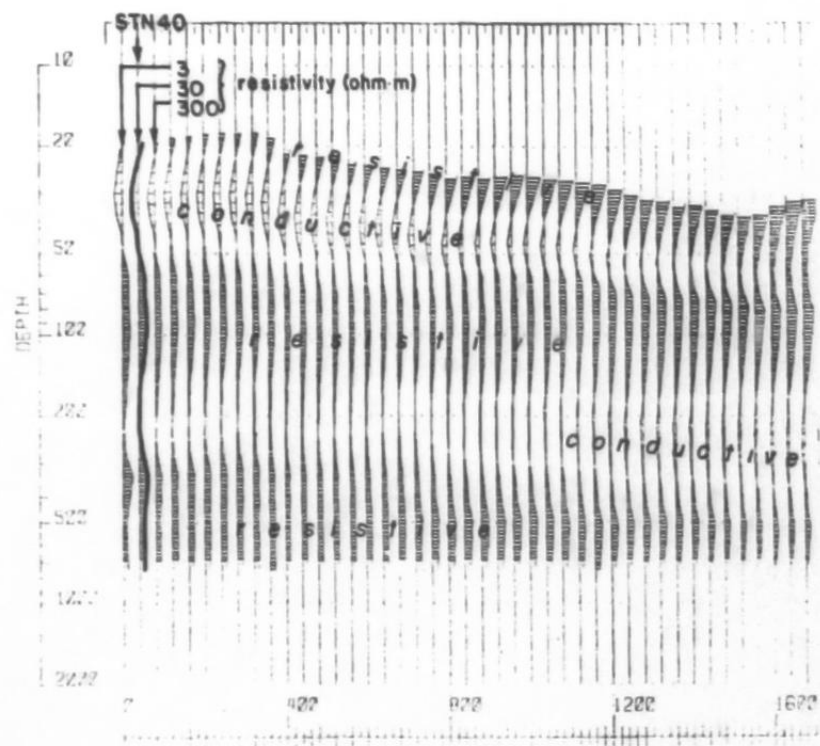


Figure 4: Presentation of Slowness Transform Apparent Resistivity (STAR) data.

INTERPRETATION REPORT

The interpretation report is largely based on the slowness transform apparent resistivity (STAR) sections. Notable features on the STAR sections are correlated to the conventional UTEM plots as a qualitative check on the DIP method. Reduced scale STAR sections are presented within the body of the report. The full scale ASD and STAR sections may be found in Appendices B and C. The conventionally processed and plotted UTEM data may be found in Appendix D.

On first inspection of the STAR sections for the two seismic lines (Figures 6a and 9a) the paucity of artefacts is notable. The artefacts are restricted to those sections of line B where coverage was 100% rather than 300% and where there is a sudden lateral change in conductivity.

The sections display a definite layered structure and there is a good correlation of depths and resistivities between the two sections (note the correlation at the intersection of the two lines). Almost the whole area is underlain by a highly resistive overburden (permafrost) extending to a depth of approximately 35 m which is essentially transparent to the EM diffusion process (i.e. the interpreted start of diffusion at time zero is at depth). Four alternating conductive and resistive layers are interpreted to lie below.

The average depth of penetration of the measured EM diffusion is 800 m*. The lateral variation within the individual layers is much greater under line A than under line B. This might indicate that gradual facies changes occur in a northeast-southwest direction in this area.

One resistive feature at the northeast end of line A breaks the monotony of the layering typical of the sections. It is interpreted as being a carbonate reef lying at a depth of 120 metres. A highly conductive zone appears to be enclosed by the reef. It is located on the southwest flank with a depth to top of 500 m.

LINE A

The resistivity structure in this section (Figure 6a) shows the greatest lateral variation of the two surveyed lines. The strongly layered character of the southwest section of the line is contrasted by a uniformly resistive feature of considerable depth below station 14000NE. The units are labelled on the interpretation sketch (Figure 6b). Two real depth sections (Figures 7a and 7b) are

* This depth is limited by the 30 Hz base frequency used for what was essentially planned as a shallow sounding survey. The resolution of deep features may also be limited by the small size of the normal coverage loops.

included to aid in appreciating the vertical scales involved, as these may not be obvious in the log depth plot.

Overburden

The inferred depth of overburden varies from 12 to 35 metres. The permafrost may in some areas be partially melted at its base. This is represented by a highly resistive (>300 ohm-m) layer just below the time zero level. Thicker, somewhat less resistive (300 ohm-m) zones at this level may be interpreted as gravelly units. The unit at 2400 NW could be a buried esker or kame moraine. The unit northwest of 13500 NW may be a better drained section of overburden owing to its proximity to the edge of the Mackenzie River Valley bluffs at the end of the line.

Unit 1

This unit is a discontinuous, moderately conductive (8-15 ohm-m) clay unit, perhaps an outwash plain, resting on the bedrock southwest of 14000NE. This interpretation would be consistent with a glacial till overburden consisting of gravelly moraines separated by clay outwash plains, as the unit pinches out below the shallow resistive unit at 2400NE. The clay unit has a maximum depth extent of about 50 m.

Unit 2

This variably resistive unit (100-200 ohm-m) is persistent along the whole section southwest of 13000NE. It extends to a depth of 180-200 m. The variation in resistivity probably reflects slight changes in composition within the unit. There is an indication that the unit reappears at the extreme northeast end of the line.

Unit 3

Although less conductive (20-30 ohm-m), unit 3 is more persistent and much thicker than the upper conductive unit (unit 1). It extends to a depth of 350 m. The unit is interfingering with rocks comprising the vertical resistive feature at 14000NE which eventually truncates it. The unit may exist at the extreme northeast end of the line. In some parts of the section the resistivity contrast between unit 3 and the underlying rocks is less than 10 ohm implying a very gradational facies change.

Units 4 and 5

These may be one unit, but the marked lateral changes in resistivity suggest the presence of two distinct facies below 350 m. Unit 4 has typical resistivities up to 120 ohm-m whereas unit 5 has an average resistivity of about 50 ohm-m. Both units display good vertical uniformity up to the greatest sampled depth at this point (about 700m). It is difficult to determine the boundary between unit 4 and

the interpreted carbonate reef at 11000NE which suggests a gradual facies change from shale to limy shale to carbonate. The correlation of unit 5 to the unit northeast of the carbonates is speculative and is only suggested by the similarity between the resistivities of the two units.

Unit Ca

Northeast of 11500NE, a resistive feature of considerable depth extent is present. It truncates all but perhaps the uppermost (unit 1) of the strata so typical of the section. There is an indication that the stratification resumes to the northeast of unit Ca adding to the speculation that it is an isolated carbonate reef protruding into shale sequences from an underlying carbonate platform. A confused pattern directly to the northeast of the unit (15400 - 16400NE) is probably due to artefacts produced by an abrupt change in lateral resistivity. This is suggested by the centering of the features on loop positions (see Figure B1, Appendix B for loop positions).

The unit displays a remarkably uniform resistivity (300 ohm-m). It appears to be comprised of an upper layer, extending from a depth of 50 m to a depth of 120 m, and lower block extending from a depth of 130 m to below the bottom of the section at 1200 m. The boundary of the upper unit is not well defined and may represent a localized facies change in the surrounding shales. The shallowest

parts of the lower block are located at 14400NE. Data from Manitou Lake well L61 located just to the southeast of (approx.) station 13840NE (Figure 1) indicates the presence of a carbonate structure below a depth of about 110 m.

Unit Br

Contained within the lower resistive block at 12400NE is a highly conductive ($< 3 \text{ ohm-m}$) zone (Br). The top of the southwest end lies at a depth of 480 m and dips steeply to reach a depth of more than 1200 m at 13600NE. The feature is definitely not a processing artefact as it is continuous across a number of loop positions. It is also evident in the conventional UTEM plots (loops 29 - 34, Appendix D) where it appears as a sudden slowing in the latest delay times (channels 3 to 1). An oil reservoir in a carbonate sequence sometimes has a much lower resistivity than adjacent, nonporous rocks, provided hydro- carbon saturation is not very high (Garg and Keller, 1984). The conductive zone may represent a localized pool of brine contained within a porous carbonate unit. The average resistivity of saturated sediments is 3 ohm-m (Telford et al., 1976) and this would probably be much lower if the sequence were saturated with a heavy brine (20% saline = 0.05 ohm-m)

LINE B

UTEM sounding data for line B was collected using both a line of small transmitter loops and two large loops. The data from the small loops was processed and assembled into sections (ASD, FASD and STAR sections). The data from the two large loops was then compared with the section data.

A number of artefacts are present in the STAR section resulting from the incomplete coverage over some parts of line B (Figures 8a, 8b and 9a). The incomplete coverage has resulted in poor resolution of deeper structures particularly (see Section A2 of Appendix A). The characteristic pattern (over-estimated resistivities inside loops) is believed to be caused by the presence of a deep layer of increasing resistivity. This occurs because of the periodicity of the UTEM signal. In effect, we should expect deeper clusters of images to account for the responses of the earlier transition of the waveform. If the conductivity at depth is not uniform, the correction for these in the reduction is not exact and where there is only 100% coverage the artefacts are not suppressed by stacking. With further improvements in the processing, we may be able to use this artefact to extrapolate (in a general sense) the resistivity trend to greater depths.

The resistivity structure of the overburden and bedrock under line B is very similar to that found under the southwest half of line A. The section is composed of

four layers below the overburden. Two disturbances in the layering at 8700 NW and 7400 NW may be caused by vertical contacts (faulting?).

Overburden

The overburden appears to have a thickness of 35 m over most of the section. A shallow resistive feature at 16000 NW may represent a gravel bed or topographical high in the bedrock. A shallow conductive feature from 5600 NW to 8000 NW probably represents a thick shale or clay unit (unit 1, Figure 8b) exposed at the surface or lying under only a very thin layer of overburden.

Unit 1

This unit is more persistent under most of line B than the unit 1 of line A, but the two units are clearly the same. It appears to thin out considerably northwest of 20000 NW. The average depth to the top of unit 1 is 30 m and it extends to an average depth of 60 m. The unit has a resistivity that averages 10 ohm-m. The unit thickens and becomes more conductive between 5600 NW and 8000 NW. Very little overburden appears to overlie this area as well.

Unit 1 is somewhat disturbed in the vicinity of 8700 NW and 7400 NW. There definitely is a sudden decrease in resistivity below the overburden, although the exact geometry of the causative beds is probably distorted. The conventional UTEM plots (loops 0259 and 0260) indicate

vertical contacts at these locations (Figure 10). The apparent vertical offsets in the units below these points may or may not be real, as the processing technique is not well behaved in the presence of sudden lateral changes in resistivity. The 100% coverage over this part of the section almost certainly augments this effect.

Unit 2

This unit is very persistent and displays a uniform thickness and resistivity. The top lies at 60 m, the bottom at 180m and has an average resistivity of 50 ohm-m. Its characteristics are very similar to those of unit 2 of line A. The artefacts caused by 100% coverage distort slightly the resistivity structure of this layer.

Unit 3

This conductive layer does not display the same degree of lateral variation of conductivity (facies changes?) as was evident in unit 3 of line A. Here the unit is more uniform, although the average resistivity of 30 ohm-m and depth extent of 100 m suggest that the two units are the same.

Unit 4

The 100% coverage artefacts are most pronounced at this depth (>320 m). As a result, the resolution of unit 4 in many places is very poor. The lateral variation in resistivity is not as great in this unit as was apparent in

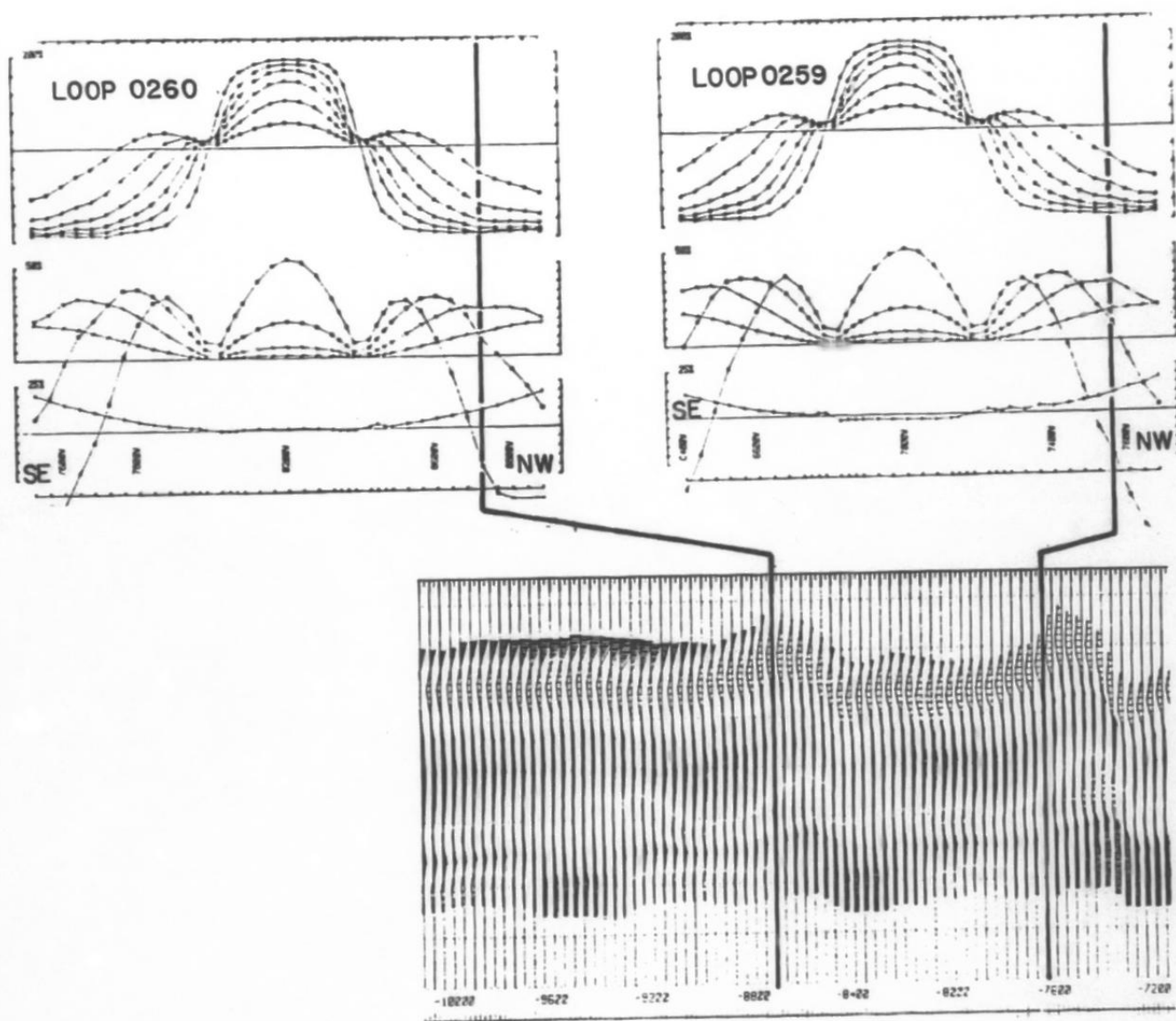


Figure 10: Vertical contacts as displayed in conventionally presented UTEM plots .
Note the reversed direction of the profiles.

the basal unit of the other section. For this reason it has not been subdivided. Its average resistivity (120 ohm-m) is similar to that of unit 4 of line A so these two units have been correlated here.

Large Loop Data

In general the two large loop data correlate well with the data from the small loops. The artefacts caused by 100% coverage are very apparent in this data as in the small loop data above. The (orthogonal) STAR sections below the loop centred at 6000 NW (Figure 11). displayed the least lateral variation in resistivity. The character of the sections is of a layered earth having the same number of layers with the same resistivities, depths and thicknesses as are found in the small loop data in the vicinity of 6000 NW. The uppermost conductive layer (unit 1) is again located just below a thin overburden layer and appears to be uniformly conductive in this area. The lower conductive layer (unit 3), however, appears to pinch out to the north - a trend which is enhanced by the effects of 100% coverage. This would agree with the hypothesis that the variation in lateral resistivity is greater in a northeast-southwest direction.

The STAR sections below the large loop centred at 22800 NW (Figure 12) display a marked variation in resistivity, particularly in the data from the cross (northeast-southwest) line. The uppermost conductive unit

(unit 1) appears to pinch out completely to the north and thicken to the south. The underlying unit (unit 2) appears to replace it. The resistivity of the basal member (unit 4) also appears to vary markedly in this direction. Unit 4 appears to be much more distinct (and resistive) to the south.

Figure 11: DIP data from large loop at 6000 NW.

- A) ASD section (on line).
- B) ASD section (cross line).
- C) FASD section (on line).
- D) FASD section (cross line).
- E) STAR section (on line).
- F) STAR section (cross line).

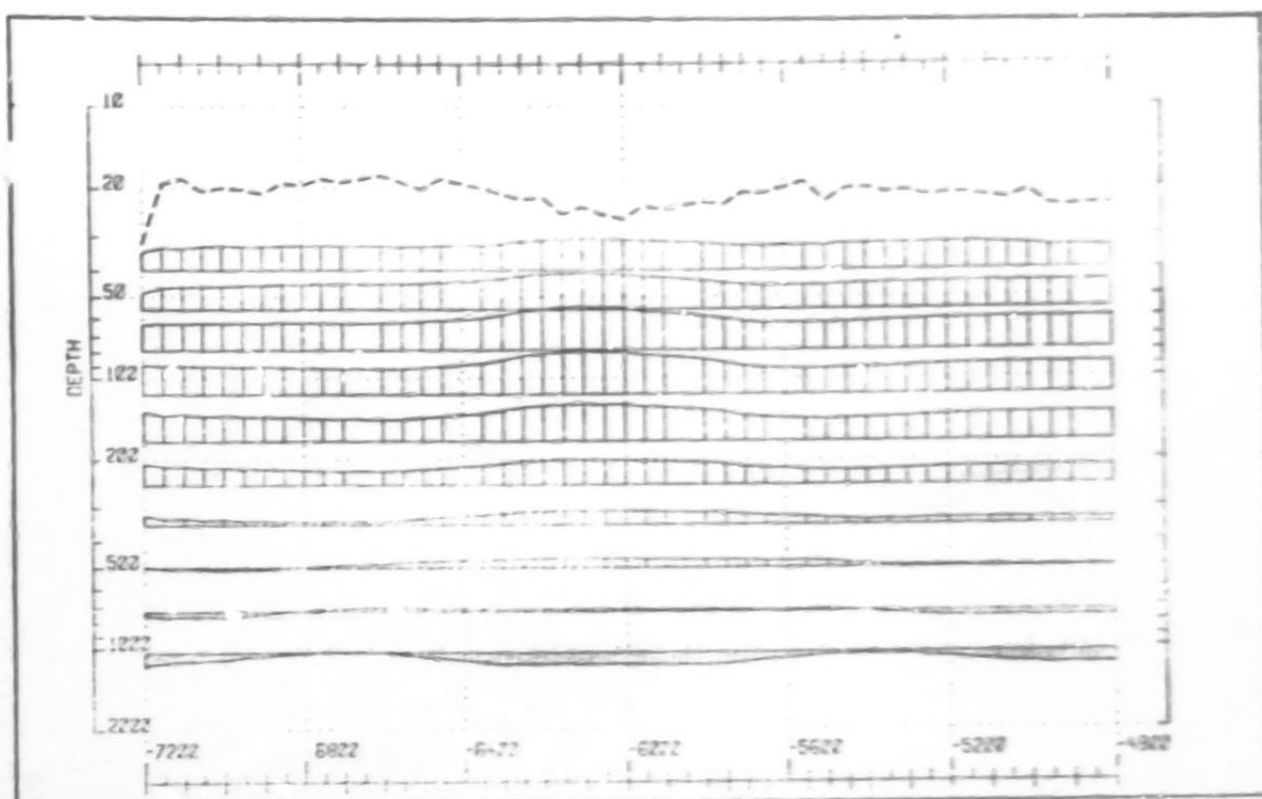


Figure 11A.

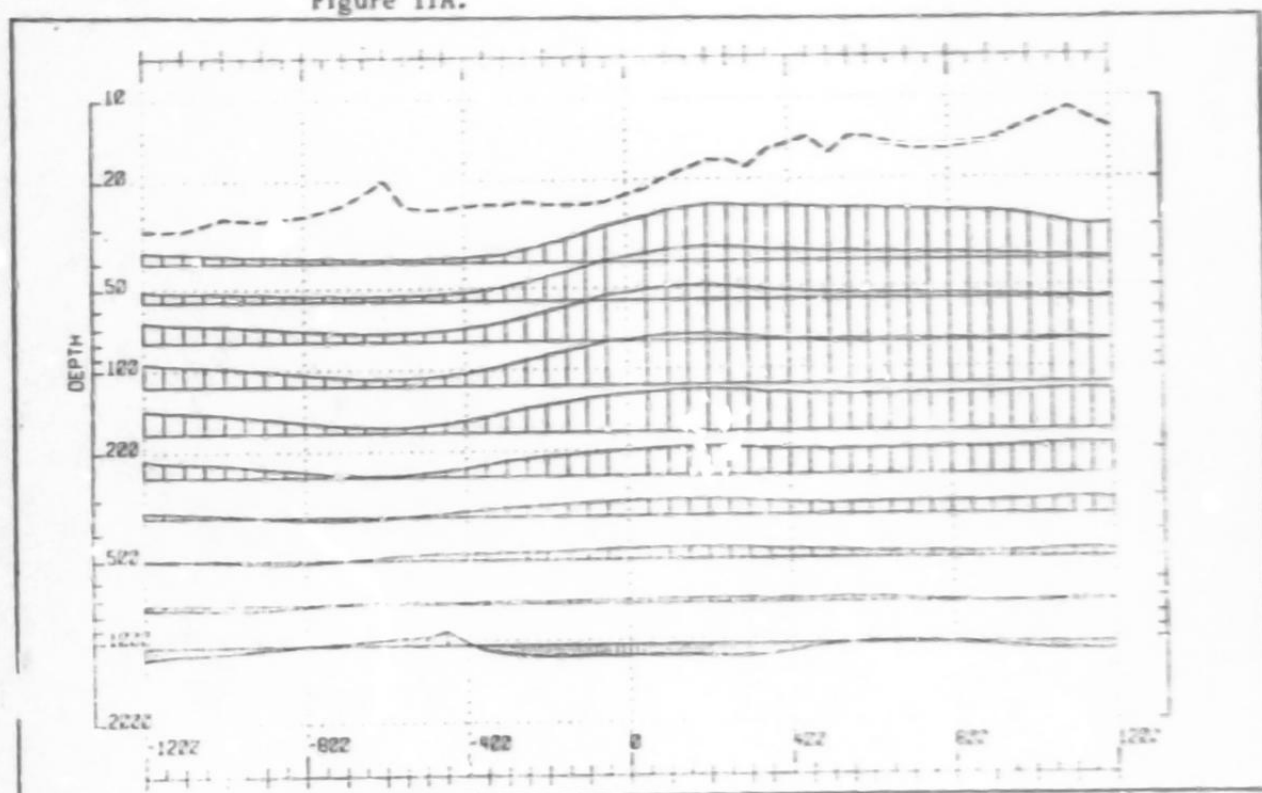


Figure 11B.

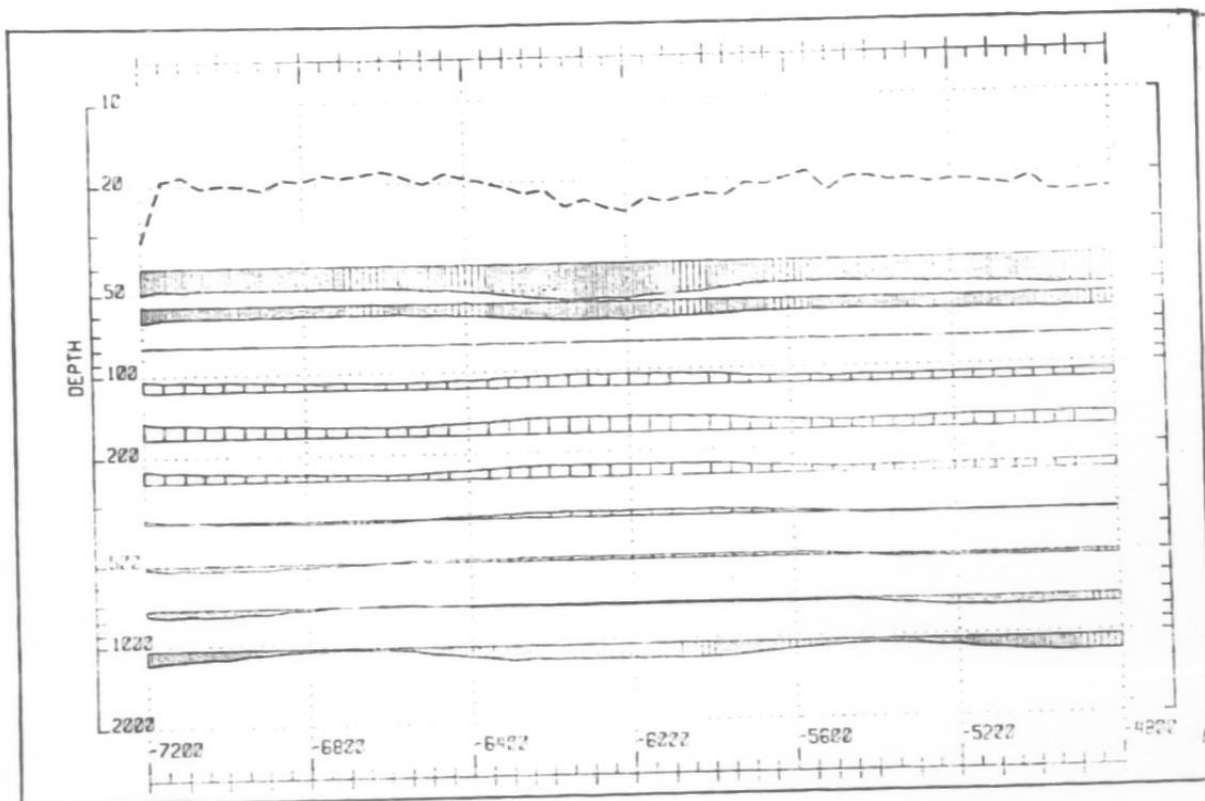


Figure 11C.

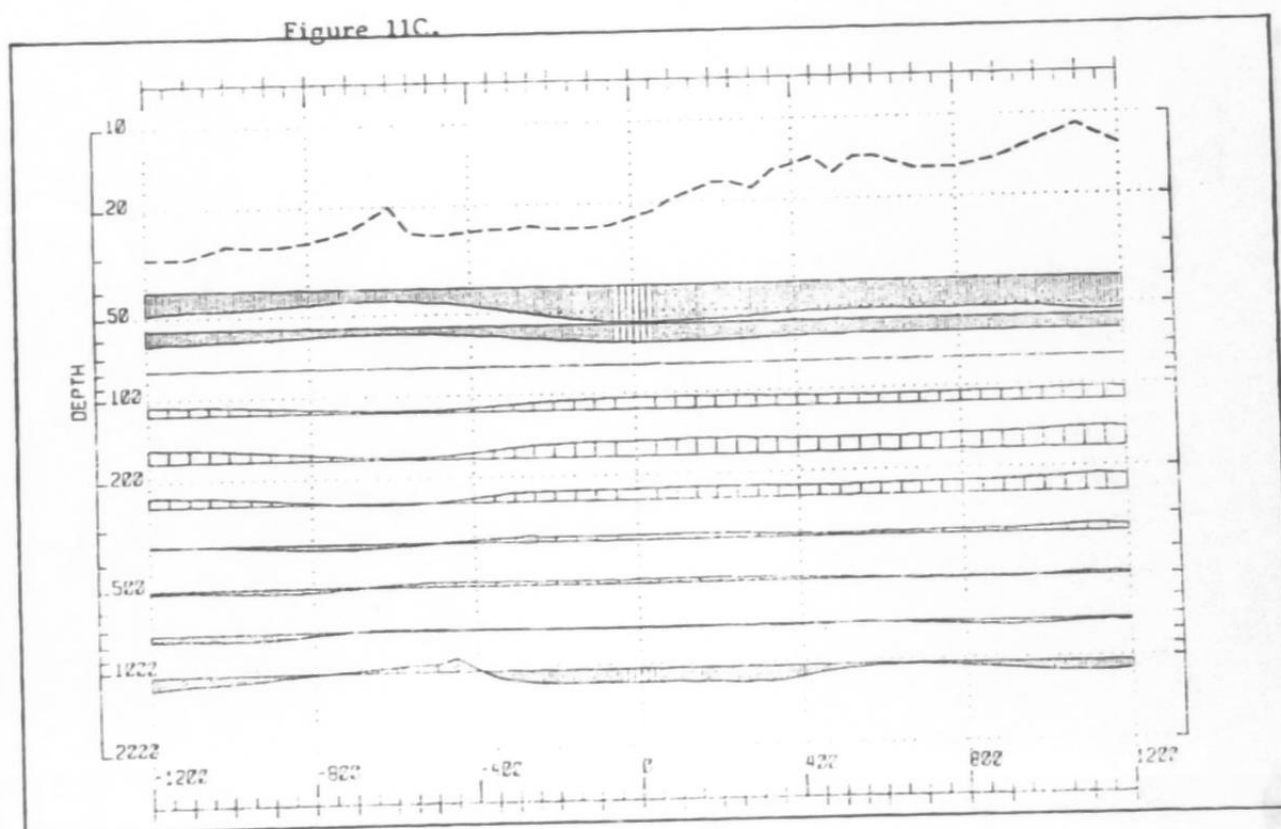


Figure 11D.

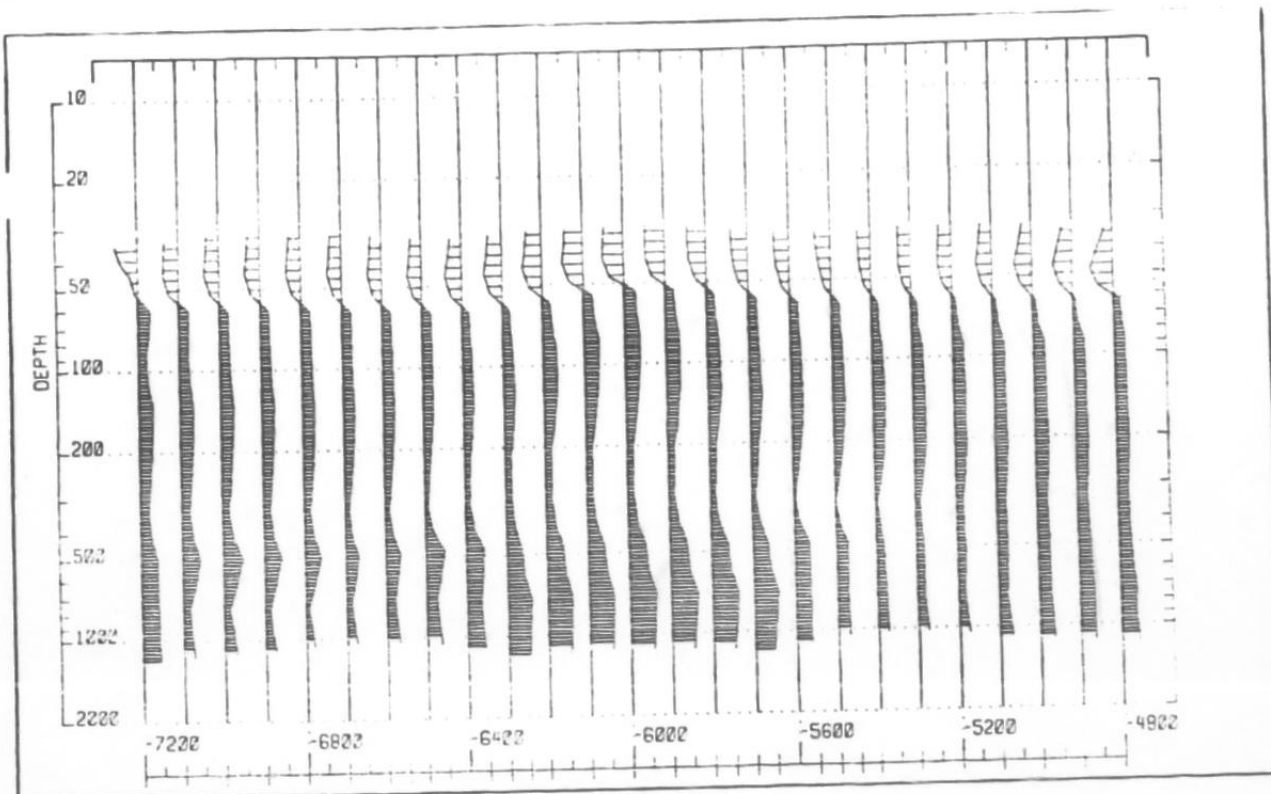


Figure 11E.

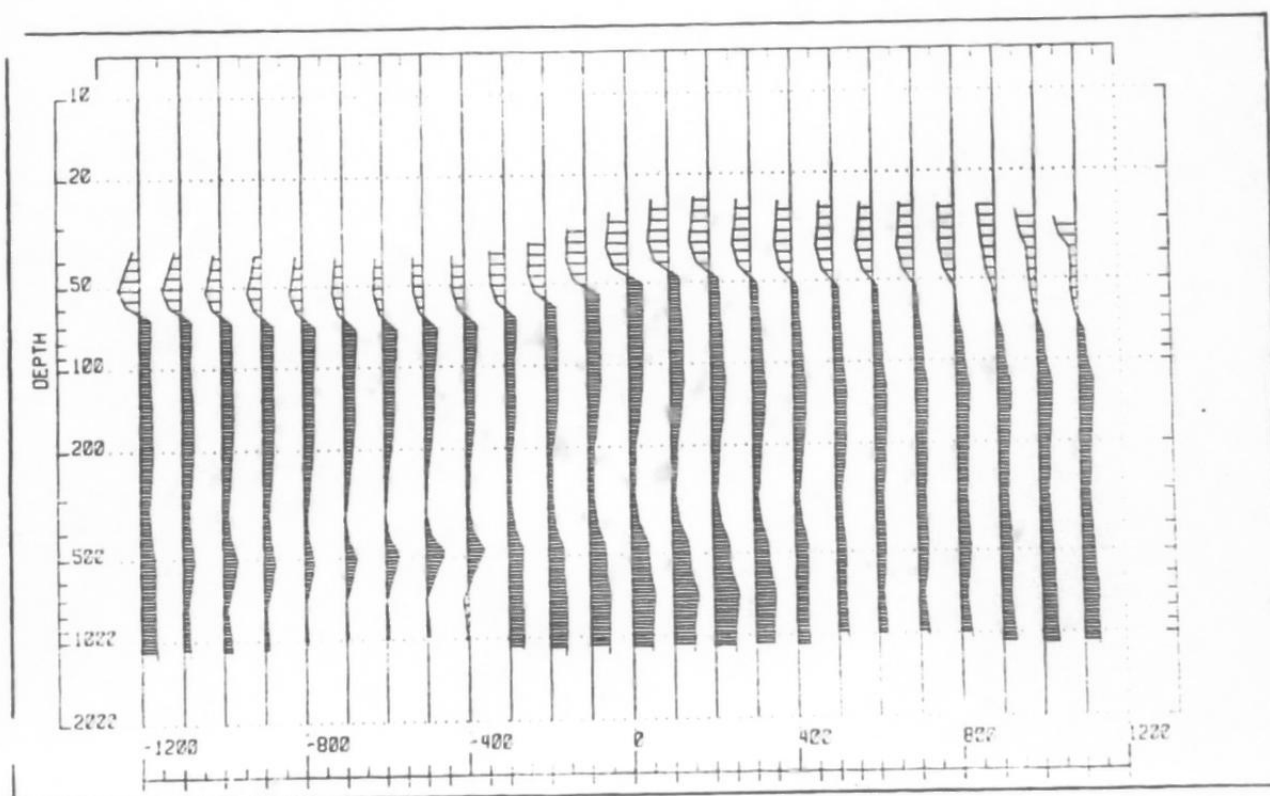


Figure 11F.

Figure 12: DIP data from large loop at 22800 NW.

- A) ASD section (on line).
- B) ASD section (cross line).
- C) FASD section (on line).
- D) FASD section (cross line).
- E) STAR section (on line).
- F) STAR section (cross line).

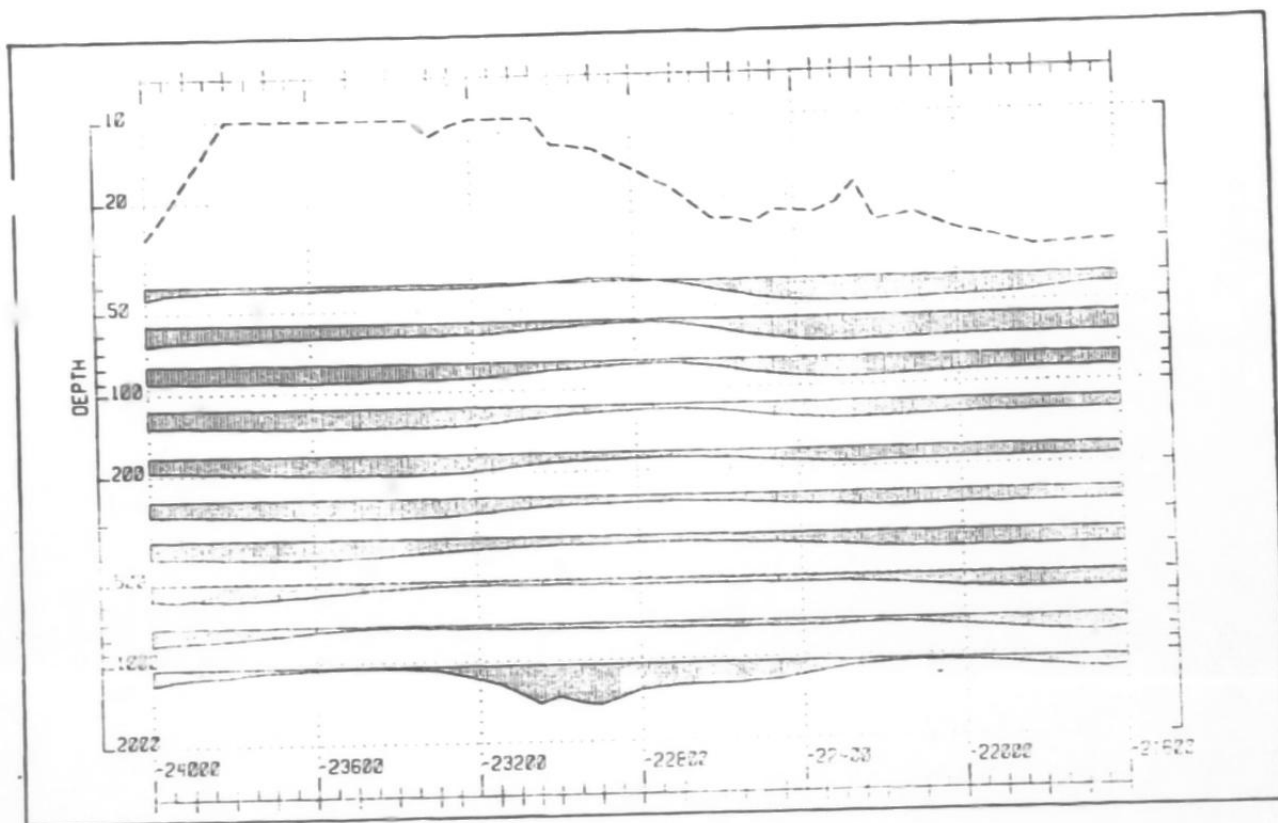


Figure 12A.

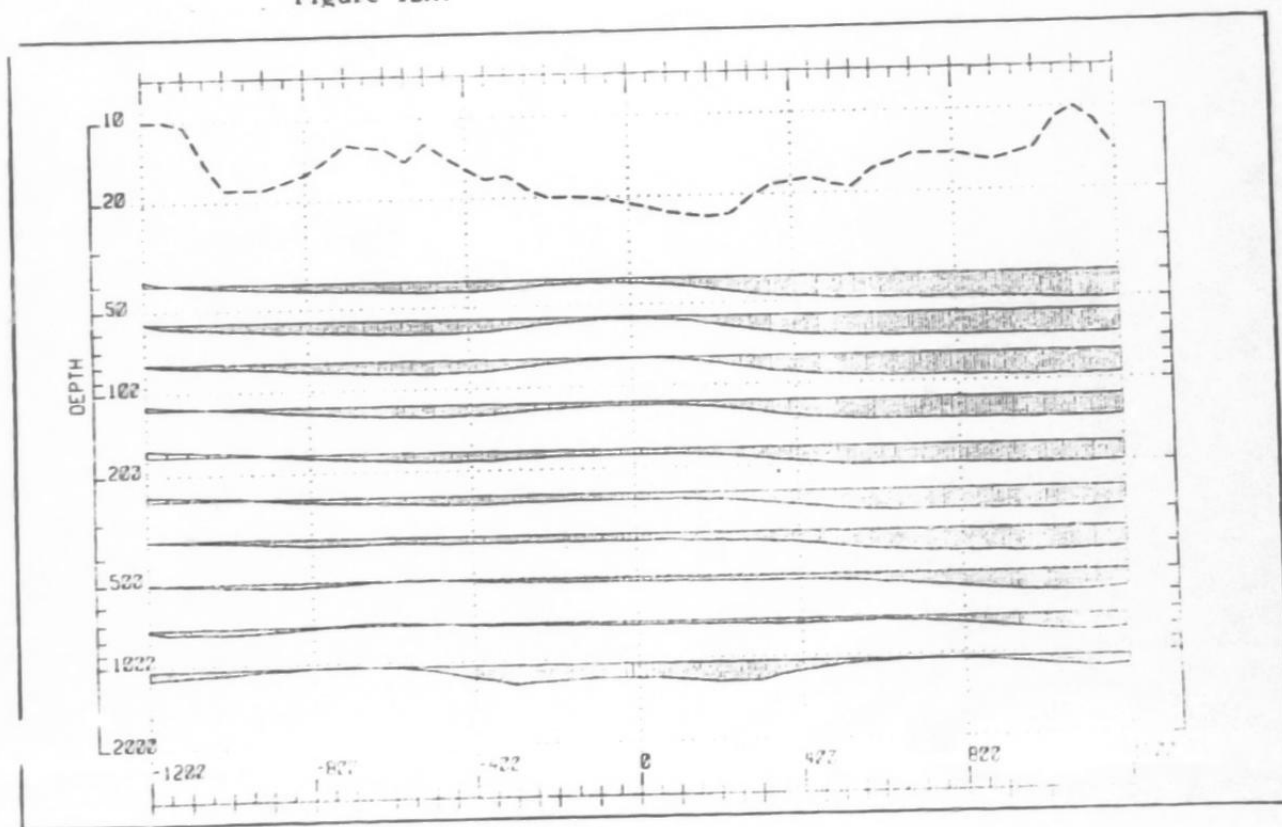


Figure 12B.

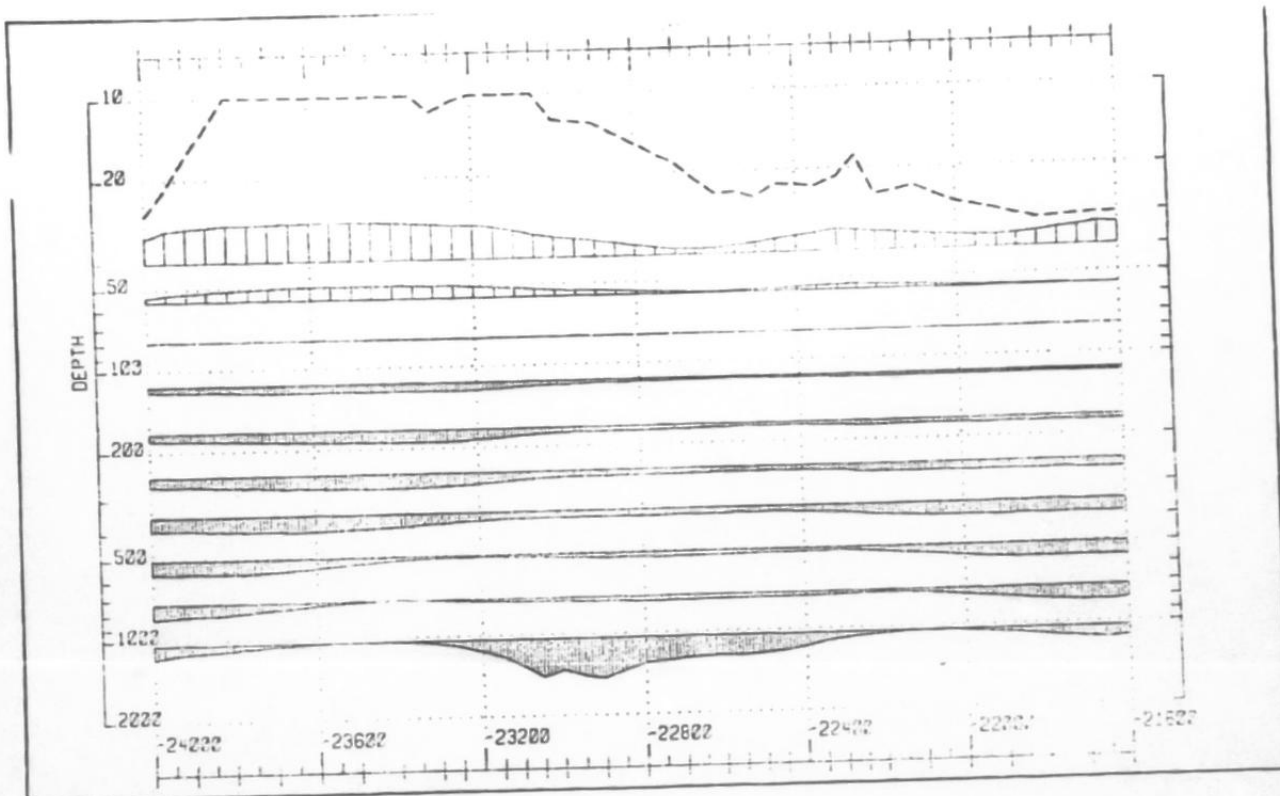


Figure 12C.

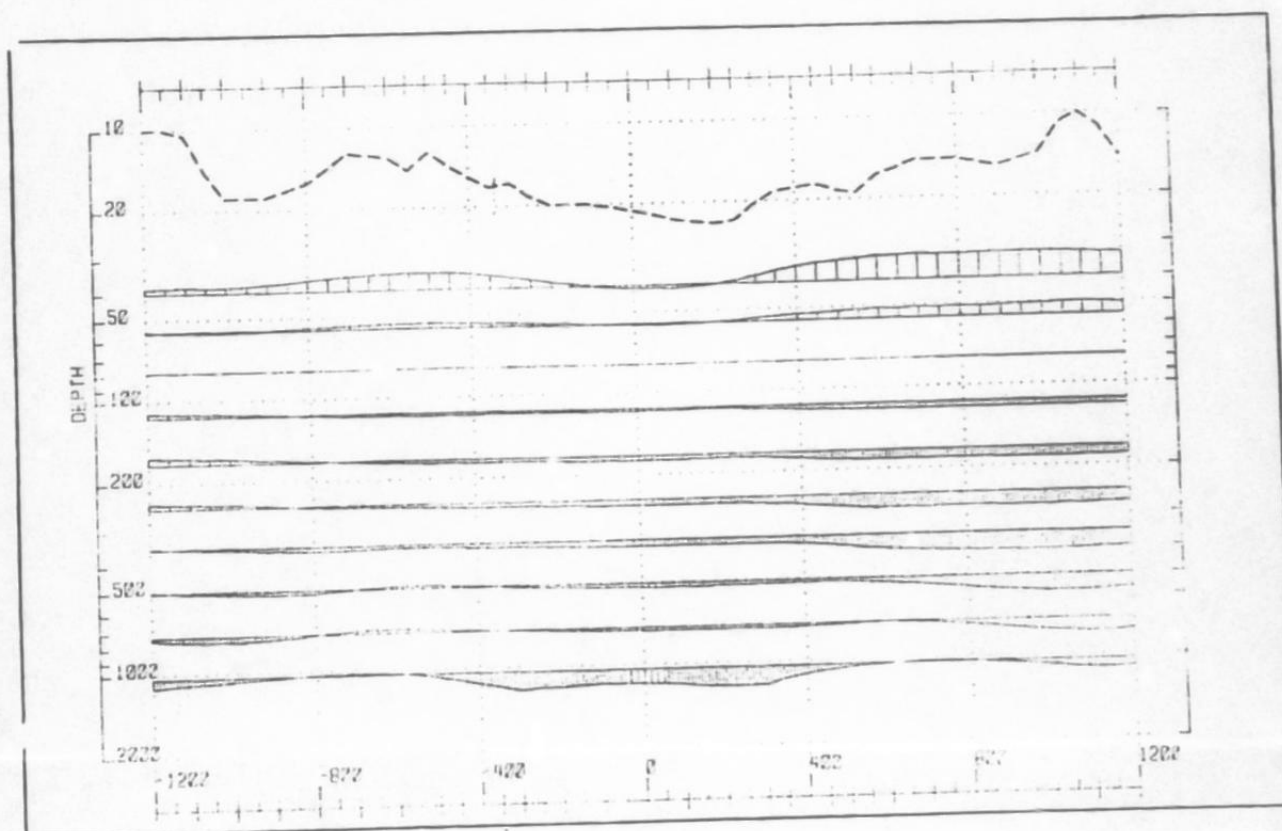


Figure 12D.

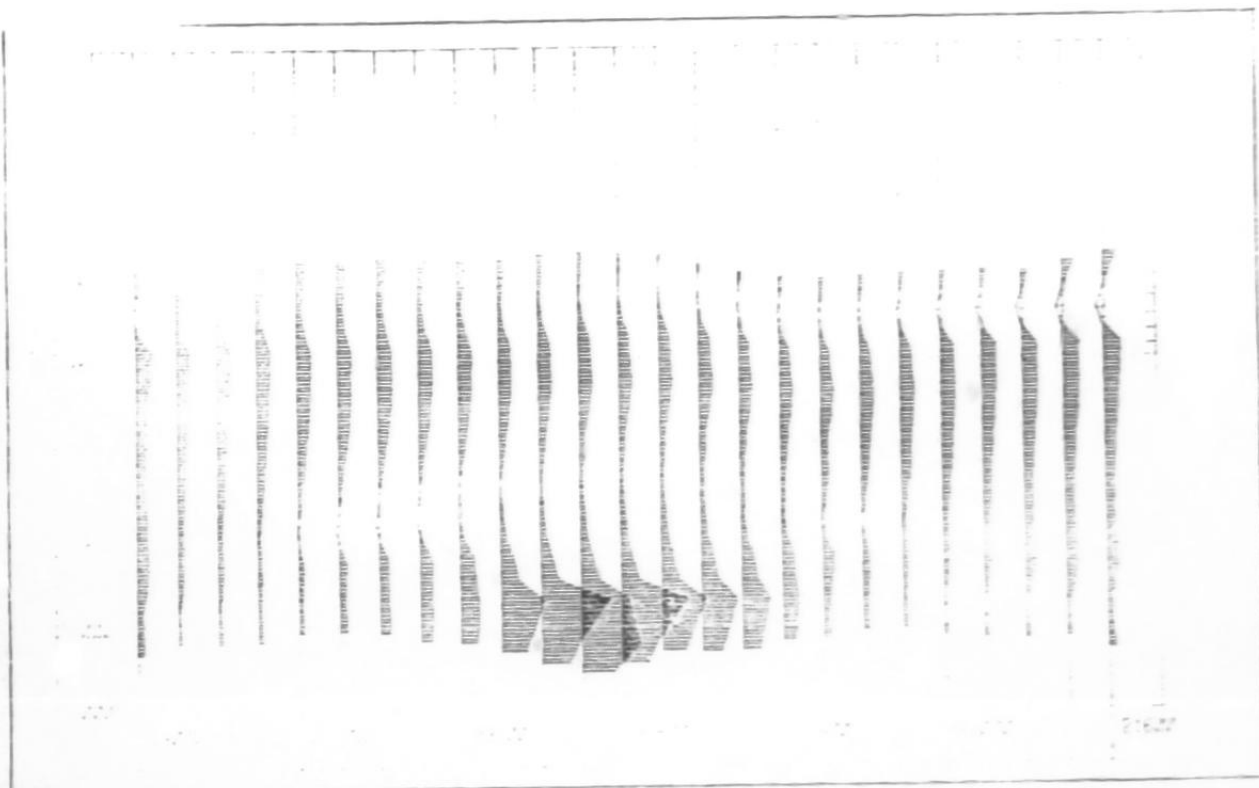


Figure 12E.

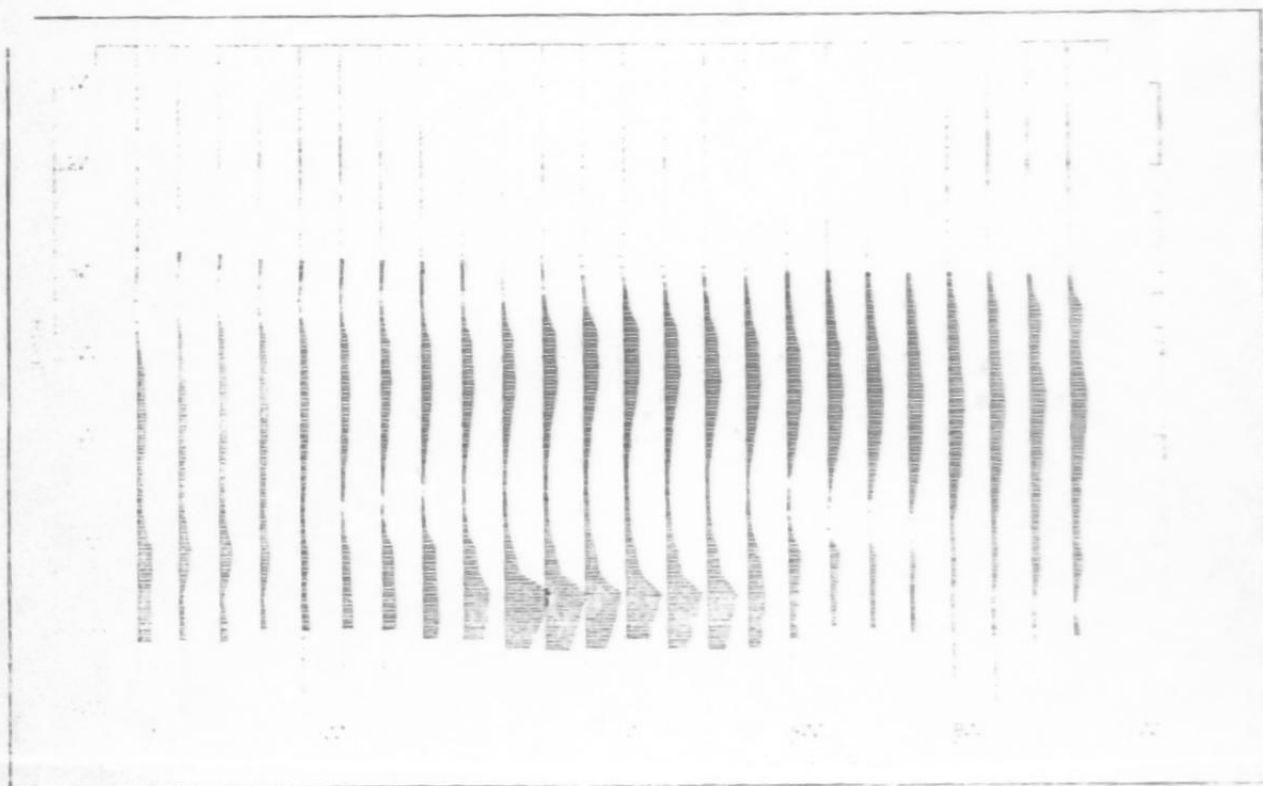


Figure 12F.

CONCLUSIONS

One of the initial aims of this survey was to determine if the UTEM data could be used to determine permafrost depths with sufficient accuracy to be of assistance in seismic static correction estimation. Analysis post survey completion, based on the recently completed BP Canada/Sohio Petroleum sponsored research project indicated that optimum depth resolution is achieved when the size of the survey loop/length of survey lines is close to the depths of interest. For the permafrost thickness here in the 30m range, it is clear that the survey line length/loop size used is far larger than ideal except for the closest stations surveyed to each transmitter loop. In this respect, the survey was not an optimum test of the potential application of UTEM to permafrost problems. Nonetheless, the variations in interpreted depths of permafrost predicted and presented on the plotted data sections show that considerable variations in permafrost thickness exist, as well as variations in the composition of immediately underlying material.

In respect of a second aim of the survey to detect a known carbonate reef buildup located under line A, the UTEM survey in combination with Depth Image Processing was an unqualified success. A highly resistive feature was detected in an unambiguous manner, which is believed to be consistent with the known location of the reef.

The STAR slowness transformed apparent resistivity plot has allowed a section to be constructed of a physical property, namely the resistivity, which has been used in a rigorous and simple manner to identify various geological horizons. On the basis of established rock-type resistivities, these horizons have been interpreted as shale, carbonate, glacial overburden and permafrost units.

Use of a 30 Hz base frequency has, in this environment, allowed for interpretation of the conductivity structure down to a depth of about 800 m, with an estimated layer boundary location error of less than 25% of interpreted depth where the section is horizontally uniform. Improvements in the vertical location of layer boundaries could be achieved using inversion techniques, particularly if the conductivity structure is known from nearby well logs.

Comparison of the UTEM results with other prospecting techniques is beyond the scope of this report, as is an evaluation in terms of known geology. The significant advances in data processing techniques as a result of the BP/Sohio sponsored research project on depth image processing have allowed for greatly improved presentation of the UTEM survey data, as well as greatly simplifying the interpretation process. This simplification and clarification has allowed for a significant increase in the confidence and detail of interpretation provided in this report compared to that of the previous Hume River Pilot

Project completed in 1983.

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- Grant, F.S and West, G.F., Interpretation in applied geophysics: McGraw-Hill, New York, 1965.
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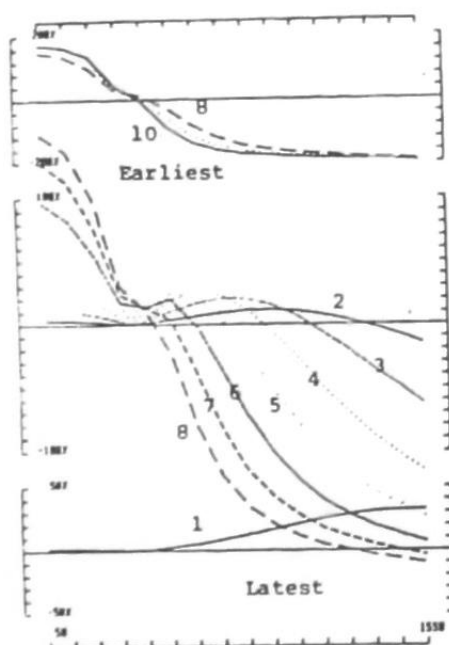
APPENDIX A
DEPTH IMAGE PROCESSING (DIP) METHOD

DEPTH IMAGE PROCESSING (DIP) METHOD

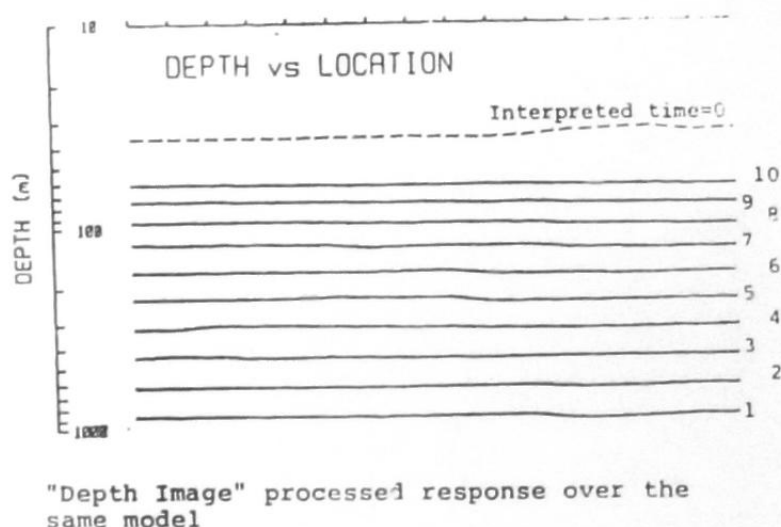
Lateral variations in conductivity for layered earth cases are easily detected using a large-loop time domain EM system such as UTEM, although the interpretation of conventionally processed and presented data is far from obvious to the untrained eye (Figure A1). At the instigation of BP Canada Ltd. Lamontagne Geophysics Ltd. has been developing and refining a system of processing time domain EM data that simplifies geological interpretation of this type of data. The initial results from a "depth image processing" test may be found in the interpretation report from the Hume River Pilot Project by Macnae (July, 1983). The latest developments are presented in the Depth Image Processing Report submitted to BP Canada Ltd. and Sohio Petroleum Company by Macnae (October, 1984).

A.1 - The Use of Source Images to Approximate the Secondary Field Over a Layered Earth

Maxwell showed (see Grant and West, 1965; pp.498-500) that the response of a thin, conducting sheet to a step change in magnetic field could be completely predicted at any point using a receding image of the source. Although no general exact solution of this form is known for a half-space or layered earth, Nabighian (1978) has published an approximation using an expanding current image at depth. Based on these two concepts, a method was devised to use first a single (1983) and then multiple (1984) current source images to keep track of the induced current distribution in



Conventionally reduced UTEM response over a 200m half space at a depth to top of 30m.



"Depth Image" processed response over the same model

Figure A1: The aim of depth image processing is to transform magnetic field data, exhibiting considerable spatial variation due to source-receiver geometry as shown at the left, into a set of straight lines. The depth of these straight lines should indicate the depth to which the induced current system has penetrated on average. The right hand diagram shows an early attempt at such a transform using a single depth image. Even with considerable spatial averaging, some "waviness" of the transformed data is apparent.

a layered earth as a function of time. An empirical approach was taken in that calculated secondary fields at a set of test points were input into an inversion program, and the distribution of images of the source computed that would provide the best fit to the calculated fields.

In the early stages of DIP development, a single image distribution (one image for each delay time) was fitted to an entire profile (i.e. one transmitter loop location). At present, a multiple image distribution is determined for each data point of the profile (to attempt geometrical correction or "normal moveout") at each delay time (to better fit a broad range of model types - eg. thin sheets, half-spaces, general layered earths). A 14 discrete image distribution was found to be optimal, considering processing costs and quality of results, although several others were tried (Figure A2). This means that a 14 discrete image distribution is fitted to the amplitude of the UTEM response for each of the selected delay times (in this case the 10 UTEM delay times) at each station along the profile.

The width of the discrete image distribution must be variable as a wide distribution is required to fit a half-space and a single image (i.e. fully collapsed multiple) is needed to fit a thin layer. The width of the distribution is determined by examining the preliminary fit of a single image to the data. The centre of the image cluster is used as reference point for the discrete image distribution (Figure A2). One half of this distance represents the inferred depth of induced current

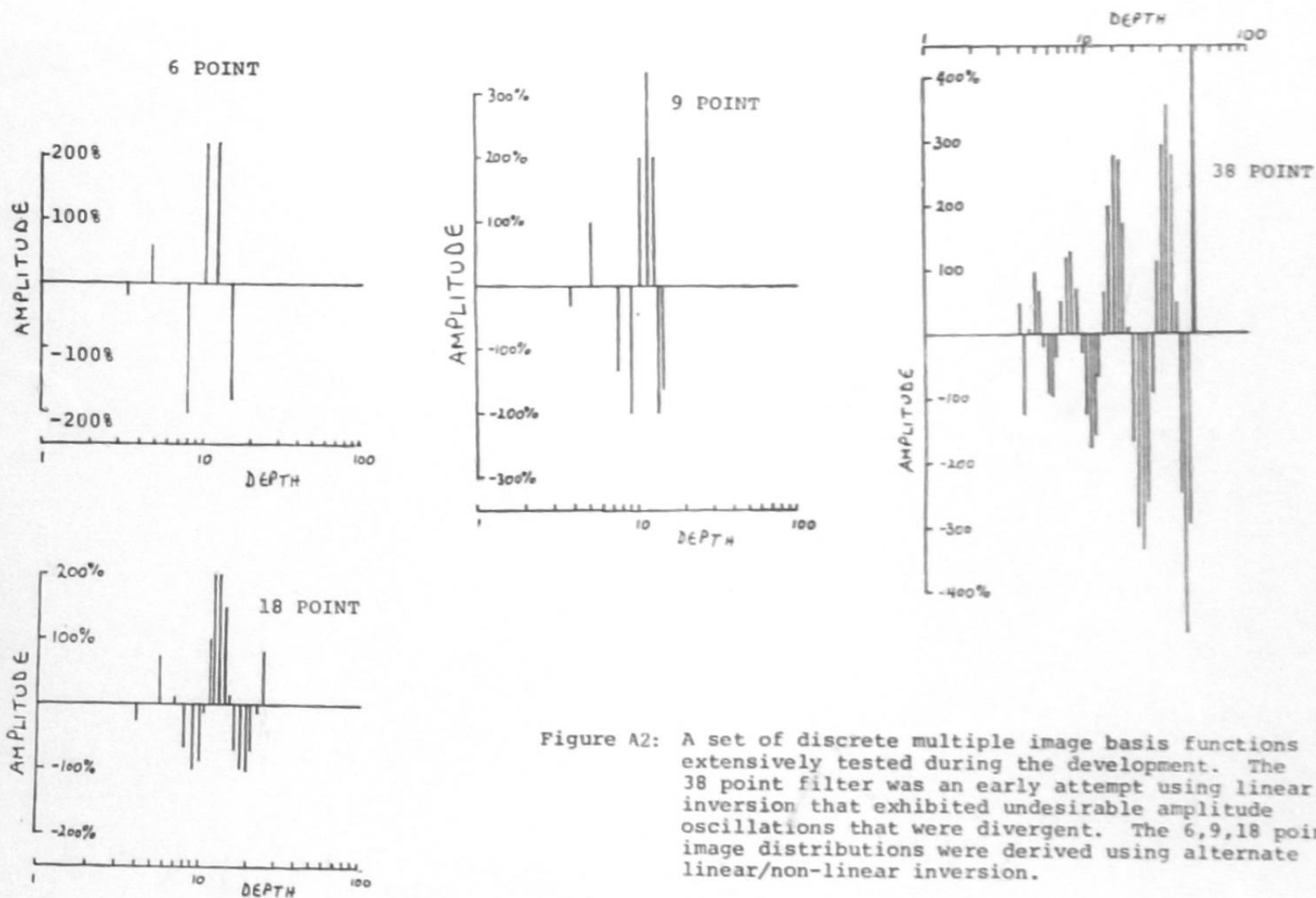


Figure A2: A set of discrete multiple image basis functions extensively tested during the development. The 38 point filter was an early attempt using linear inversion that exhibited undesirable amplitude oscillations that were divergent. The 6,9,18 point image distributions were derived using alternate linear/non-linear inversion.

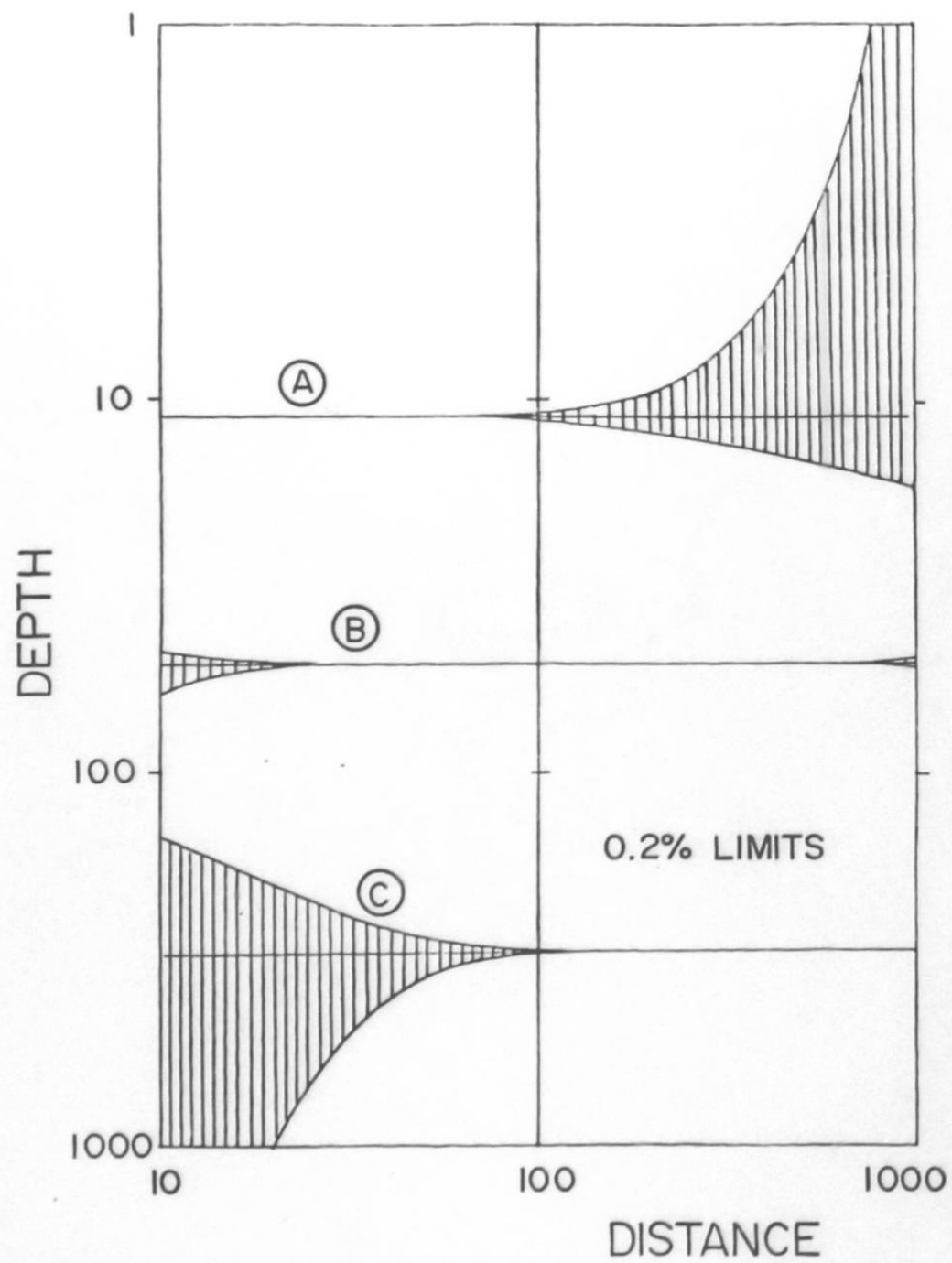


Figure A3: Error bars on fitted depth of a single dipole image as a function of the depth of the reference and the dipole source-receiver distance, for an error limit of 0.2% of the source step amplitude.

penetration and is known as the "apparent source depth" (ASD).

A2 - Errors

Figure A3 shows the error limits on fitted depth of image as a function of dipole source-receiver distance for a reading accuracy of 0.2%. The large error bars at some distance to depth ratios indicate that good resolution of image depth can only be achieved provided the source-receiver distance is within a factor of 5 of the image depth. As a result of this we would expect a variable performance of the depth image transformation to effect normal moveout along any typical profile. It would appear that multiple coverage of a profile using both near and far sources can guarantee adequate performance of the transformation when the data are weighted. A survey designed for 300% coverage is presented in Figure A4.

A3 - Presentation of DIP Data

The DIP data are usually presented as ASD curves plotted on a log depth scale as a function of station position. There is one ASD curve for each delay time and time zero. A reference level is plotted for each delay time which is a flat level, usually the arithmetic mean of the ASD at that delay time, or the ASD for a selected model (half-space). A shading scheme is used to accentuate the areas where the ASD deviates from the reference level (Figure A5). The ASD's may also be normalized to a selected

MEASURED
VERTICAL MAGNETIC
FIELD

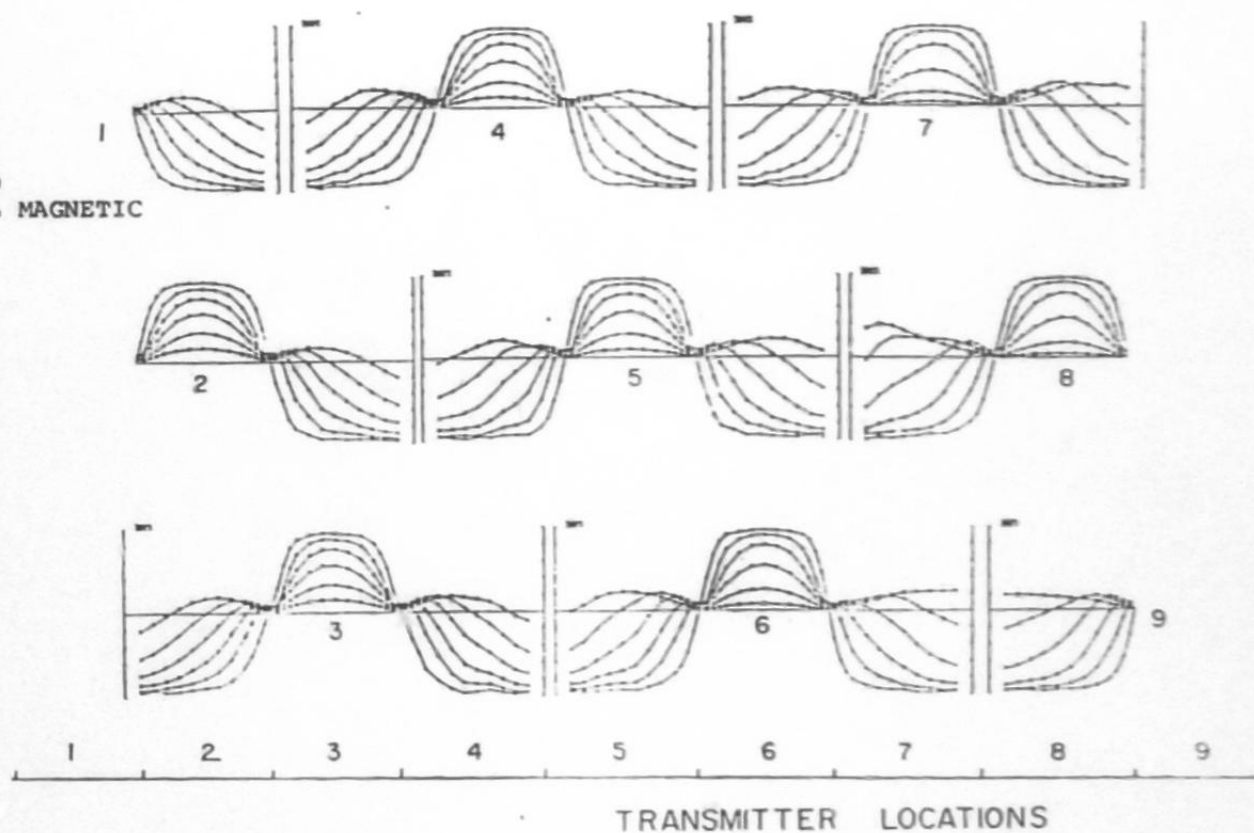


Figure A6 Early delay time data measured along a 3km profile. Each receiver station was occupied three times and data read from different transmitter loops as shown. The form of the vertical component UTEM response consists of a central positive over the transmitter loop, and a characteristic pattern of migrating crossovers outside the loop.

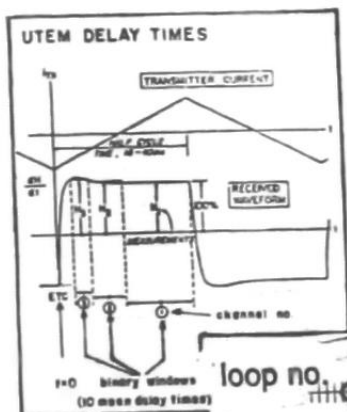
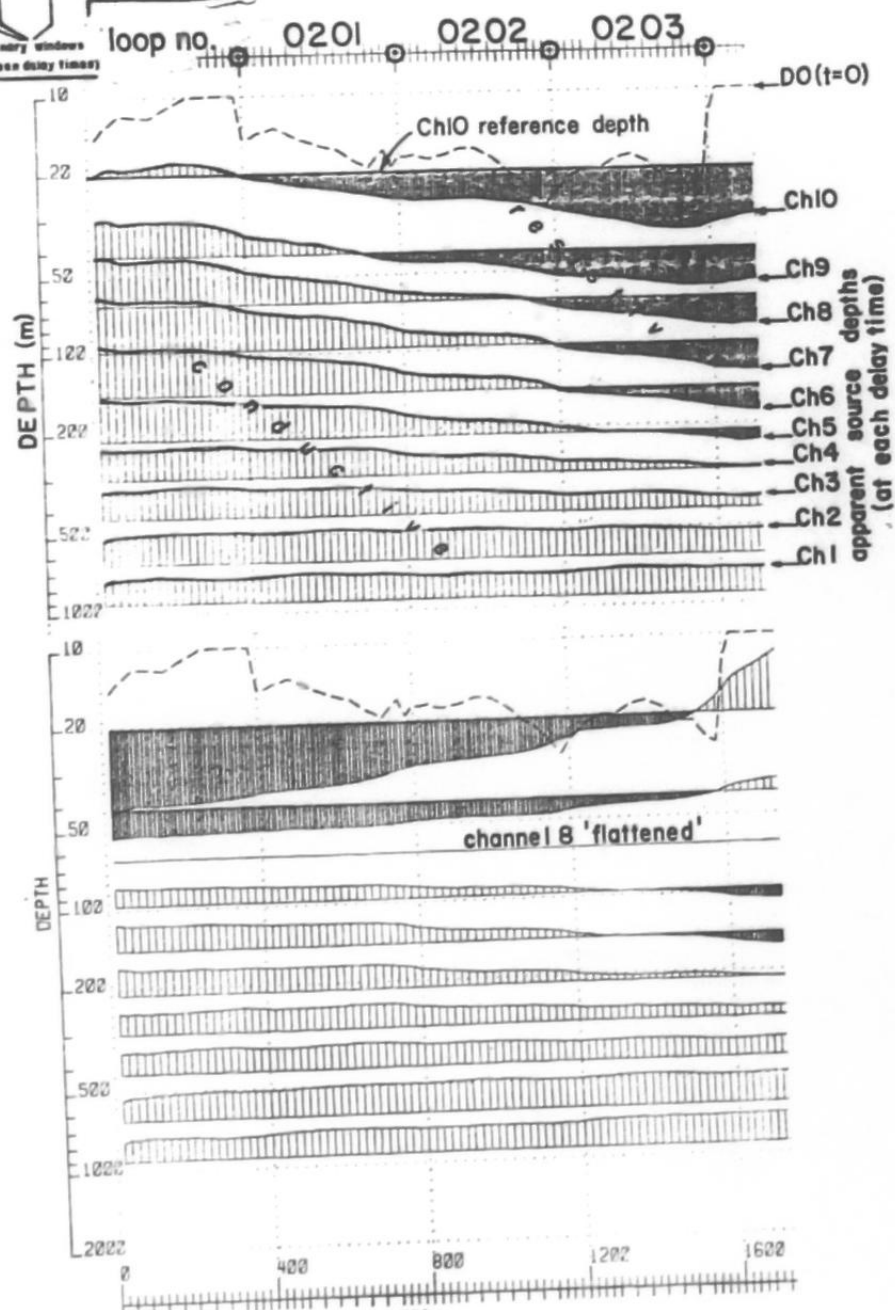


Figure A5 (top): Presentation of ASD data.

Figure A6 (bottom): Presentation of FASD data.

inset left : UTEM delay times.



ASD by shifting the time zero such that the selected ASD appears as a constant depth (Figure A6). This "flattening" technique effectively corrects the image cluster regression for any anomalous behaviour above the selected ASD.

A4 - A Comparison of EM Diffusion Slowness and Integrated Conductance

It was verified by numerical models that the slowness (inverse velocity) of the EM diffusion (approximated by the ASD) should be roughly proportional to the integrated conductance. In Figure A7 this is well illustrated. The plot of log (integrated conductance) vs log (depth) and the plot of log (slowness) vs log (depth) are virtually the same except for a constant factor of about $\sqrt{2}$. The behaviour is observed over a broad range of layered earth models. This implies that the slowness of EM diffusion (estimated by ASD's) may be used to determine the conductivity structure of the ground.

A5 - Estimation of Conductivity (Resistivity) vs Depth Using DIP Data

As illustrated above, the slowness of EM diffusion into a layered earth is directly proportional to the integrated conductance of the layered earth and, furthermore, that the constant of proportionality is approximately $\sqrt{2}$. This may be stated as:

$$\frac{dt}{dD} = \sqrt{2} \int_0^D \sigma \mu_0 dD'$$

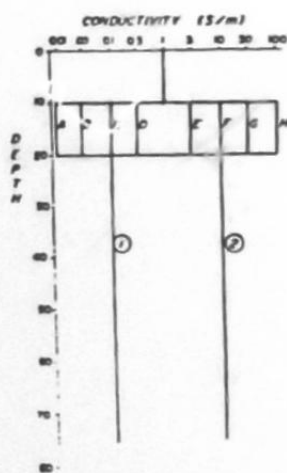
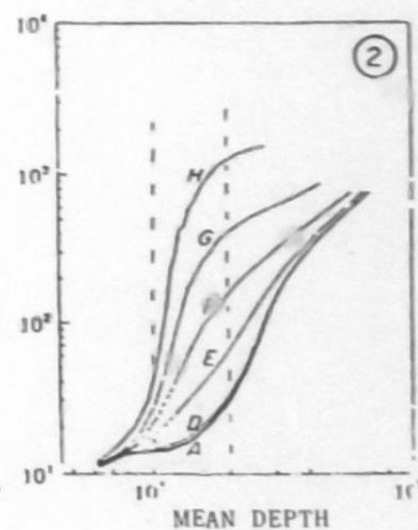
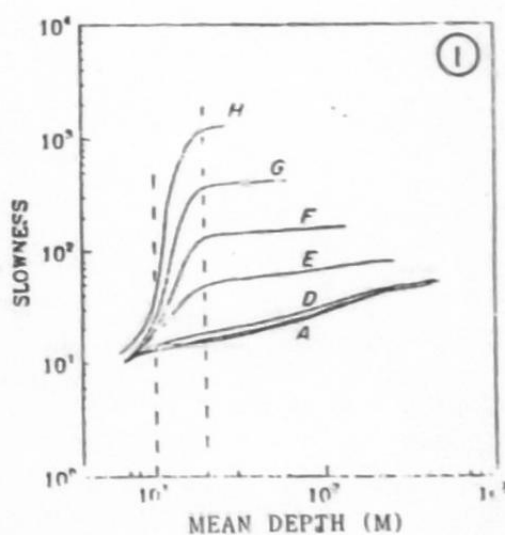
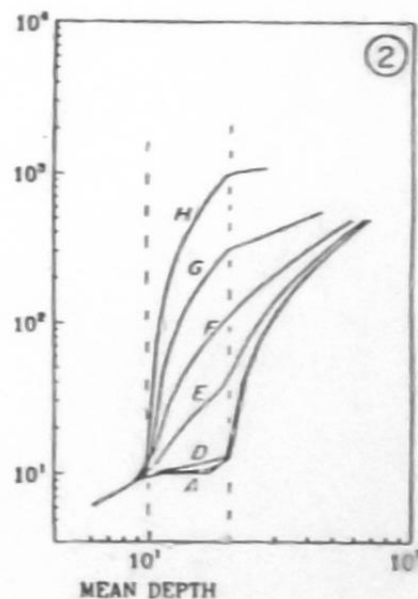
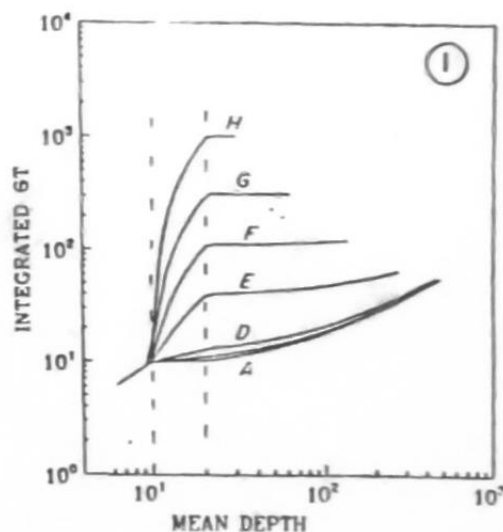


FIGURE A7: Conductivity-depth structure of a 3 layer model, with variable second layer conductivity. At the upper right the same models are presented in a log(integrated conductance)-log(depth) format. The lower curves present the results of fitting image distributions to calculated secondary magnetic fields as a function of time over the layered earth models specified above. At each fitted depth the slowness of the downward current migration is estimated by $\Delta t/\Delta d$ using the time and depth differences between successive channels. The slowness is of course just the inverse velocity of the downward diffusion of current into the earth.



where D is the apparent depth of diffusion. Therefore, the apparent conductivity at any given depth may be estimated as:

$$\sigma_a = \frac{1}{\sqrt{4\mu_0}} \frac{d^2 t}{dD^2}$$

In practice, the second derivative is estimated using a spline operator. Figures A8, A9 and A10 illustrate the ability of the method to predict the original model for three cases.

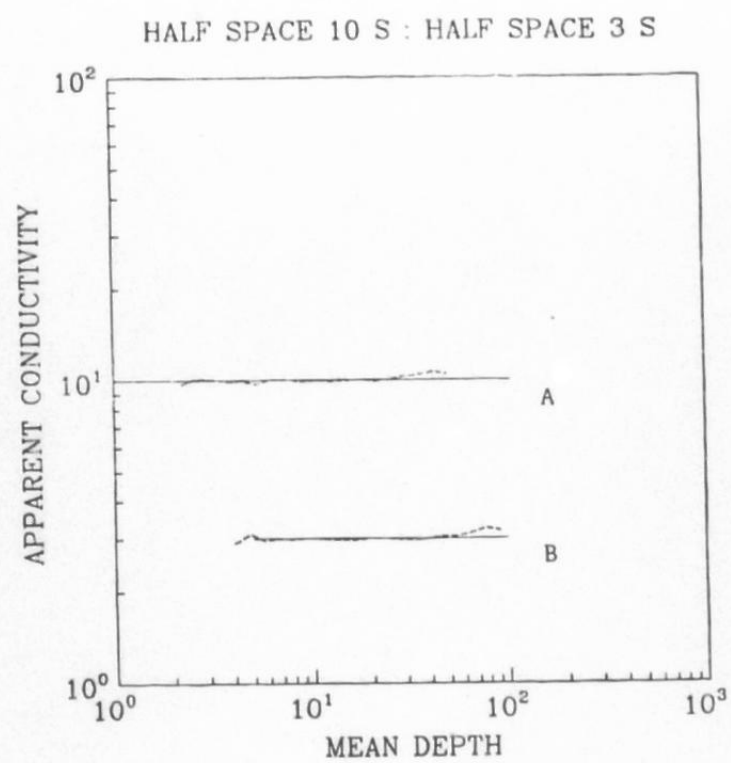
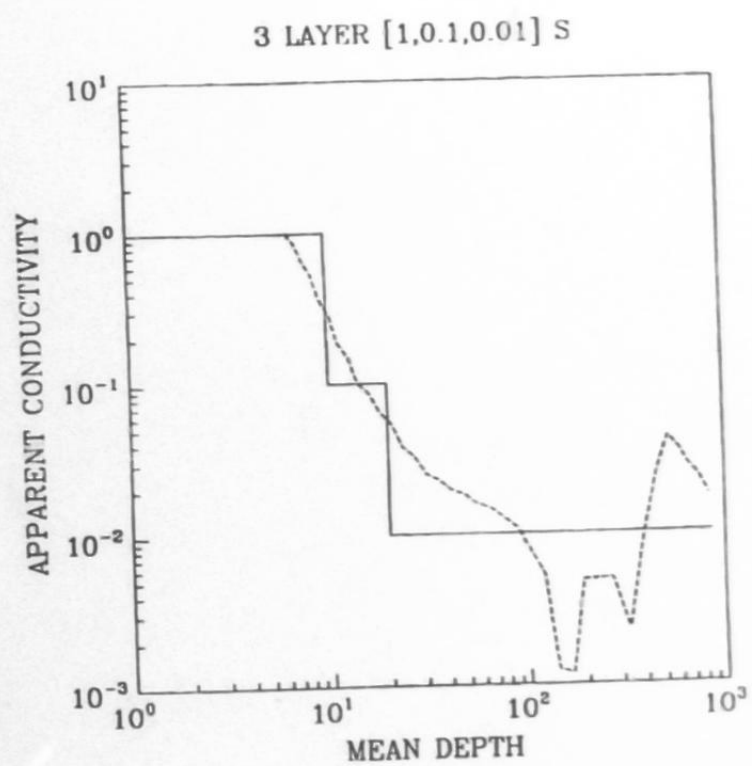
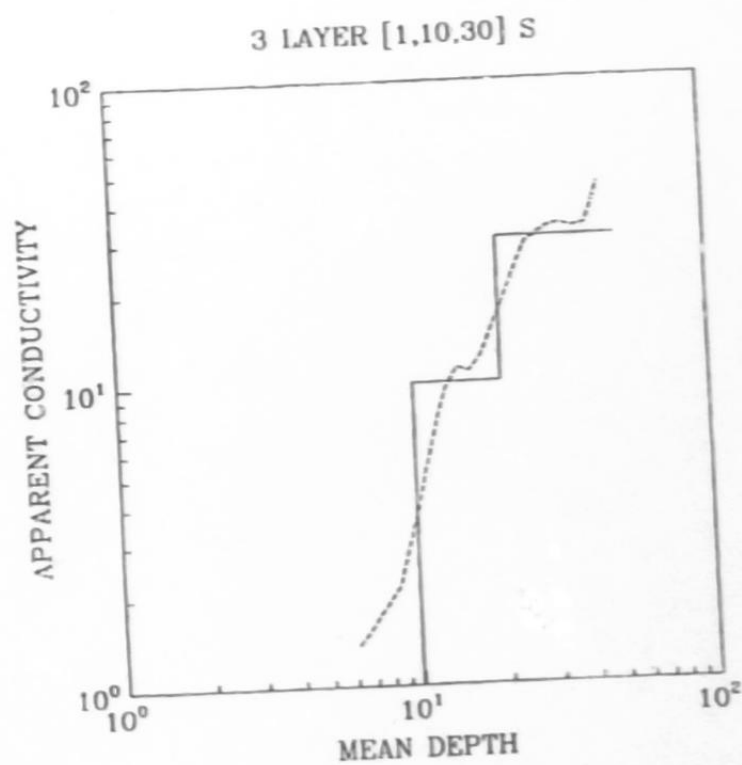


Figure A8: STAC sections from model data
A) 10S half-space, B) 3S half-space.

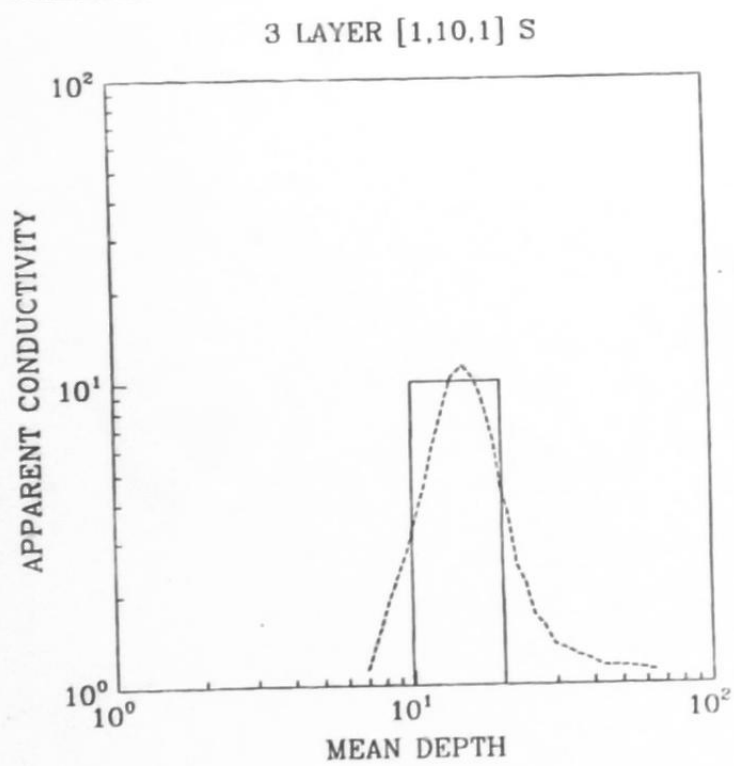


(B) Decreasing conductivity with depth.

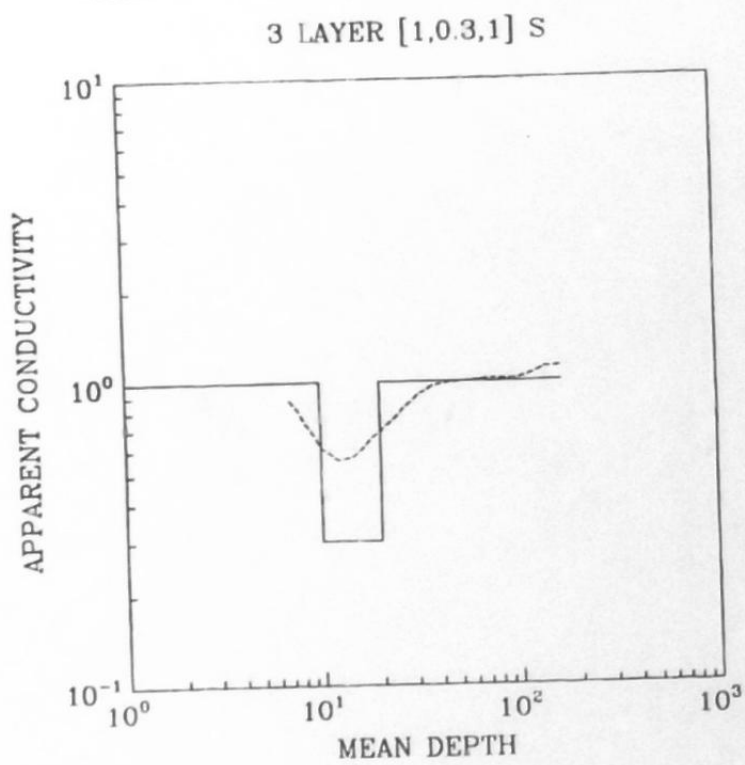


(A) Increasing conductivity with depth.

Figure A9: STAC sections from model data. Increase and decrease of conductivity with depth.



(A) A conductive layer.

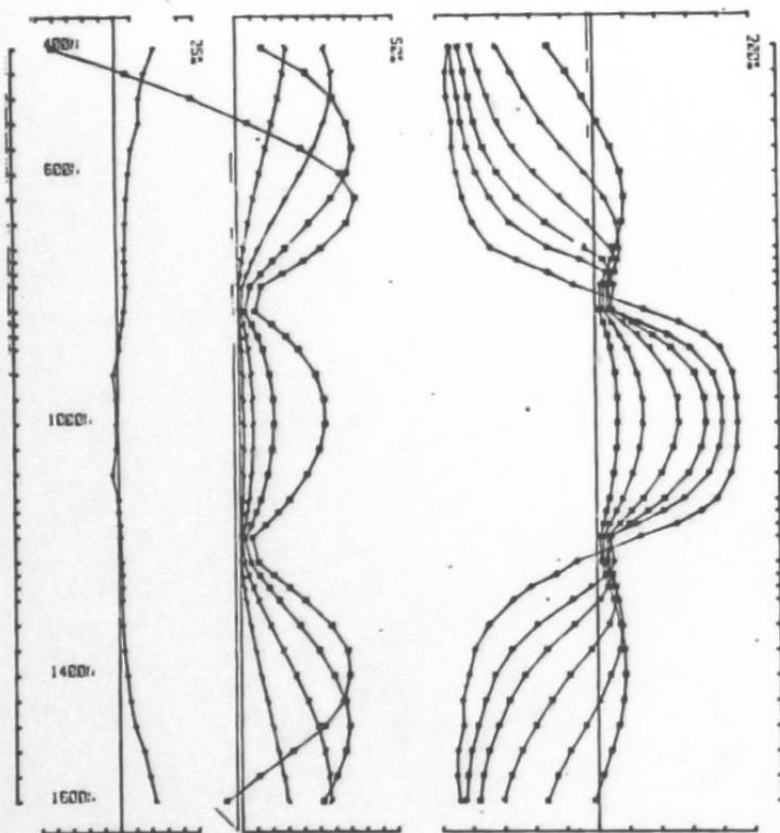


(B) A resistive layer.

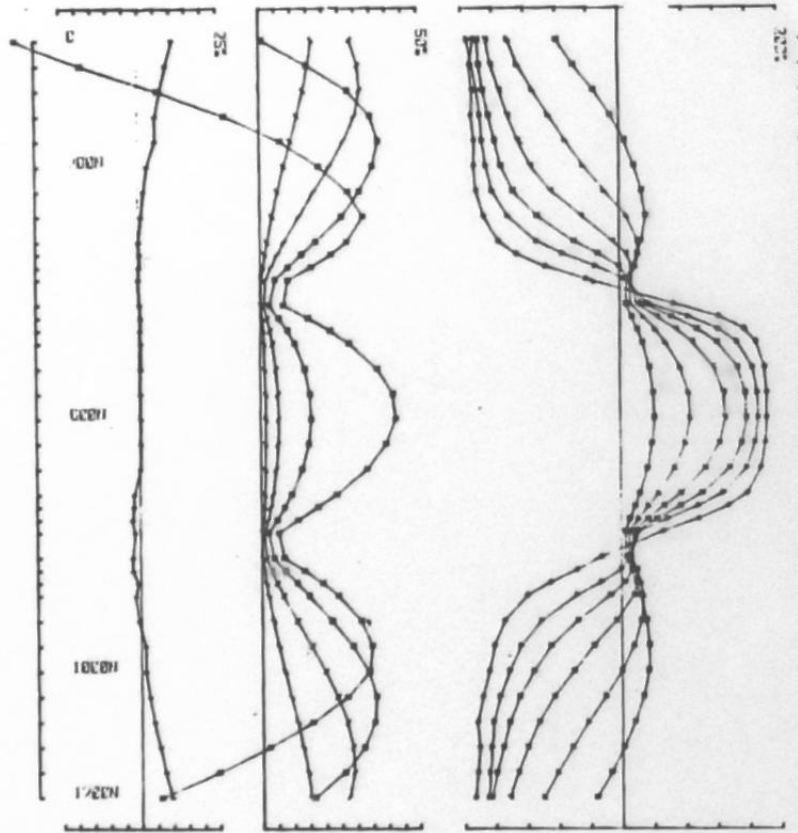
Figure A10: STAC sections from model data. Isolated layers.

APPENDIX B
APPARENT SOURCE DEPTH (ASD) AND
FLATTENED APPARENT SOURCE DEPTH (FASD) SECTIONS

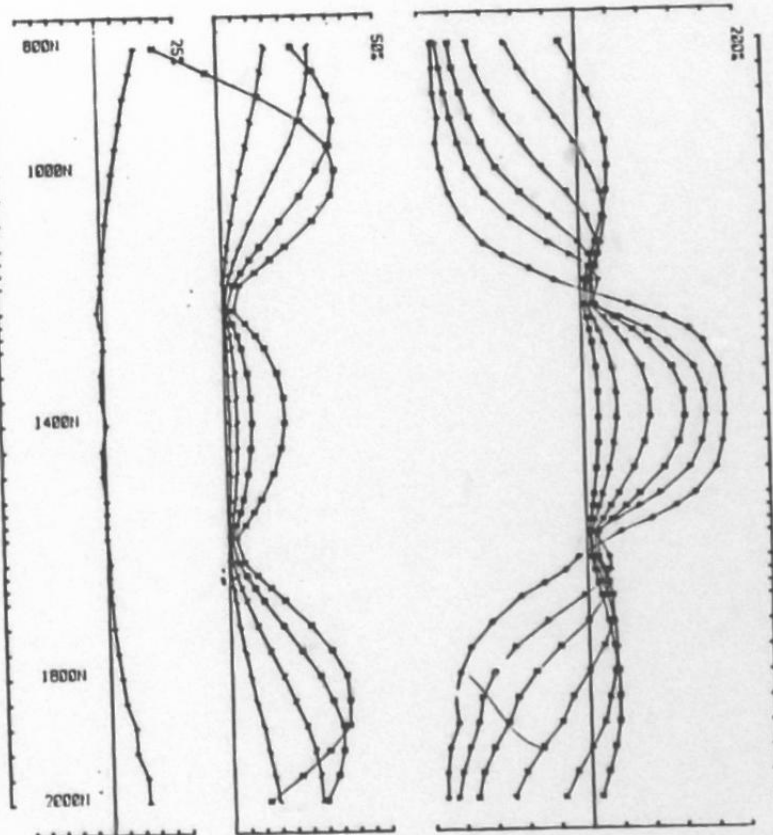
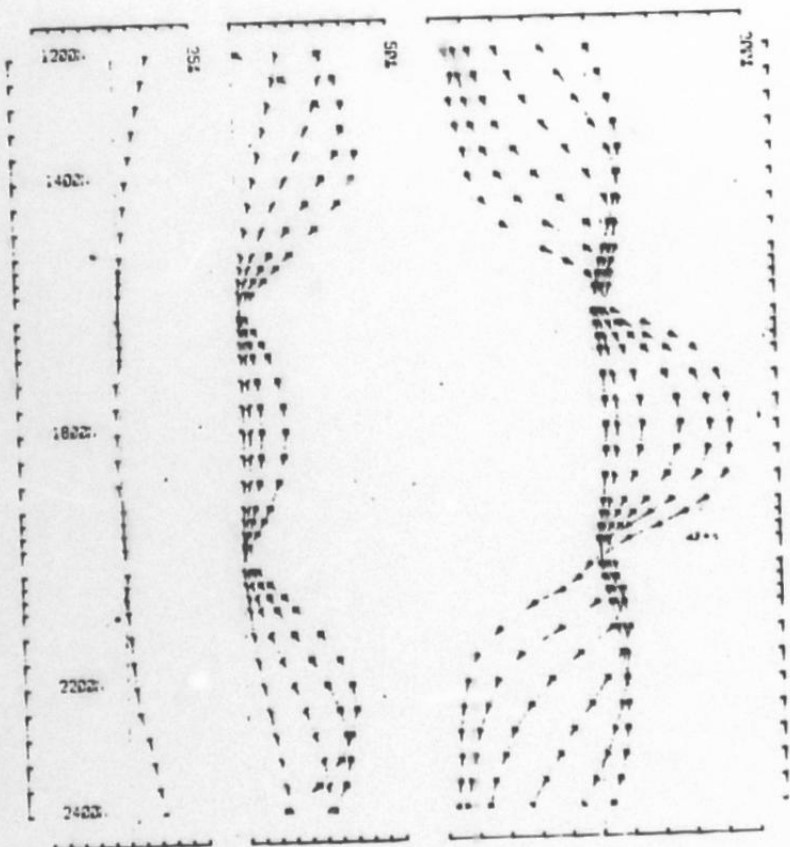
APPENDIX D
CONVENTIONALLY PRESENTED UTEM DATA



UTEM SURVEY conducted by LAMONTAGNE GEOPHYSICS Job 4007
 Project Area PA-ITOU LAKE Survey for BP (Fractal) 30.9/4
 Loop 0202 Line H component H_z secondary Ch 1

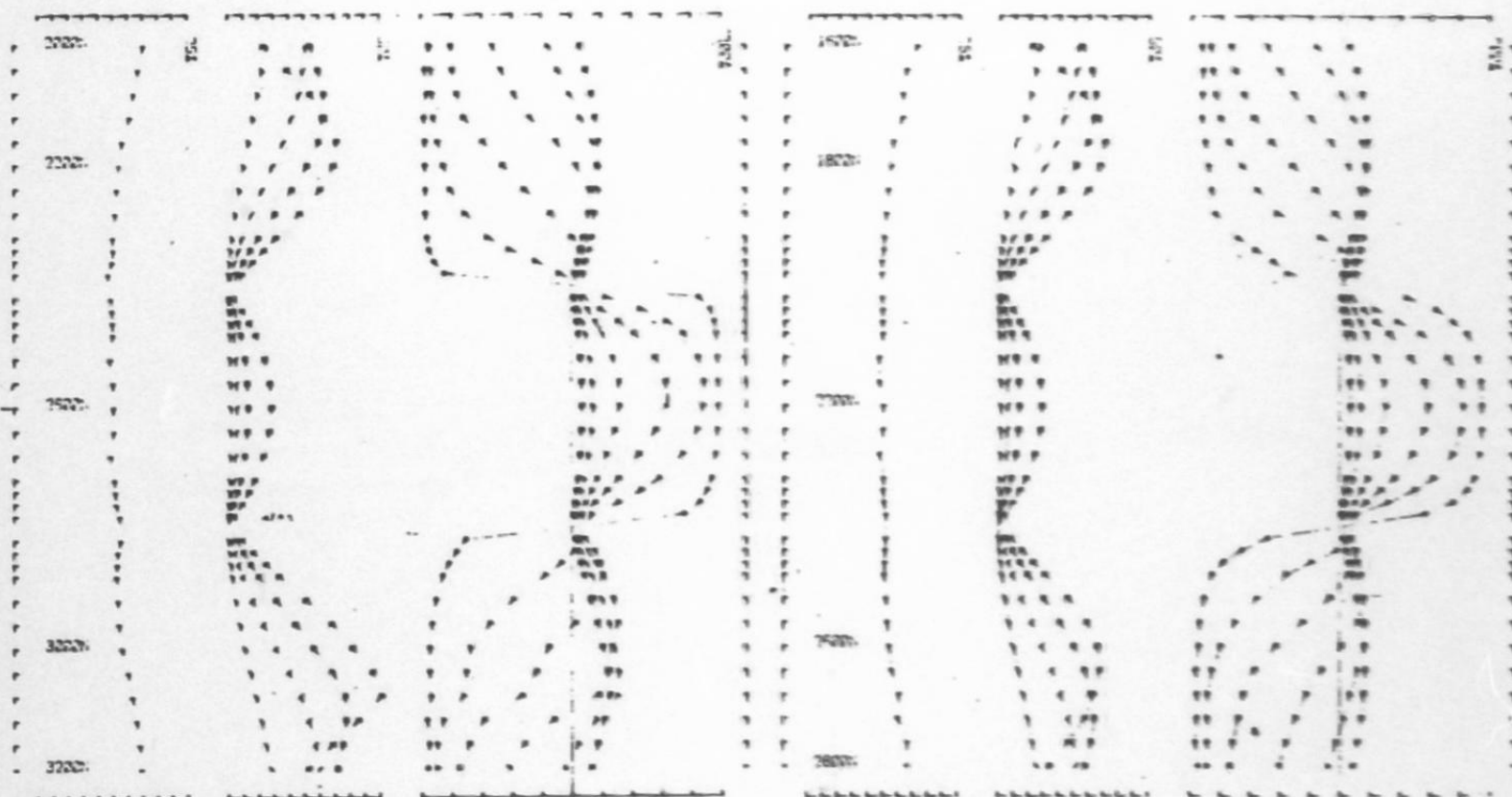


UTEM SURVEY conducted by LAMONTAGNE GEOPHYSICS Job 4007
 Project Area PA-ITOU LAKE Survey for BP (Fractal) 30.9/4
 Loop 0201 Line H component H_z secondary Ch 1



UTEM SURVEY conducted by LAMONTAGNE GEOPHYSICS Job 4002
 Project Area MANTILL LAKE Survey for BP (treasure) 30.574
 Loop 0224 Line 0 component Hz secondary Ch 1

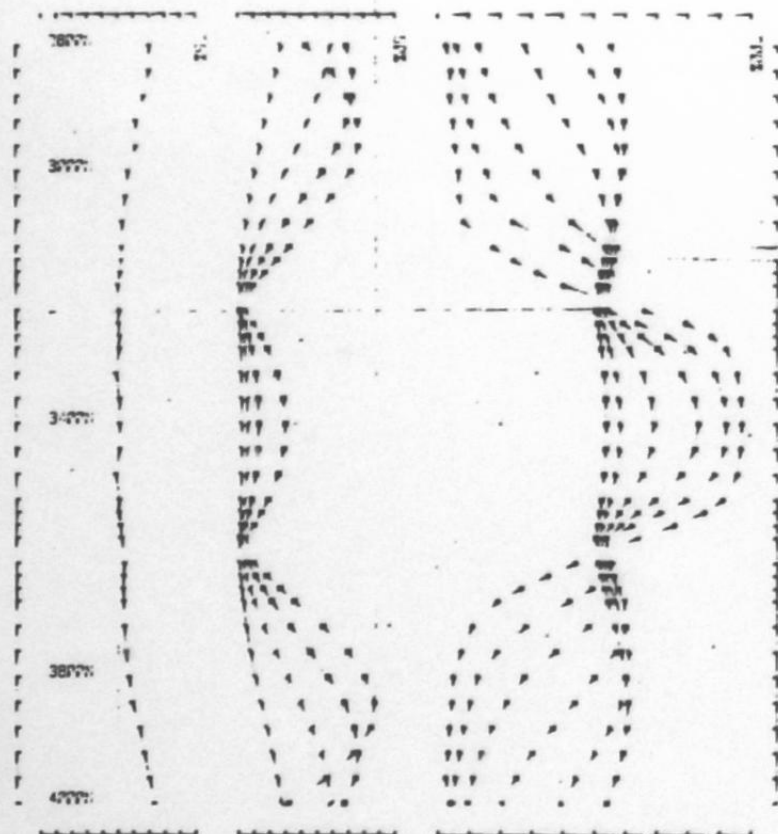
UTEM SURVEY conducted by LAMONTAGNE GEOPHYSICS Job 4002
 Project Area MANTILL LAKE Survey for BP (treasure) 30.574
 Loop 0703 Line A component Hz secondary Ch 1



UTER SURVEY conducted by LAMONTAGUE GEOPHYSICS Job 4202
Project Area: MONTAGUE LAKE Survey for

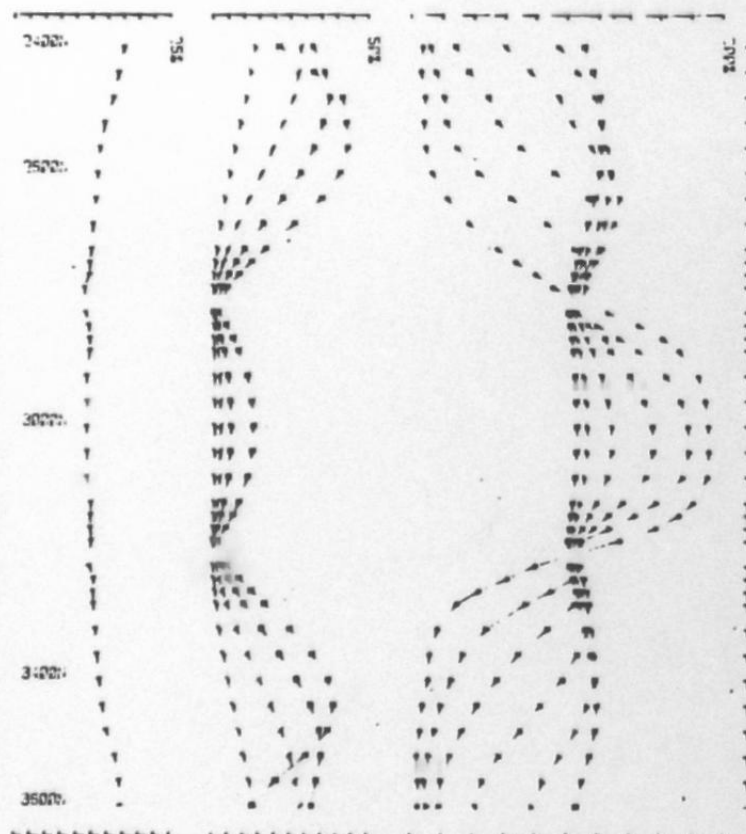
900

UTER SURVEY conducted by LAMONTAGUE GEOPHYSICS Job 4202
Project Area: MONTAGUE LAKE Survey for 500 (approx) 100, 500
Location: PSC Line 2 component 100 secondary Ch 1



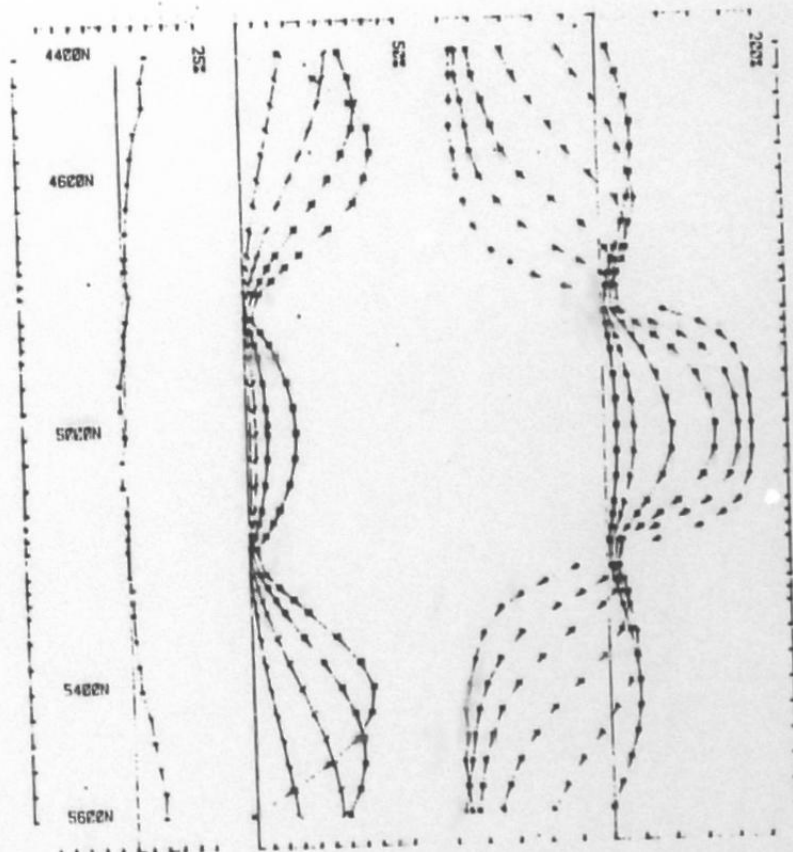
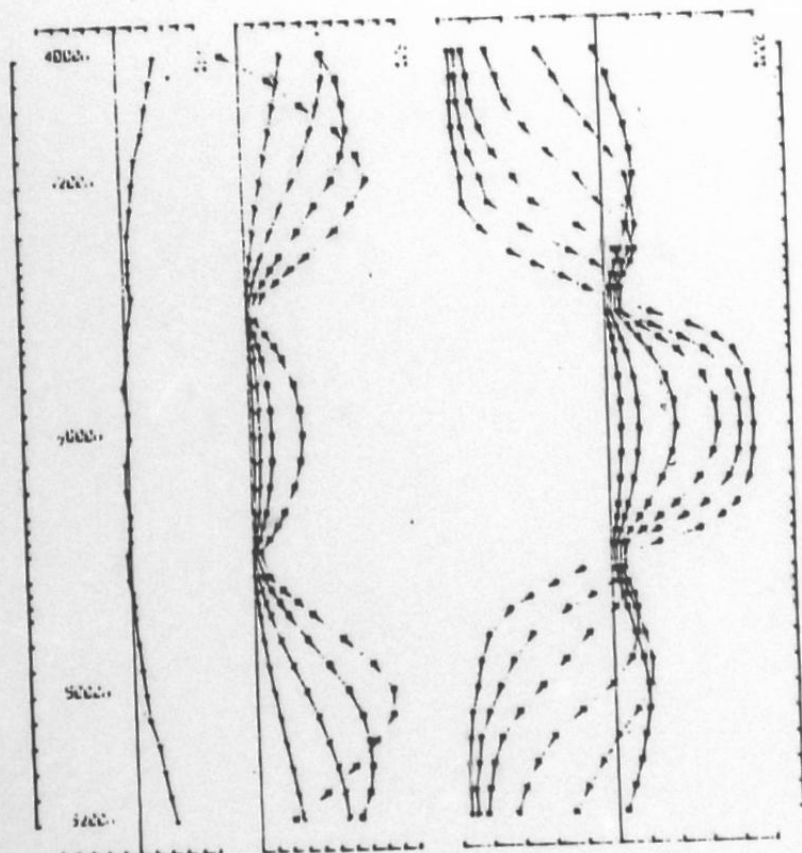
UTEX SURVEY conducted by LAMONTAGNE GEOPHYSICS Job 4000
Project Area PRUITT LAKE Survey for 0100

0100



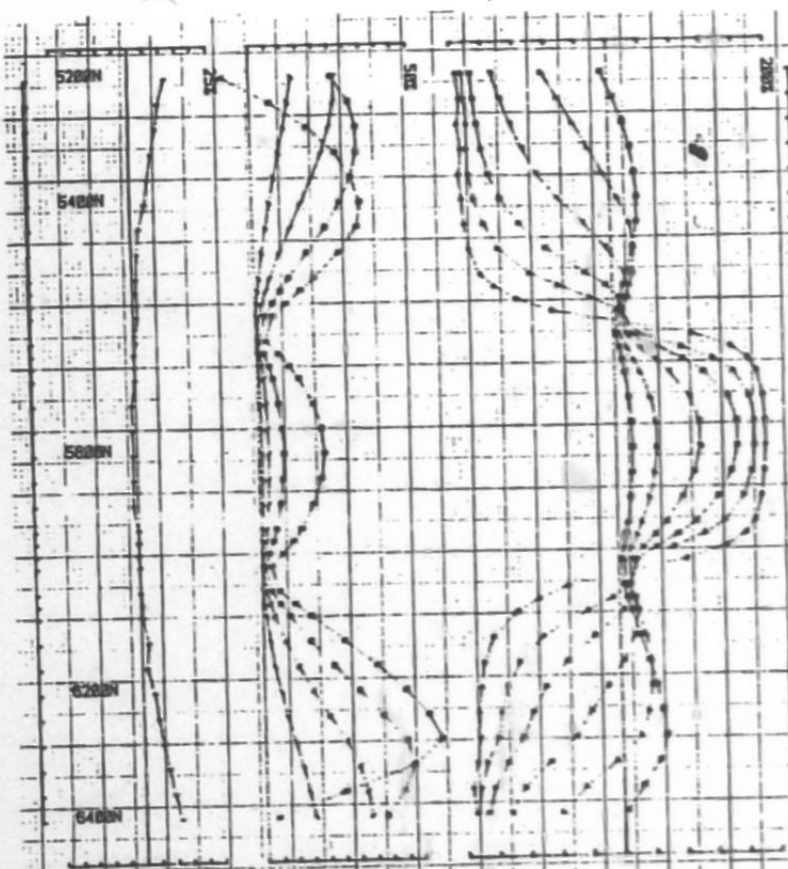
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Project Area PRUITT LAKE Survey for 0100

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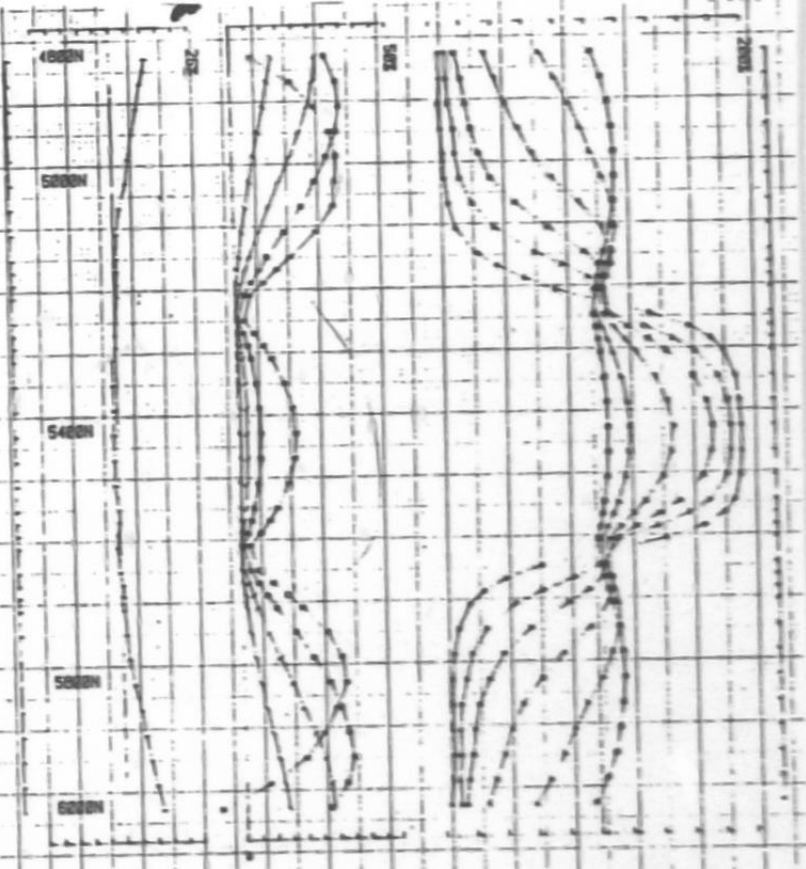


UTAH SURVEY conducted by LAMONTAGNE GEOPHYSICS Job 4782
 Project Area MANITOU LAKE Survey for BP Fractals 38,074
 Loop 0212 Line A component Hz secondary Ch 1

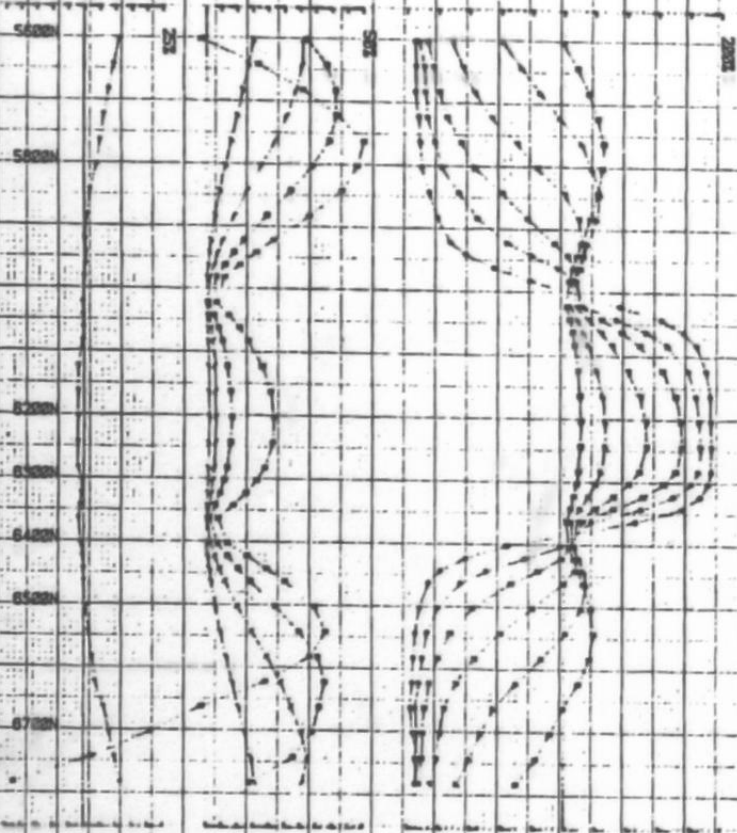
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 Project Area MANITOU LAKE Survey for BP Fractals 38,074
 Loop 0212 Line A component Hz secondary Ch 1



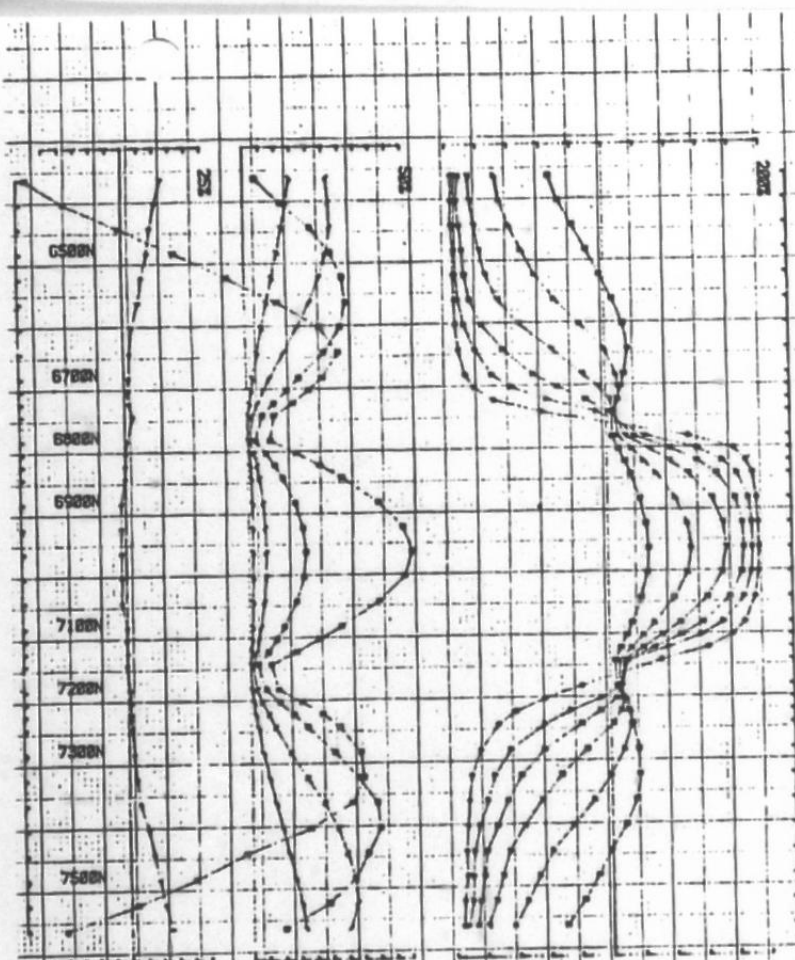
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 Project Area: MONTICLOSA LAKE Survey for: BP - Finalist 38,974
 Location: E214 Line A component Hz secondary Ch 1



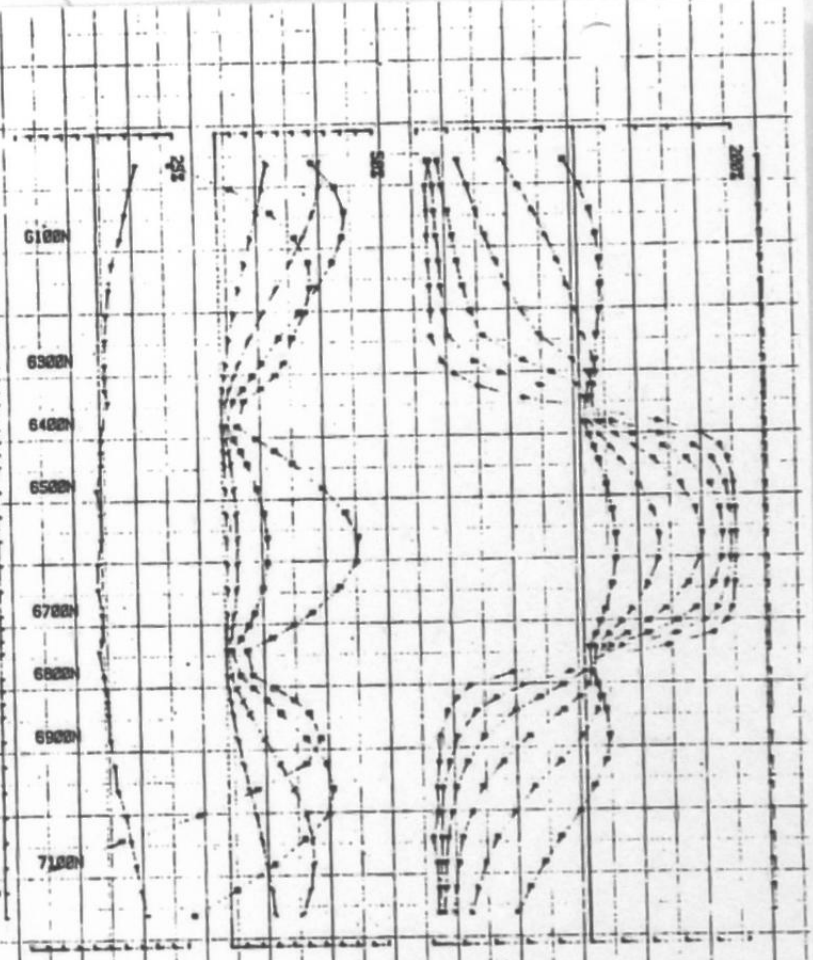
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 Project Area: MONTICLOSA LAKE Survey for: BP - Finalist 38,974
 Location: E213 Line A component Hz secondary Ch 1



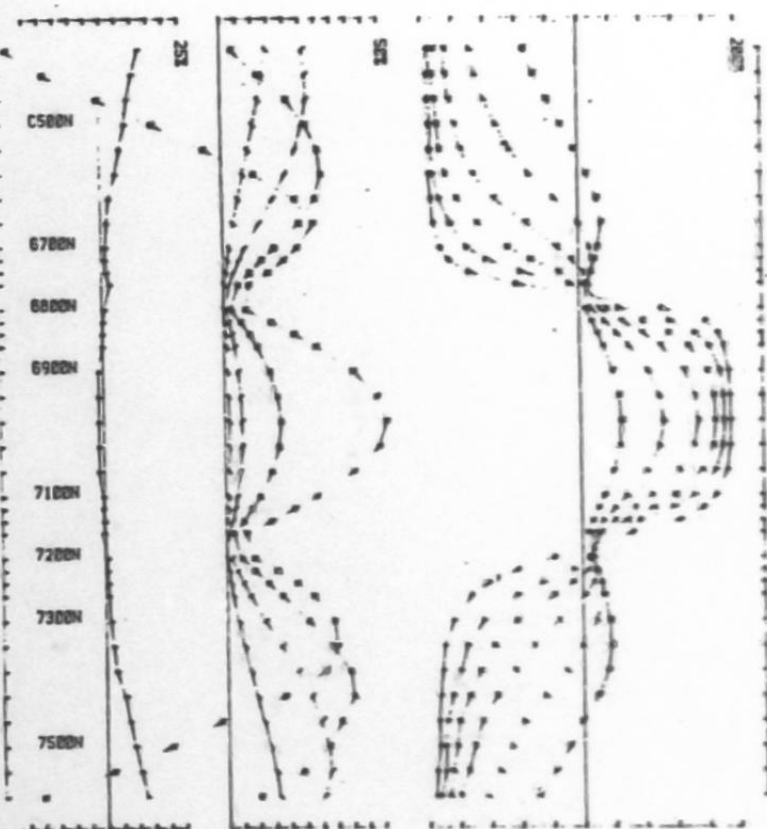
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Project Area: MANITOU LAKE Survey for BP, Fracture 38.974
Lapse: 8215 Line A - component H_z secondary On 1



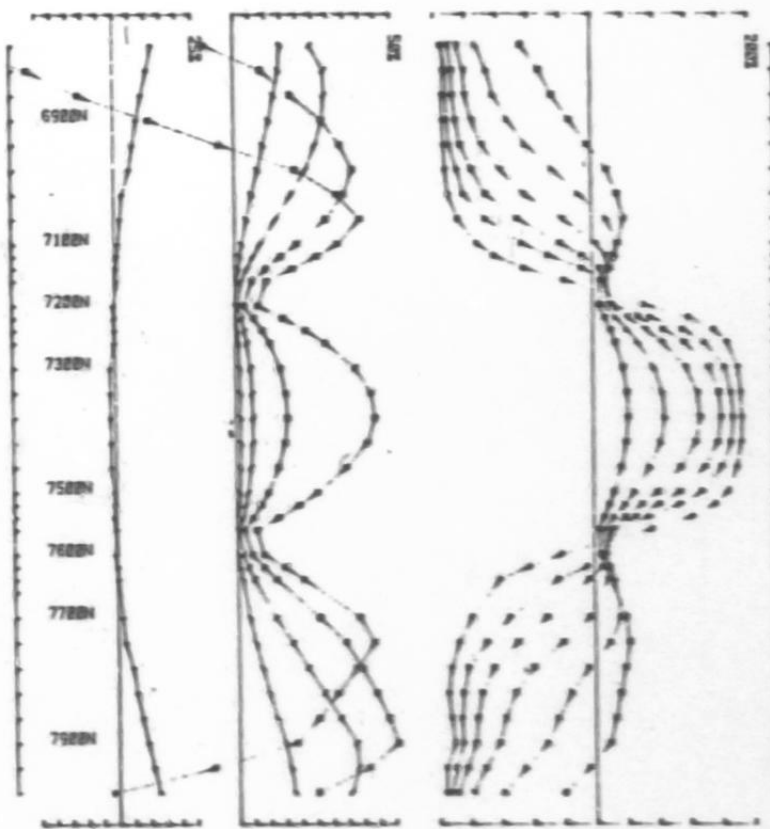
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 Project Area MANITOU LAKE Survey for BP frequency 38.974
 Line 0217 Line R component Hz secondary Ch 1



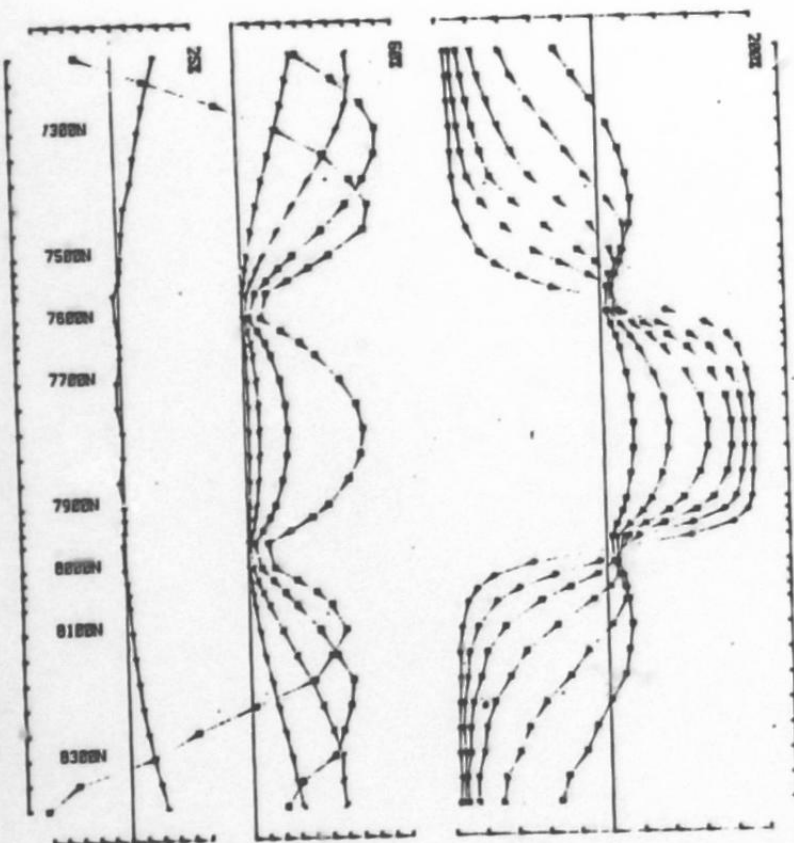
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 Line 0216 Line R component Hz secondary Ch 1



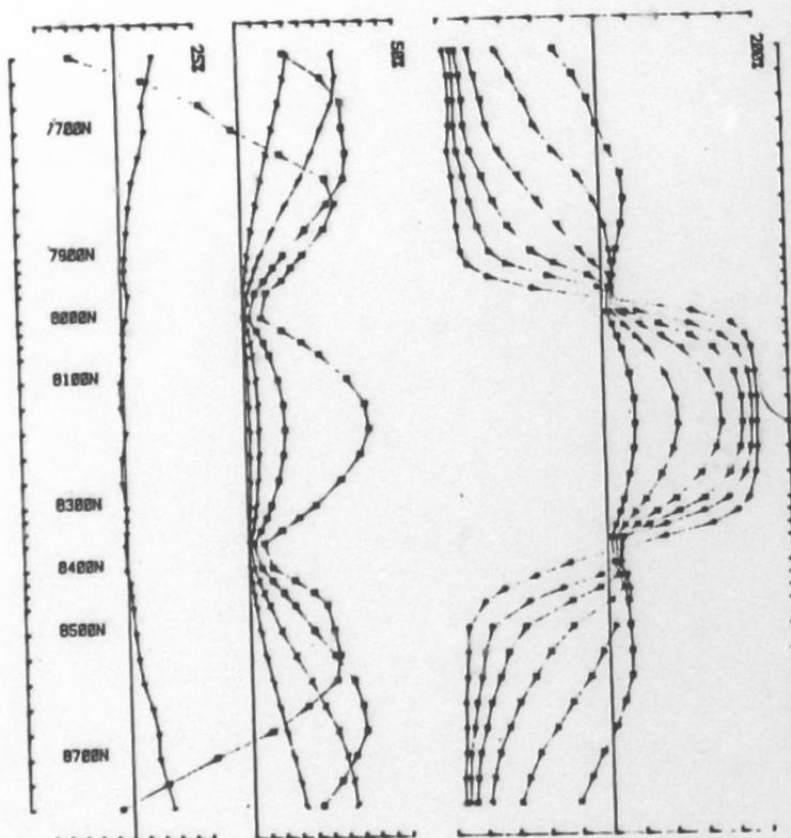
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 Project Area HANITOU LAKE Survey for BP final 3C-9-4
 Lapins 0217 Line R component Hz secondary Ch 1



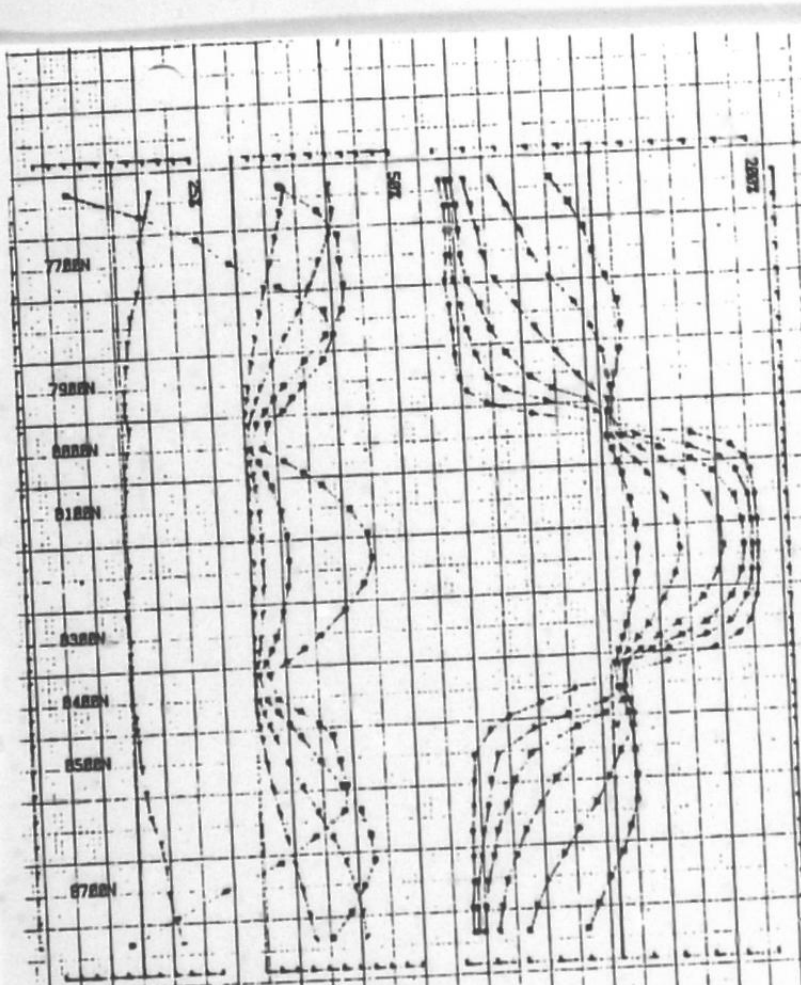
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 Project Area HANITOU LAKE Survey for BP final 3C-9-4
 Lapins 0218 Line R component Hz secondary Ch 1



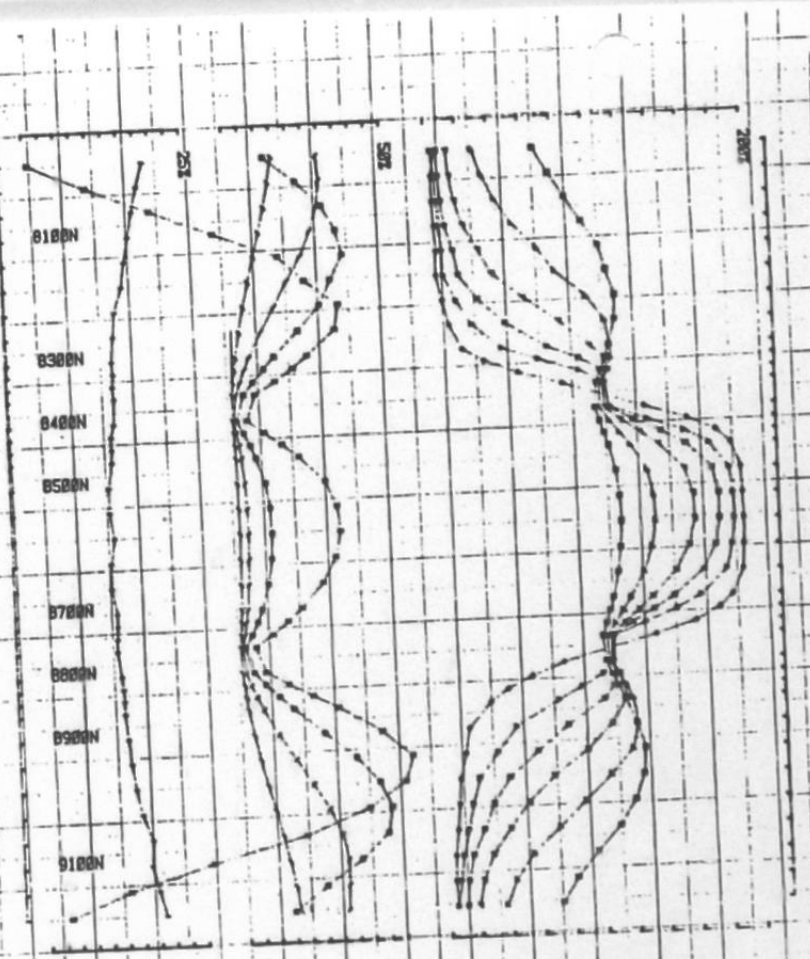
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 Project Area MANITOU LAKE Survey for BP fractional 38.974
 Loop 0219 Line A component - Hz secondary Ch 1



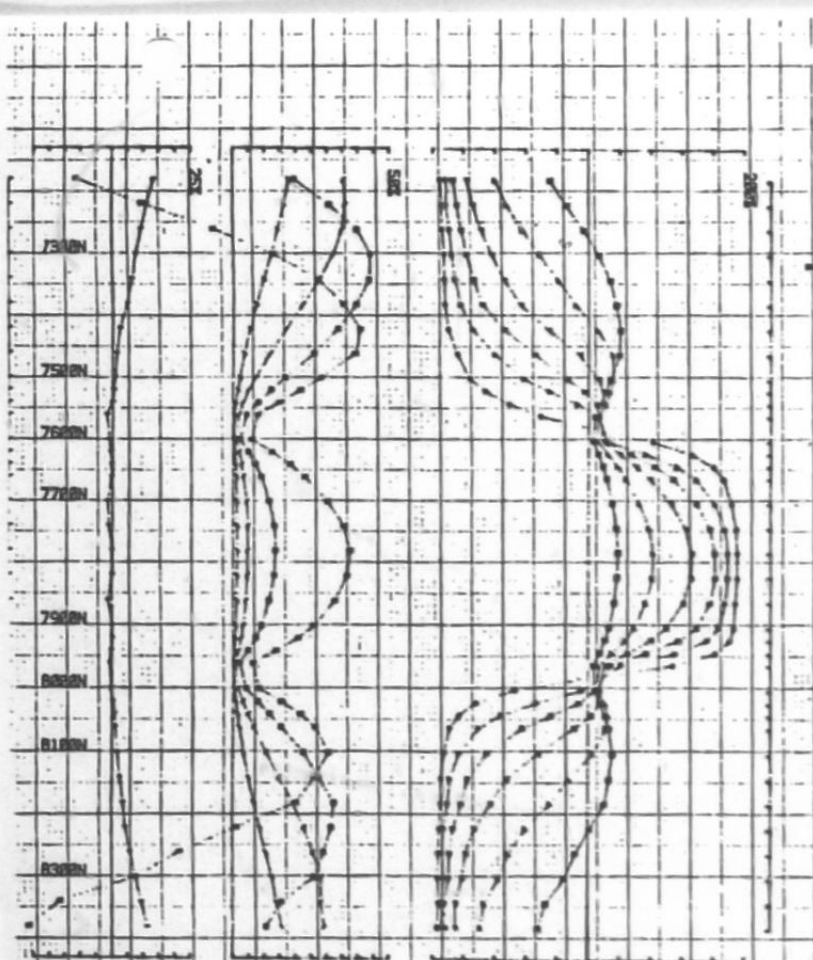
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 Project Area MANITOU LAKE Survey for BP fractional 38.974
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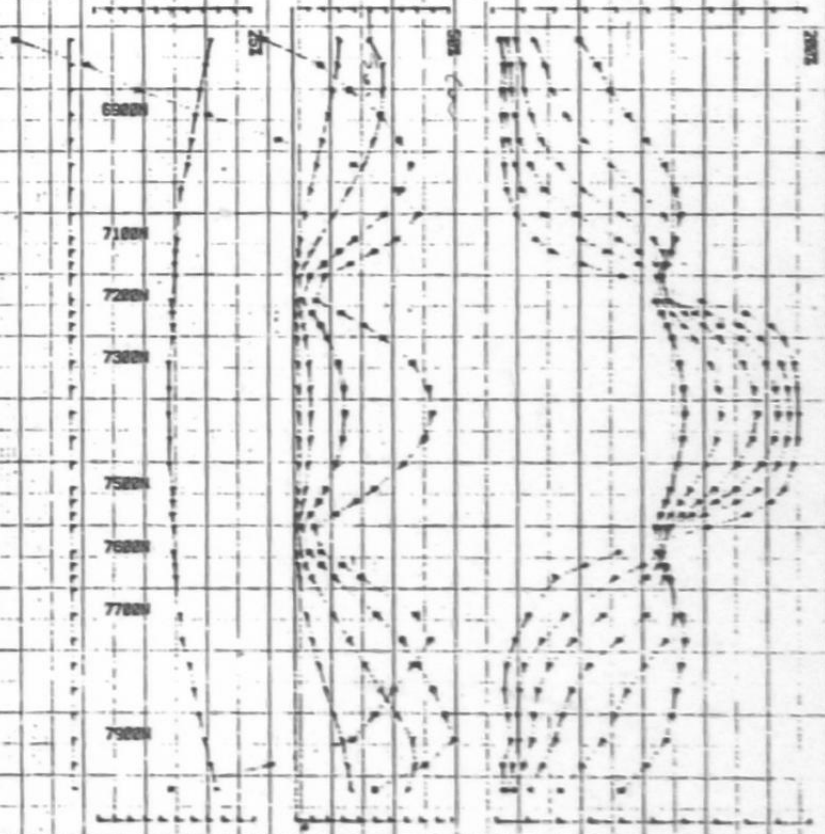
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 Project Area MANITOULAKE Survey for BF frequency 38.974
 Loop 822B Line A component Hz secondary Ch 1



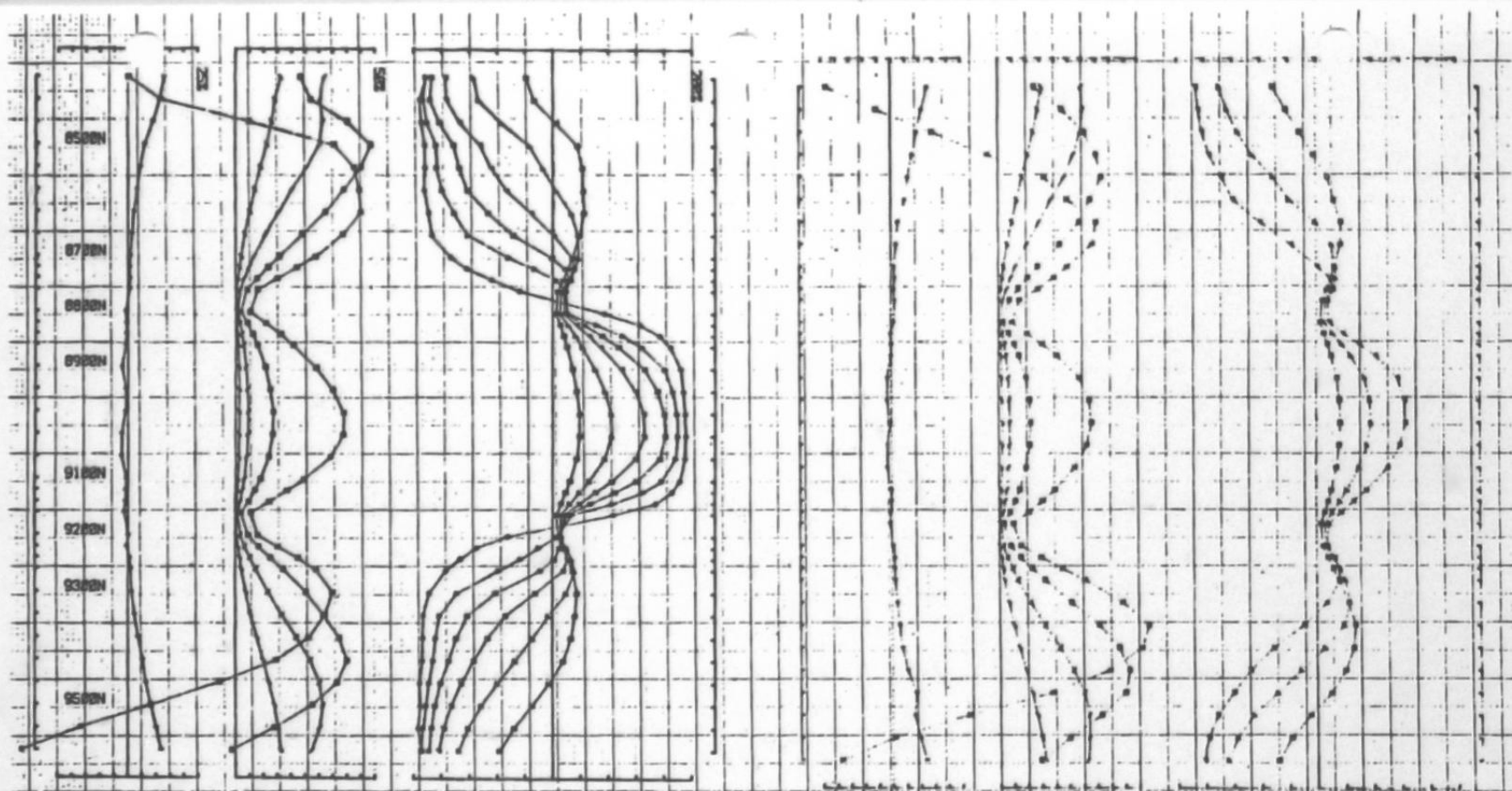
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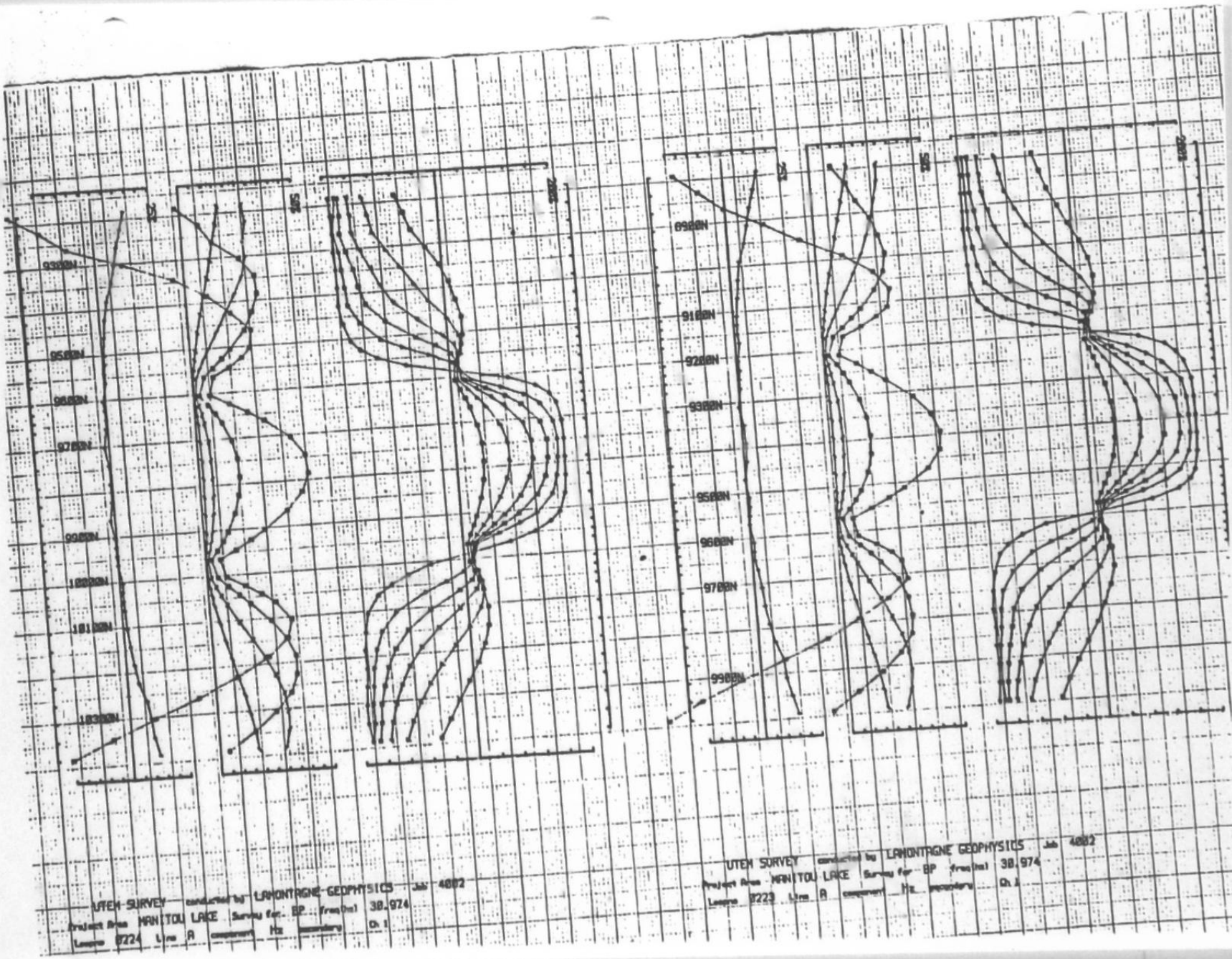
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 Project Area MANITOULAKE Survey for BP fractal 38.974
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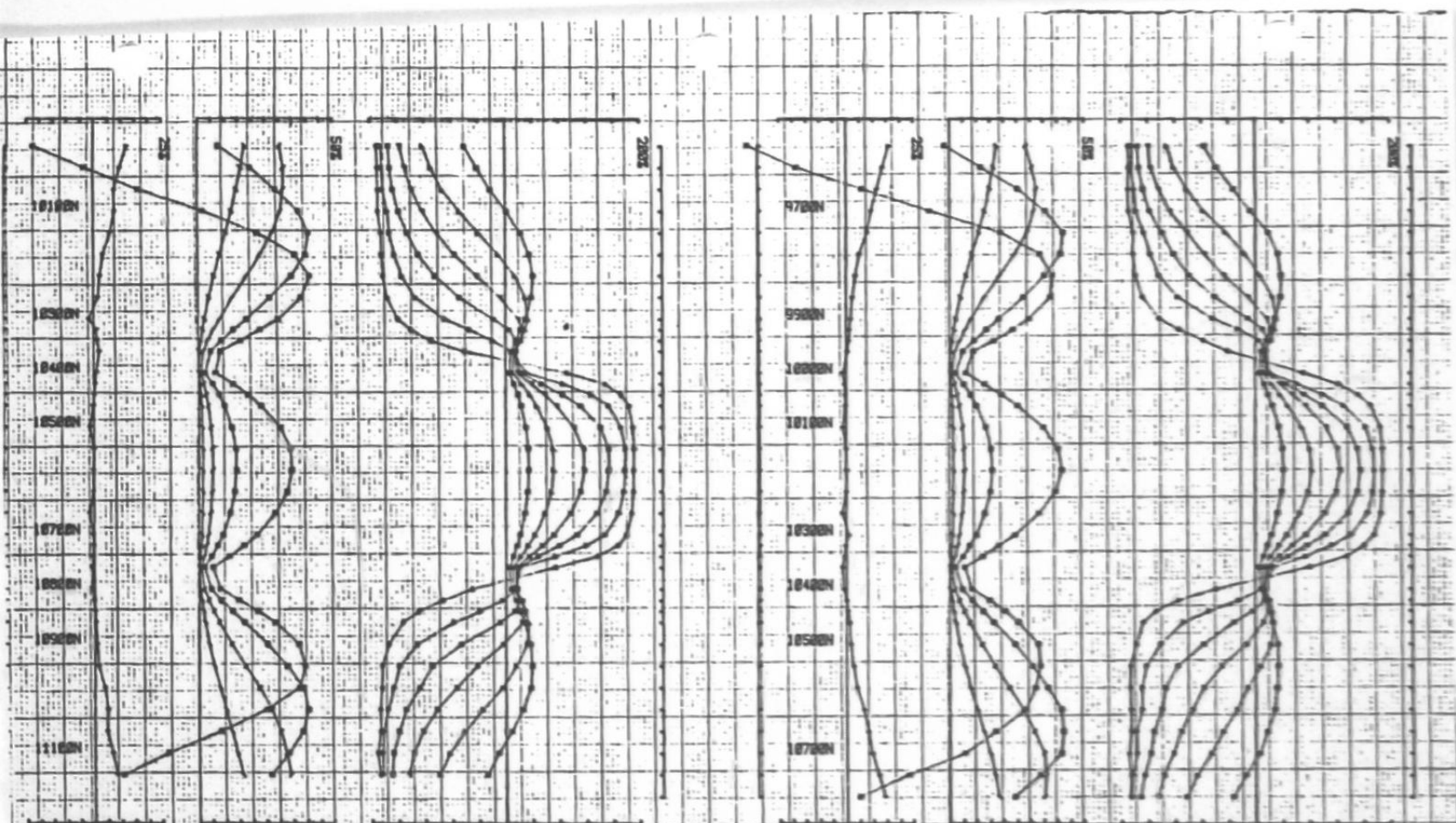


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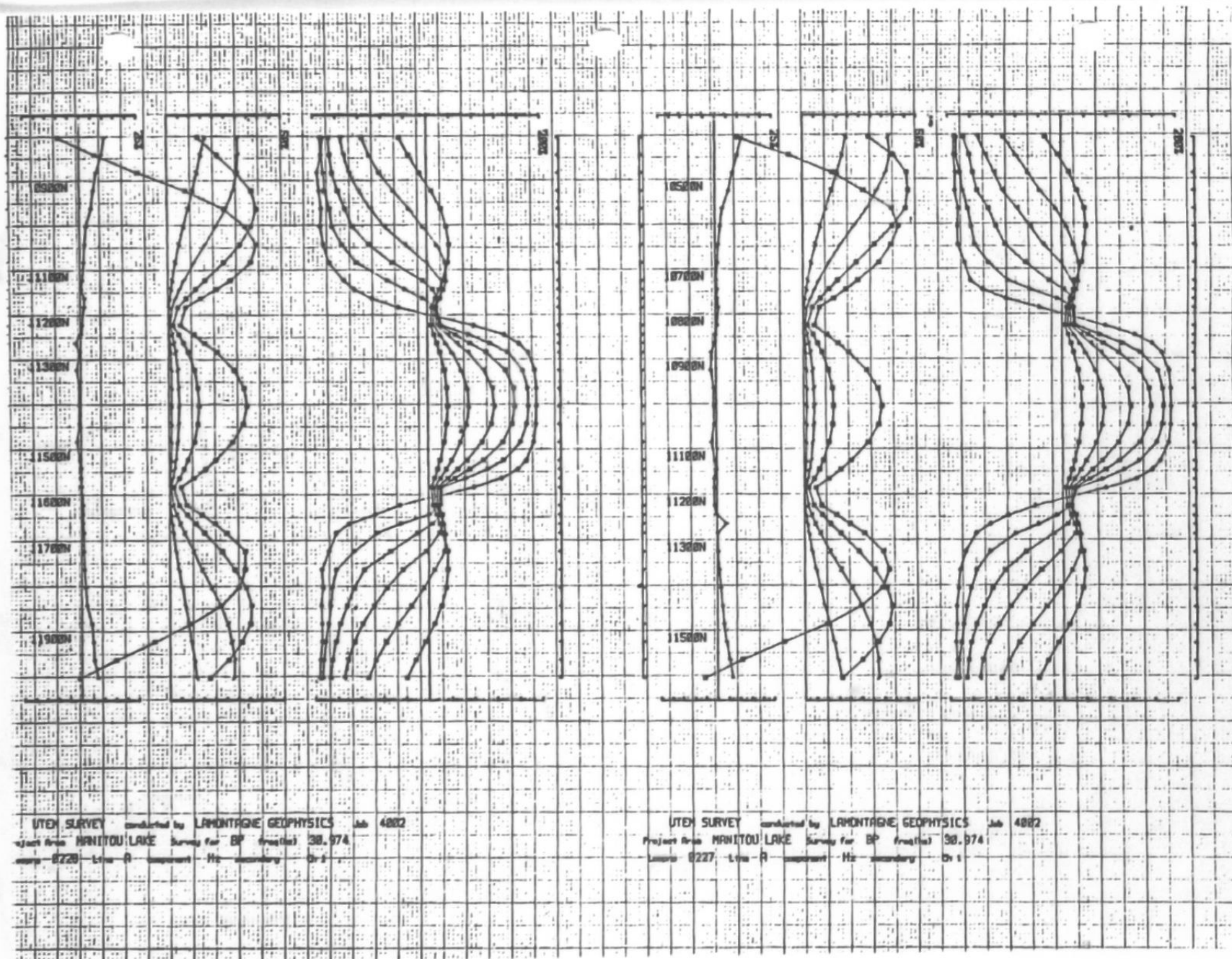
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 Lines 0222 Line A constant Hz anomaly Ch 1

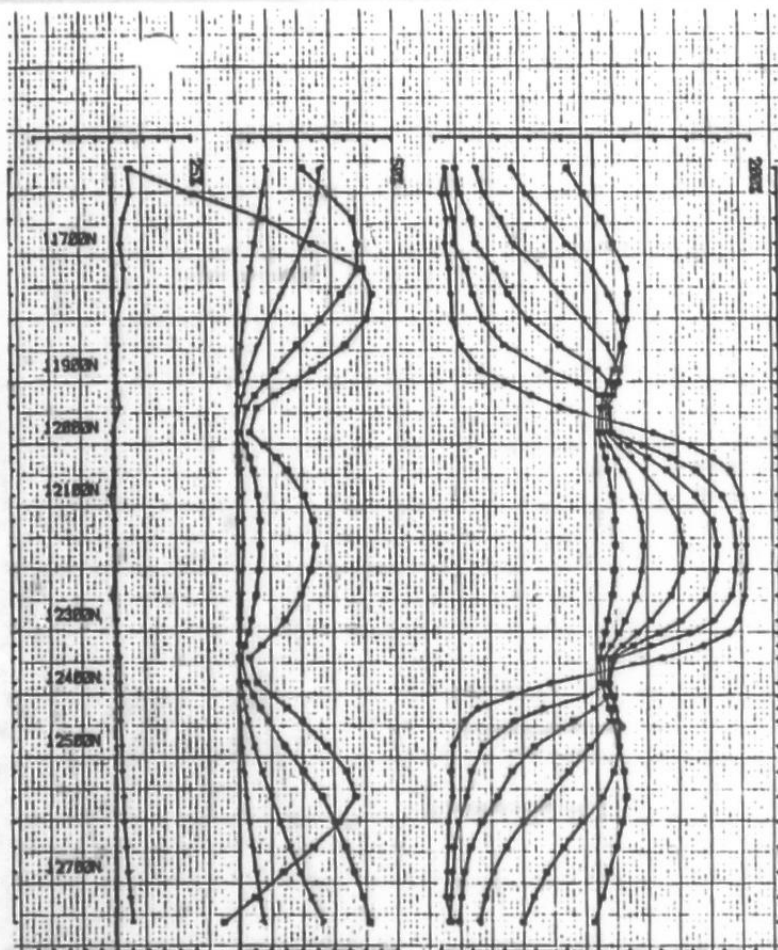




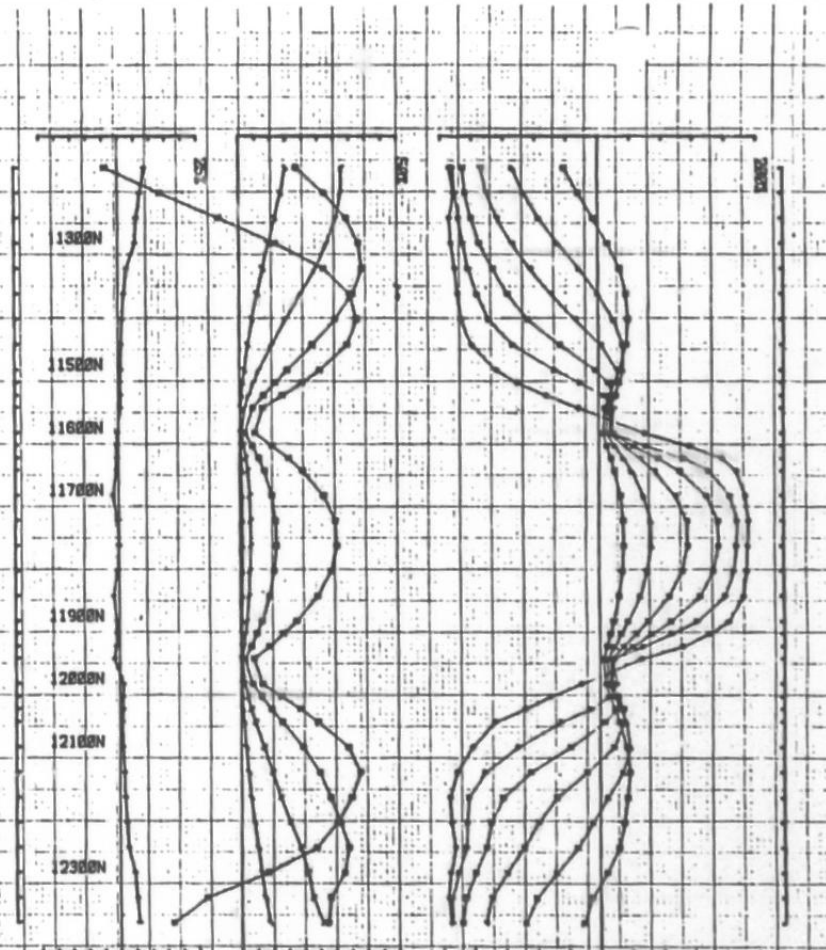
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 start @ 8:00 AM MONTELLA LAKE Survey for BP Fracture 30.974
 Loop 8225 Line A segment Hs secondary Ch 1

UTAH SURVEY conducted by LAMONTAGNE GEOPHYSICS Job 4882
 Project Area MONTELLA LAKE Survey for BP Fracture 30.974
 Loop 8225 Line A segment Hs secondary Ch 1

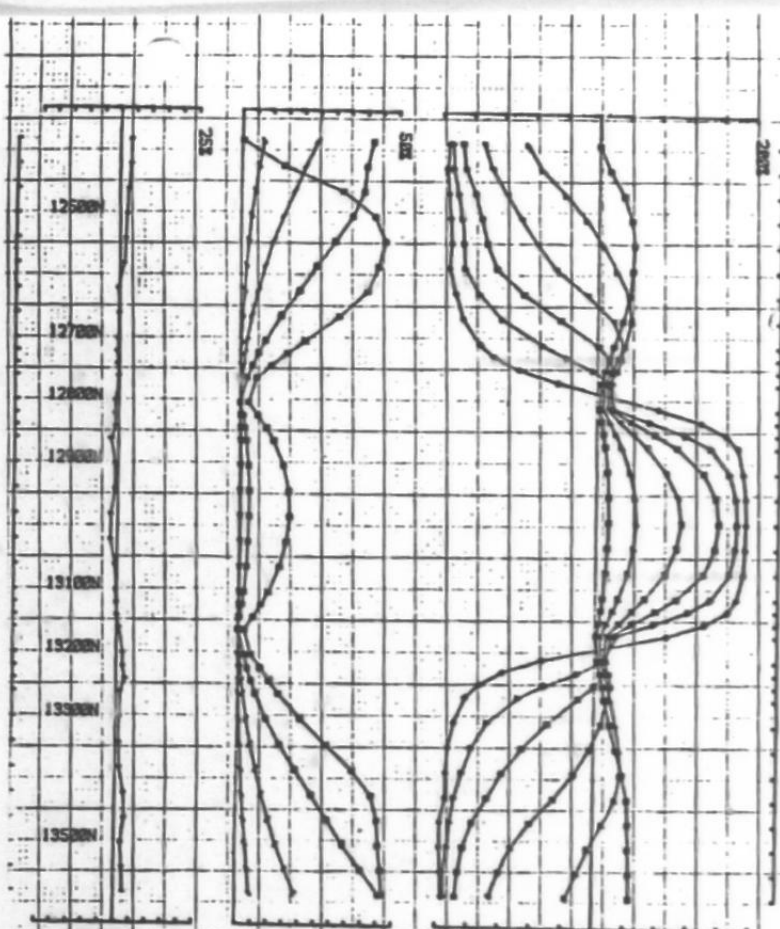




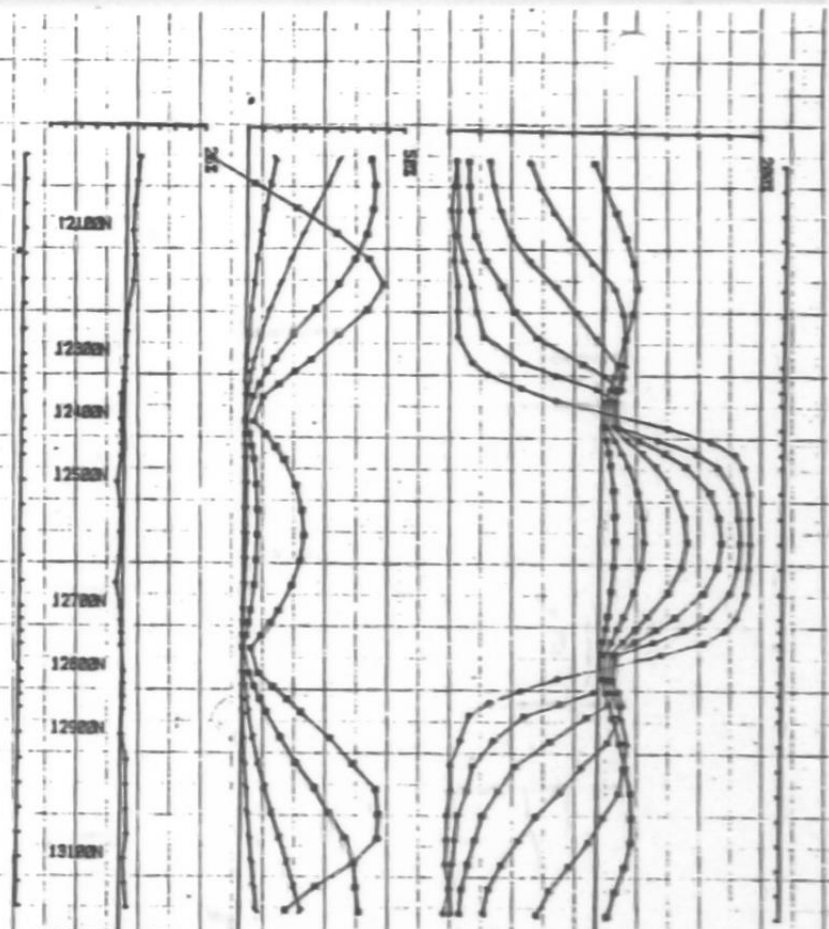
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 Project Area: HANITOU LAKE Survey for BP (total) 38.974
 Line: 0228 Line A Instrument: Hz secondary Ch. 1



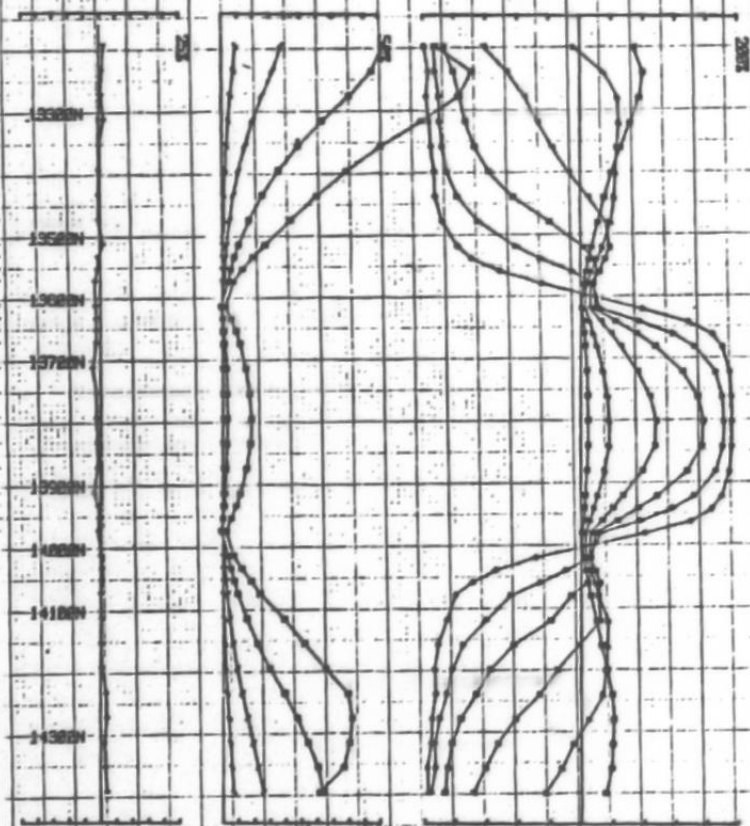
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 Project Area: HANITOU LAKE Survey for BP (total) 38.974
 Line: 0229 Line A Instrument: Hz secondary Ch. 1



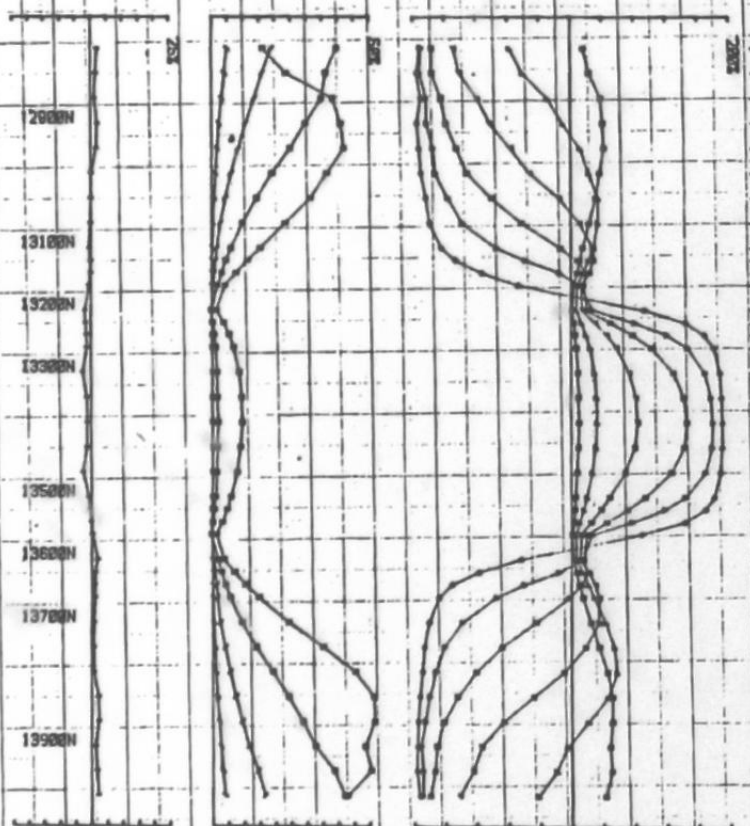
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 Project Area HANITOU LAKE Survey for BP Fractals 38,974
 Line 8232 Line A component Hz secondary Ch 1



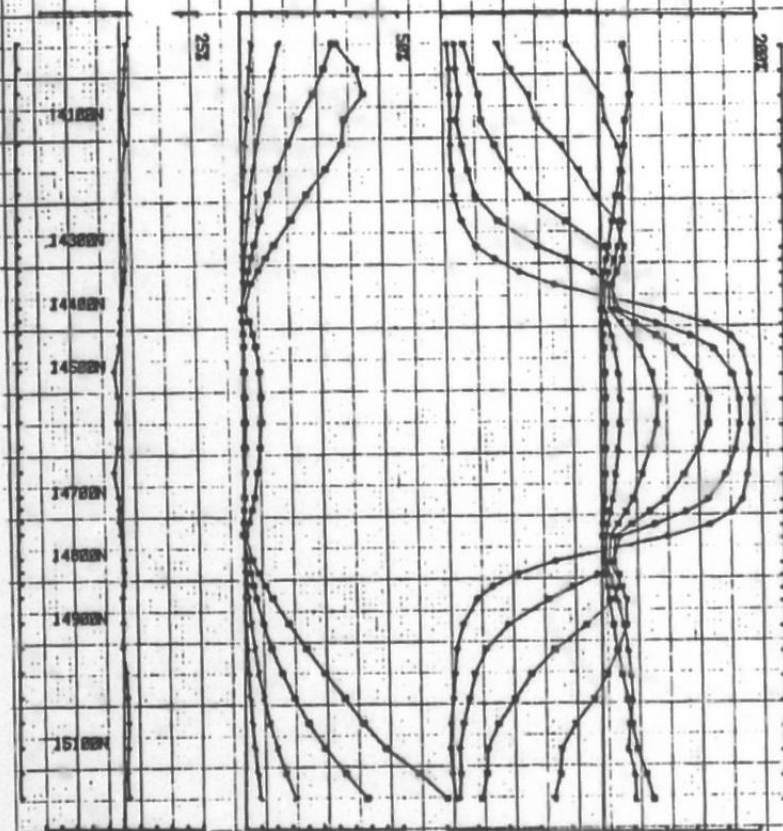
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 Project Area HANITOU LAKE Survey for BP Fractals 38,974
 Line 8231 Line A component Hz secondary Ch 1



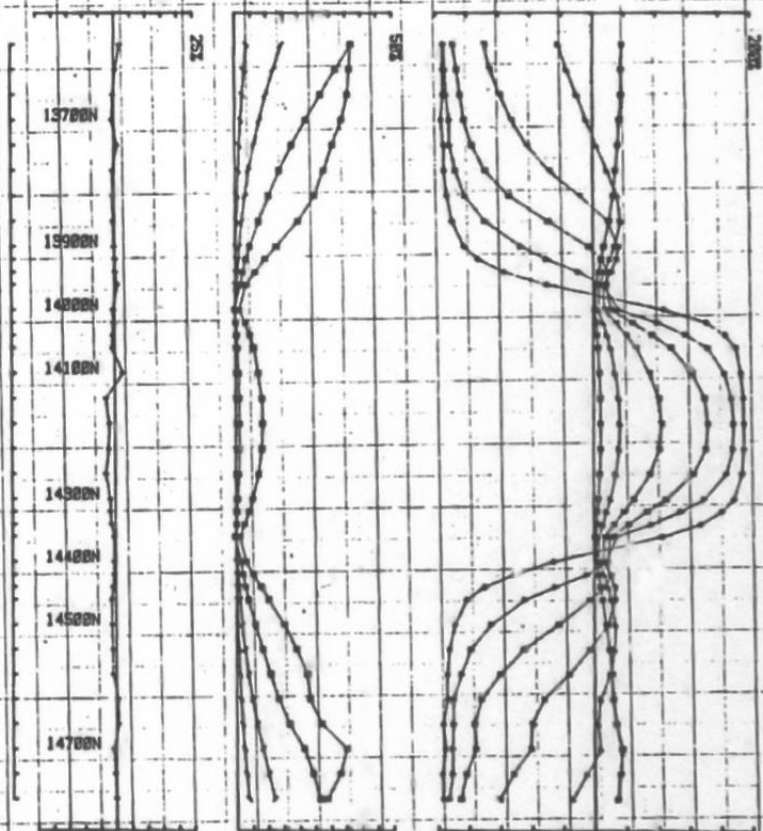
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 Project Area: MANITOU LAKE Survey for BP freshet 38.974
 Loop 8204 Line A component Hz secondary 0.1



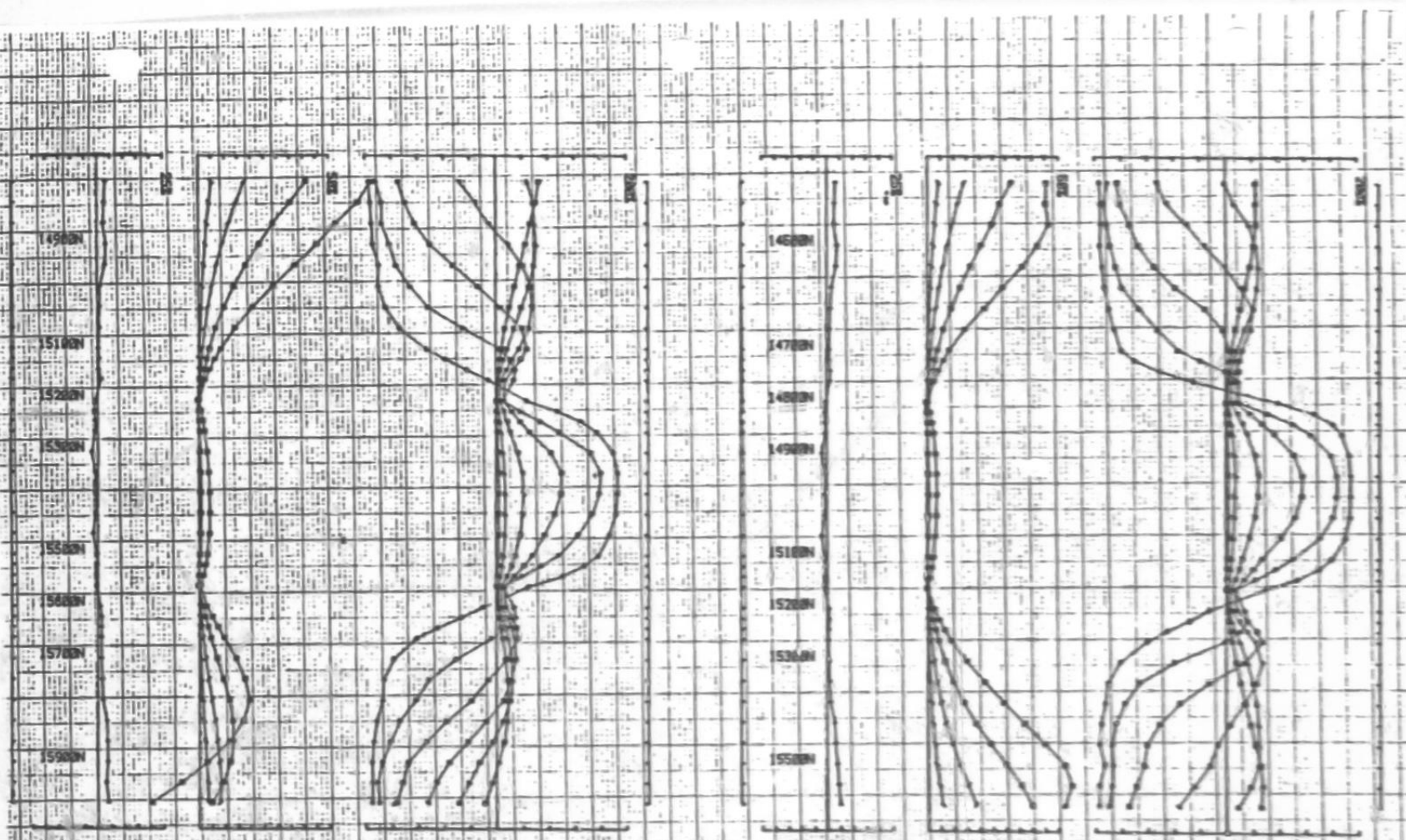
UTAH SURVEY conducted by LAMONTAGNE GEOPHYSICS July 4892
 Project Area: MANITOU LAKE Survey for BP freshet 38.974
 Loop 8205 Line A component Hz secondary 0.1



UTEH SURVEY conducted by LAMONTAGNE GEOPHYSICS Job 4882
 Project Area: MANITOU LAKE Survey for BP (Fractal) 38.974
 Loop: 0235 Line A component Hz secondary Ch 1

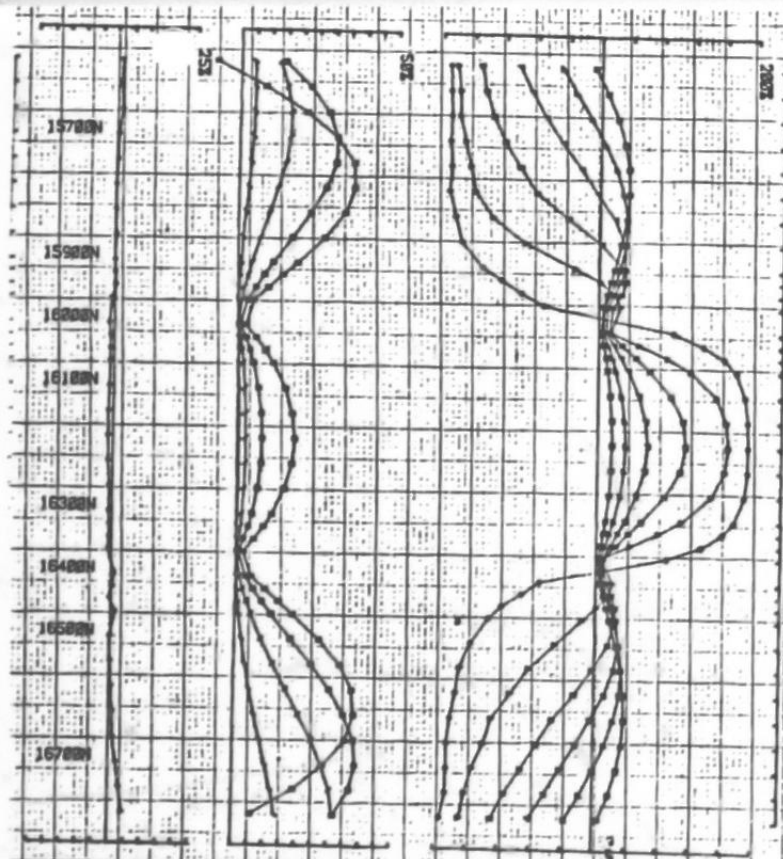


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 Project Area: MANITOU LAKE Survey for BP (Fractal) 38.974
 Loop: 0235 Line A component Hz secondary Ch 1

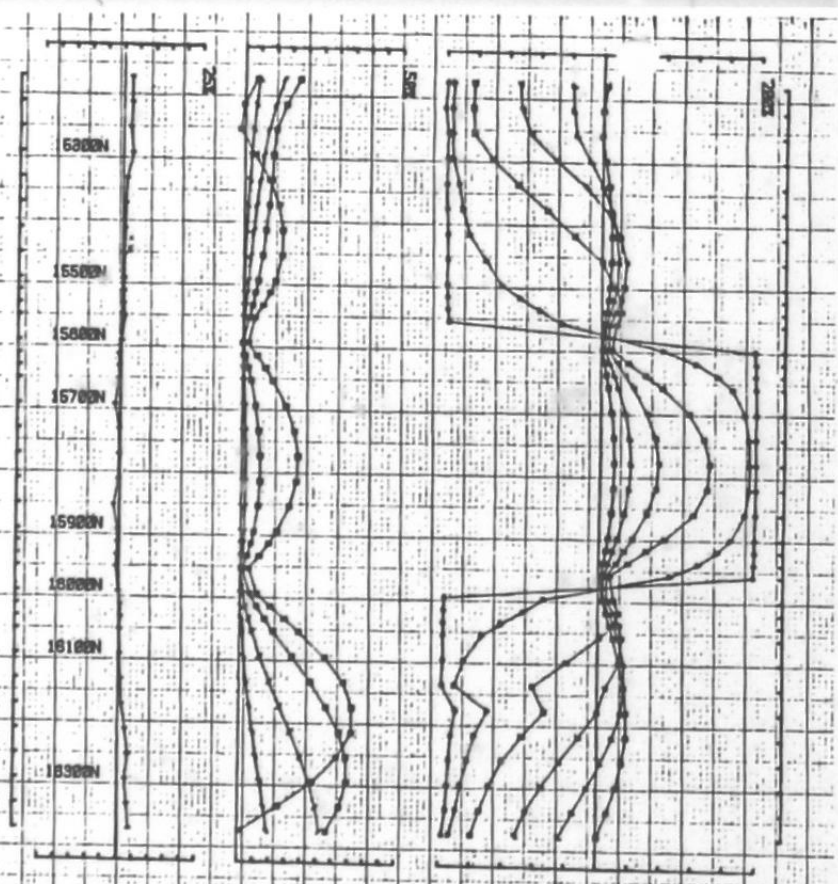


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 Project Area MINNIDOU LAKE Survey for OF finished 08.974
 Station 0730 Line A segment HC secondary Ch 1

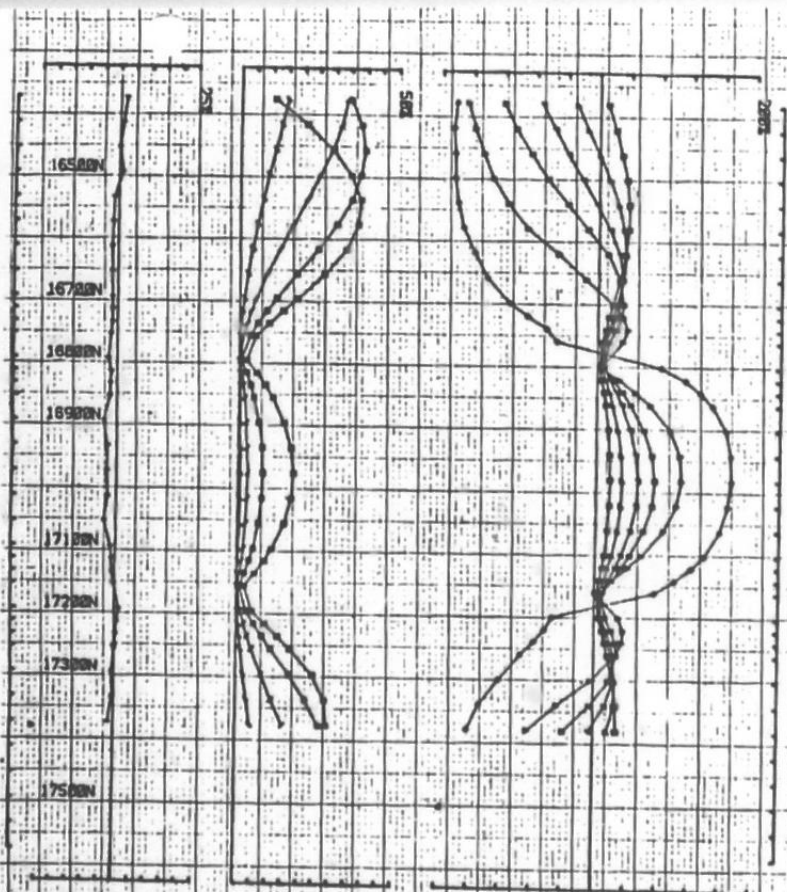
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 Project Area MINNIDOU LAKE Survey for OF finished 08.974
 Station 0737 Line A segment HC secondary Ch 1



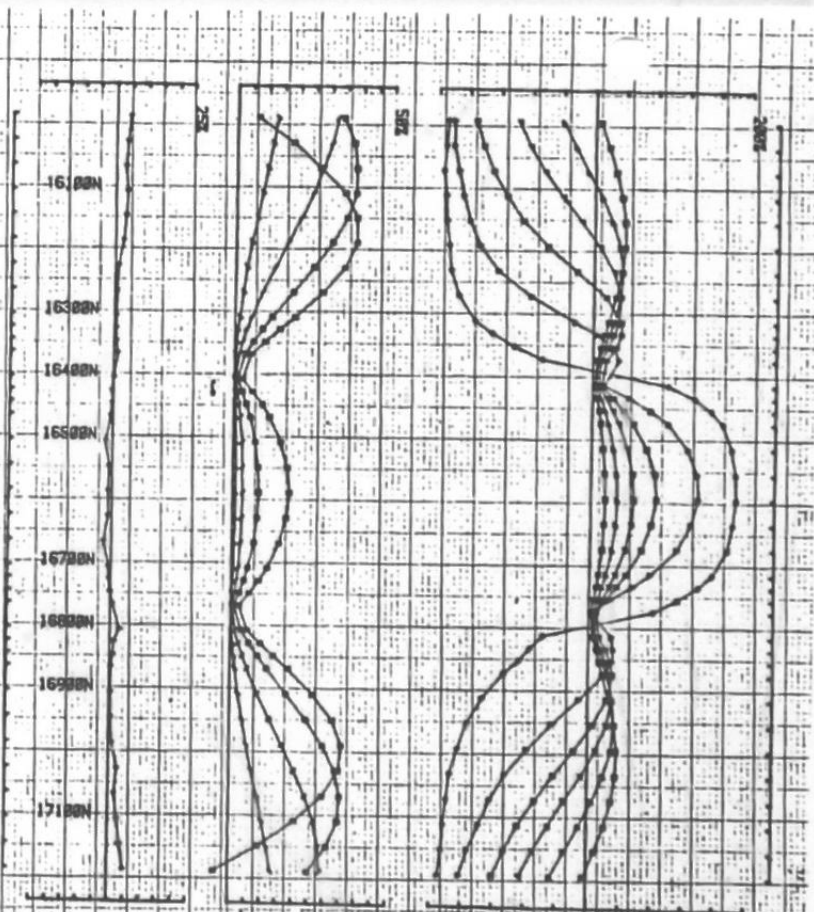
UTAH SURVEY conducted by LARONTAGNE GEOPHYSICS Job 4892
 Project Area MONTICLOKA Survey for BP Fracture 38.974
 Line 8248 Line R component Hz secondary Ch 1



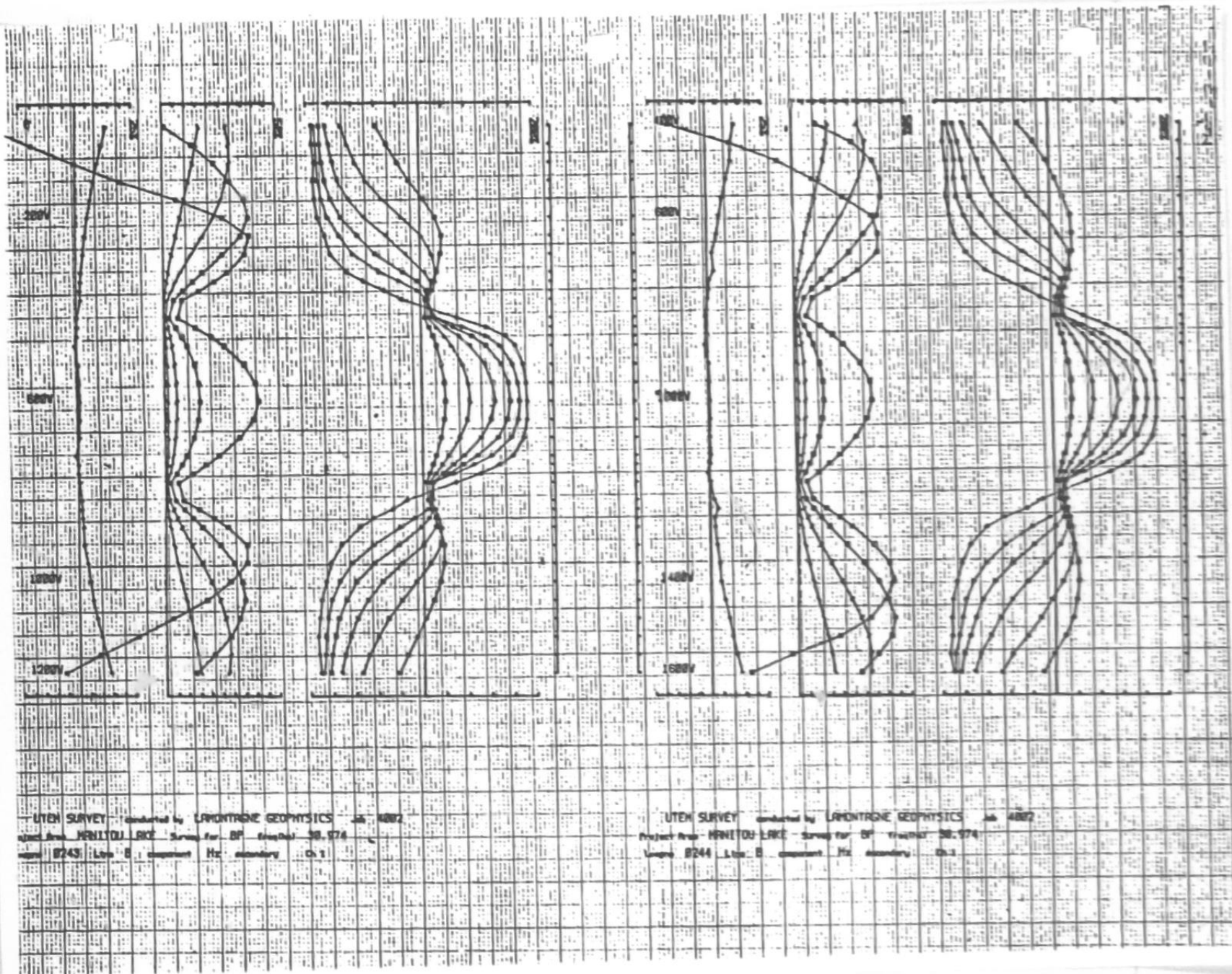
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 Project Area MONTICLOKA Survey for BP Fracture 38.974
 Line 8239 Line R component Hz secondary Ch 1

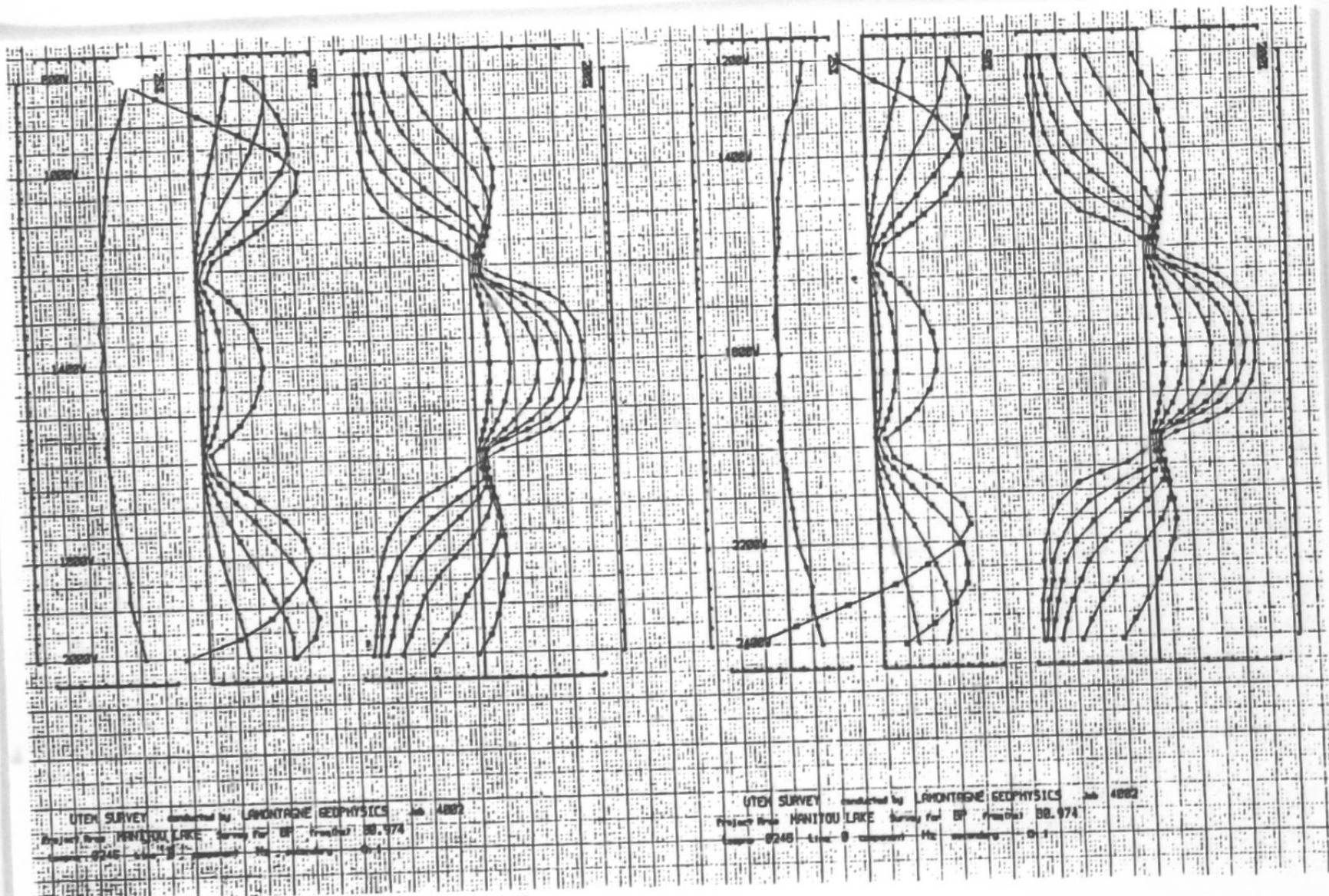


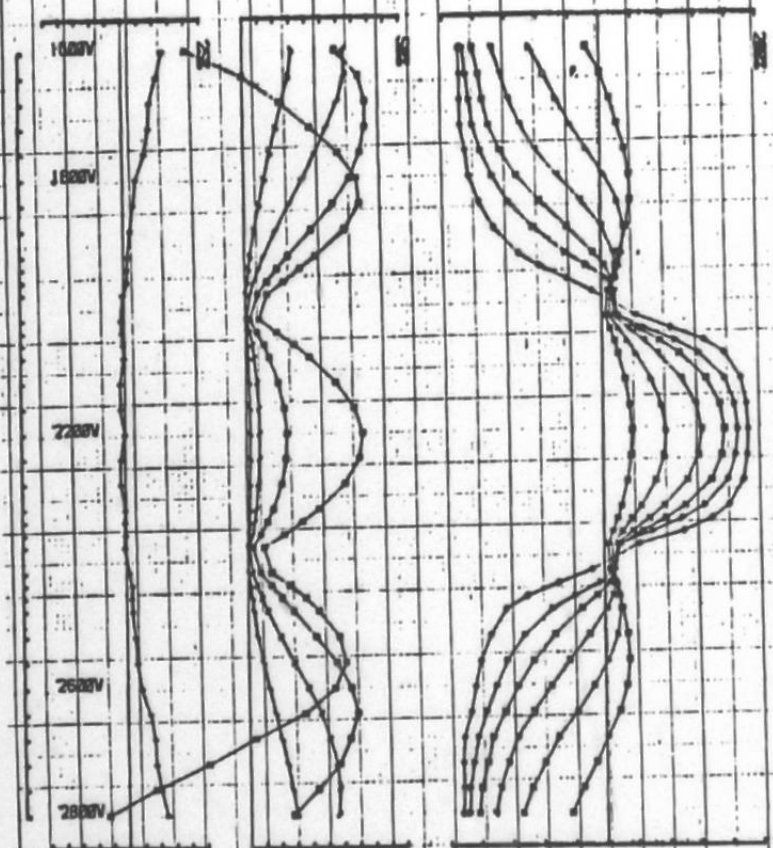
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 Project Area MANITOU LAKE Survey for BP Fractals 38.974
 Loop 0242 Line A component Hx secondary Q.1



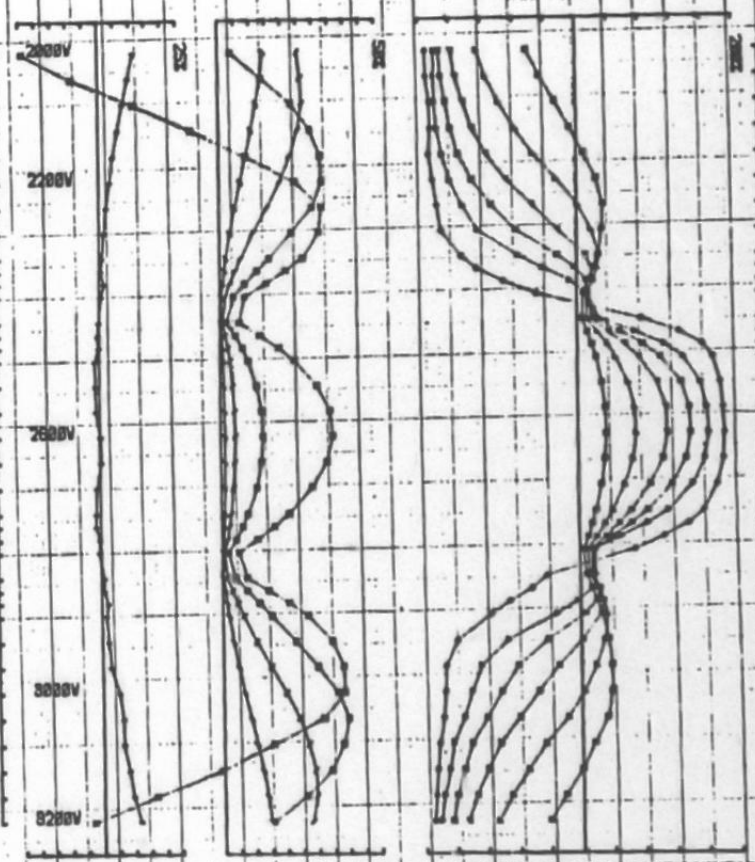
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 Loop 0241 Line A component Hx secondary Q.1



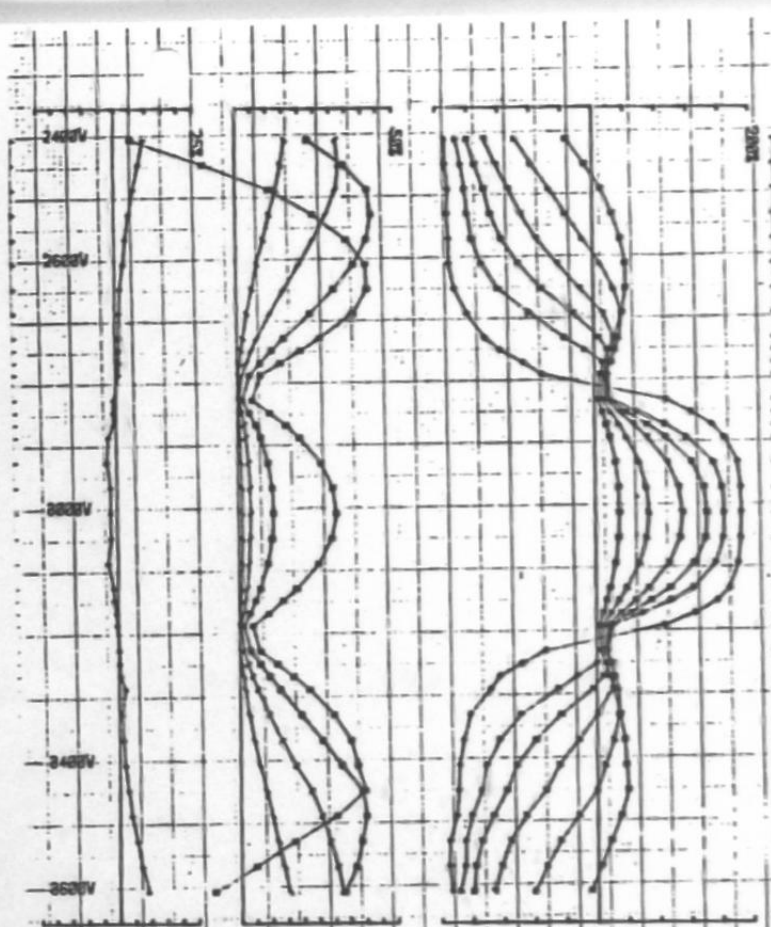




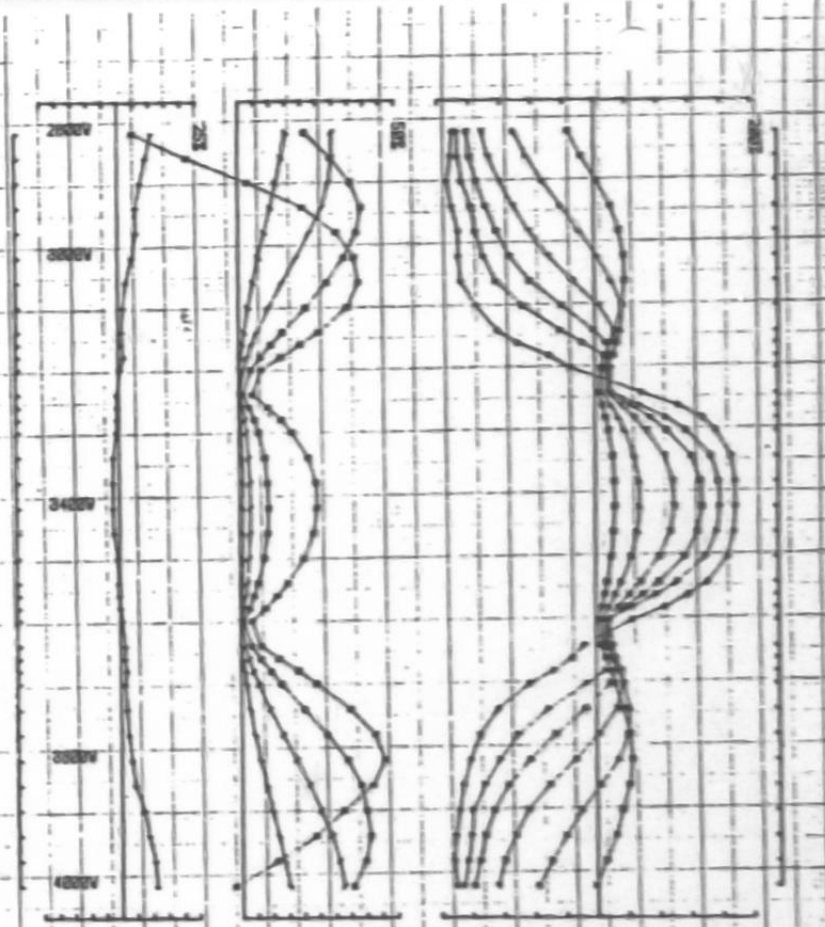
UTAH SURVEY conducted by LAHONTAGNE GEOPHYSICS Job 4882
 Project Area MONTICLOSA LAKE Survey for BP (Fossil) 38.974
 Loop 8247 Line B component Hz secondary Ch 1



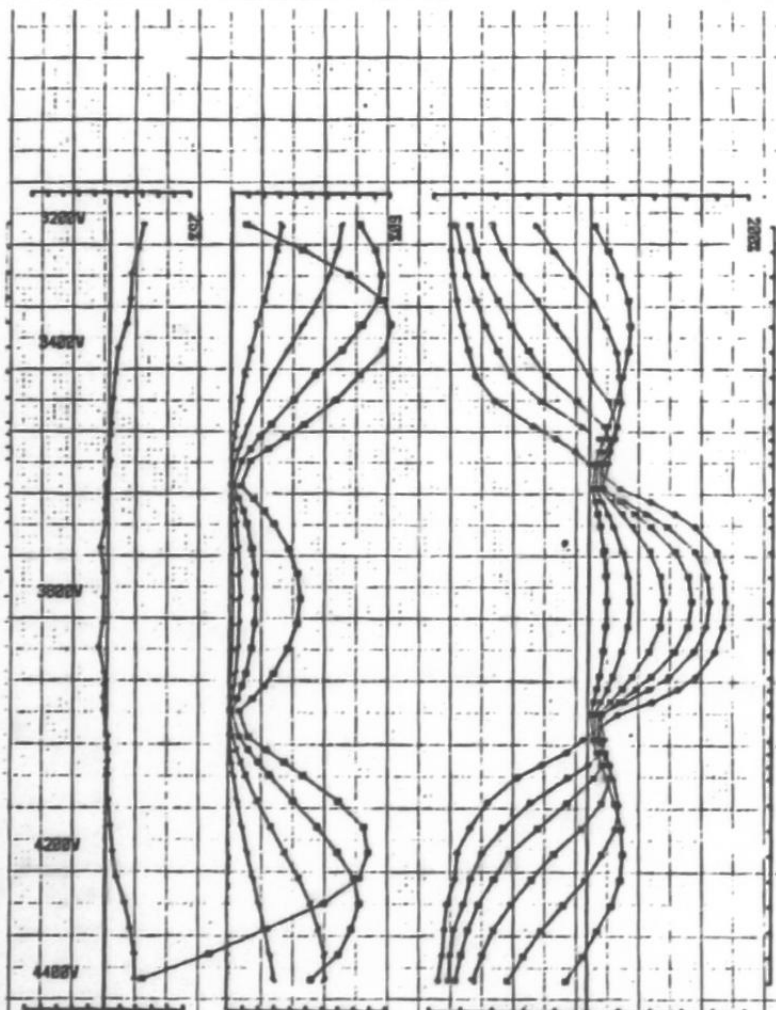
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 Loop 8248 Line B component Hz secondary Ch 1



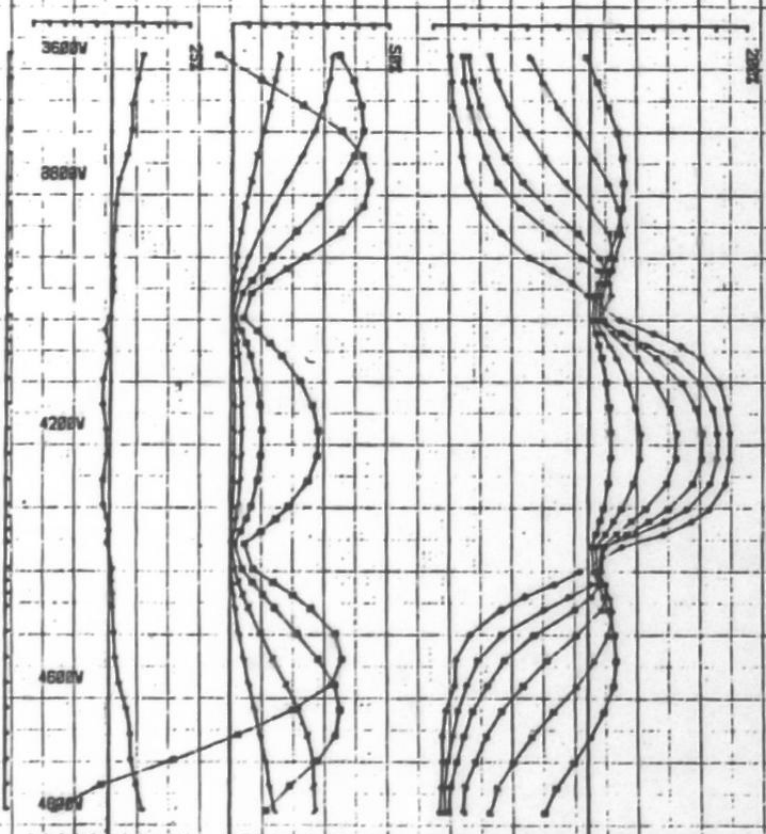
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 Project Area MANTOU LAKE Survey for EP Frequency 30,974
 Alpha 0249 Line 20 Equipment Hz secondary Ch 1



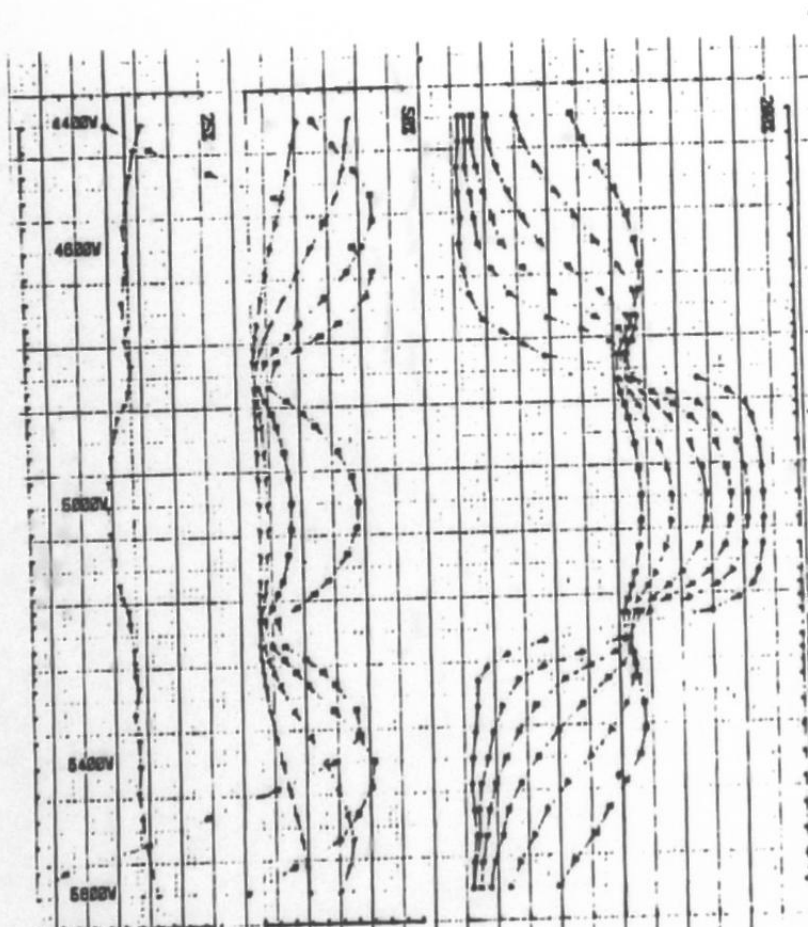
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 Project Area MANTOU LAKE Survey for EP Frequency 30,974
 Alpha 0250 Line 20 Equipment Hz secondary Ch 1



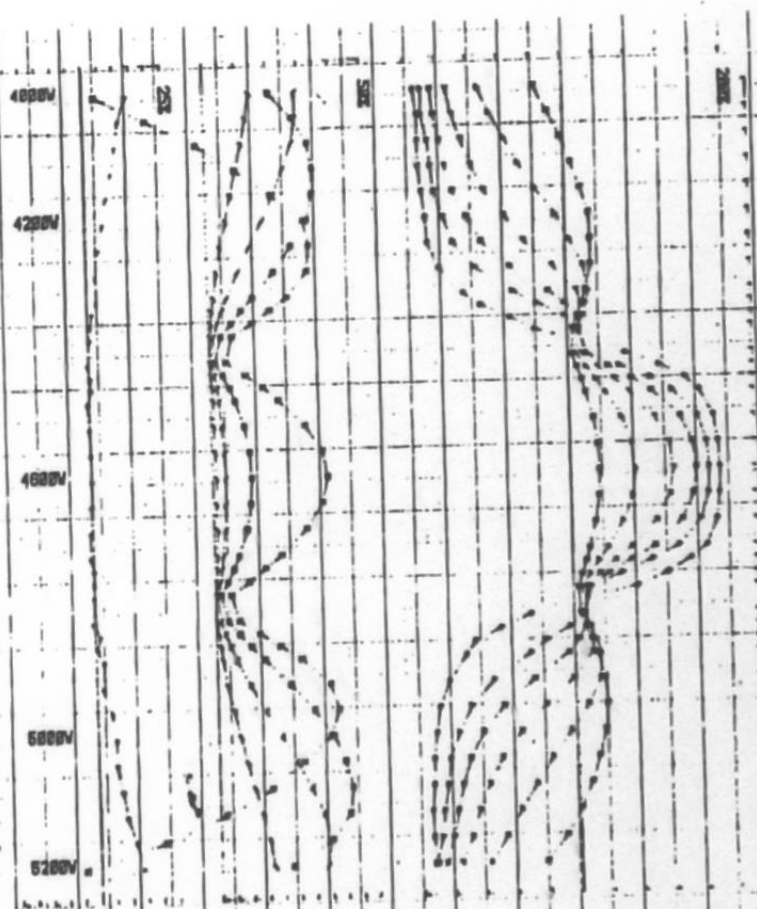
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 Project Area MANITOU LAKE Survey for BP frequency 38.974
 Loop 8251 Line 8 component Hz secondary Ch 1



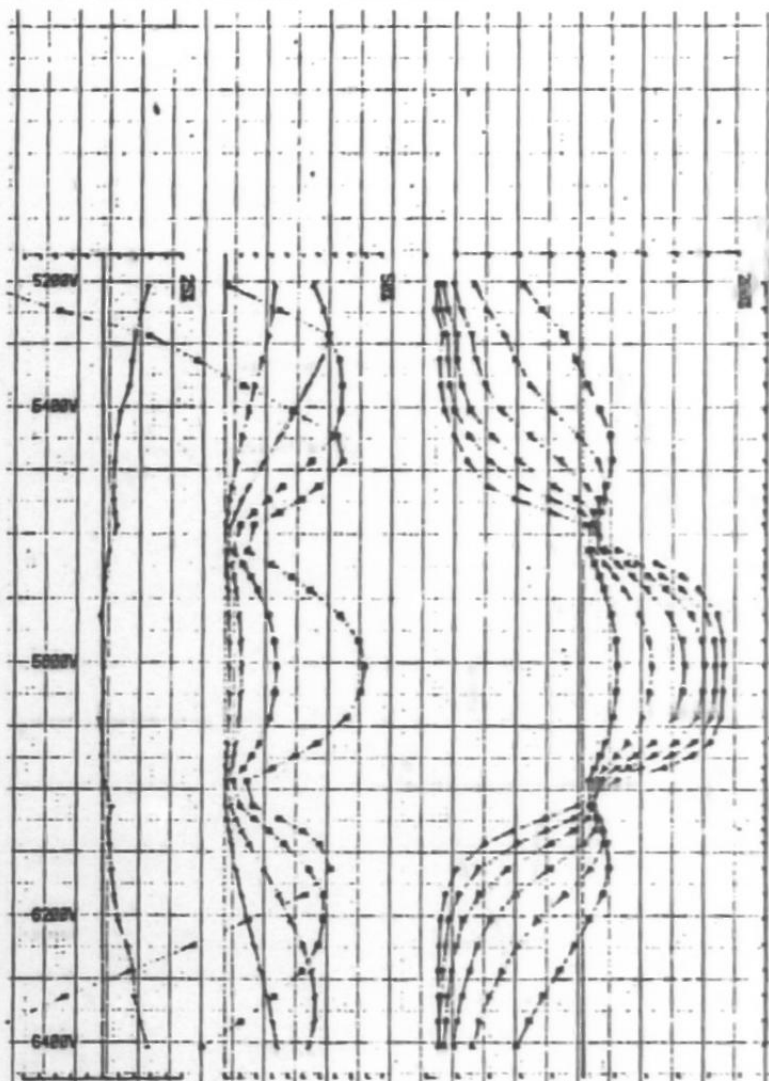
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 Project Area MANITOU LAKE Survey for BP frequency 38.974
 Loop 8252 Line 8 component Hz secondary Ch 1



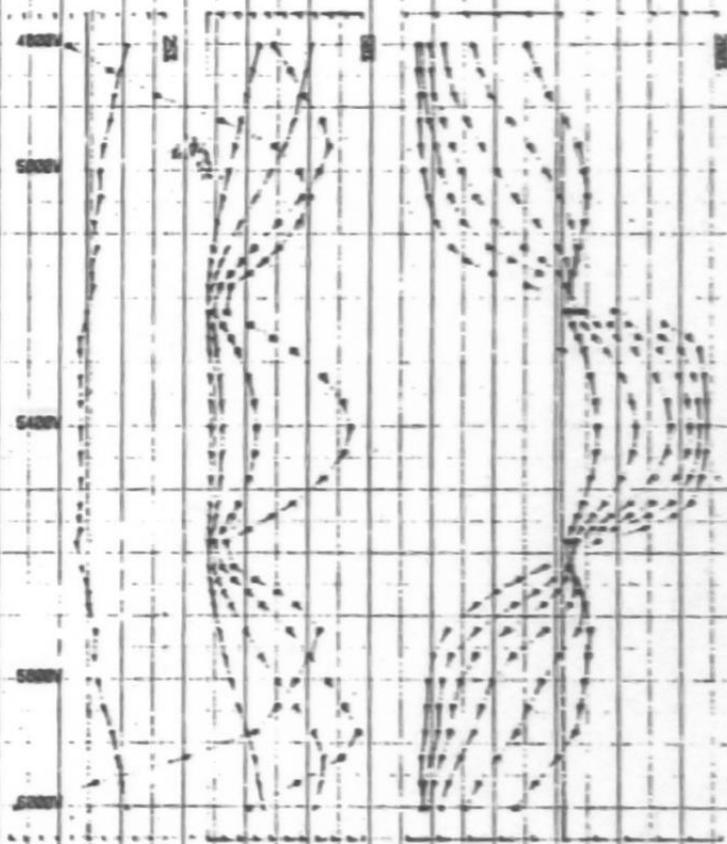
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 Project Area: MANITOU LAKE Survey for BP Fracture 38.974
 Logno: 8254 Line B: segment Hs secondary Ch 1



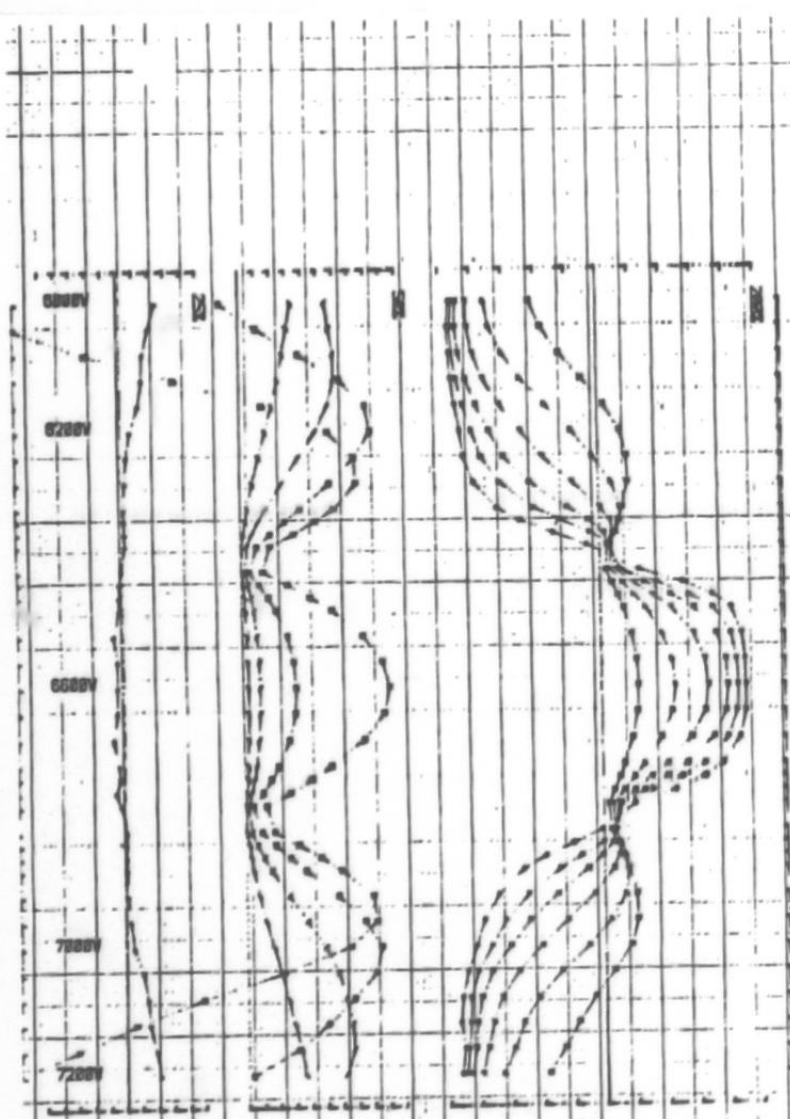
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 Project Area: MANITOU LAKE Survey for BP Fracture 38.974
 Logno: 8253 Line B: segment Hs secondary Ch 1



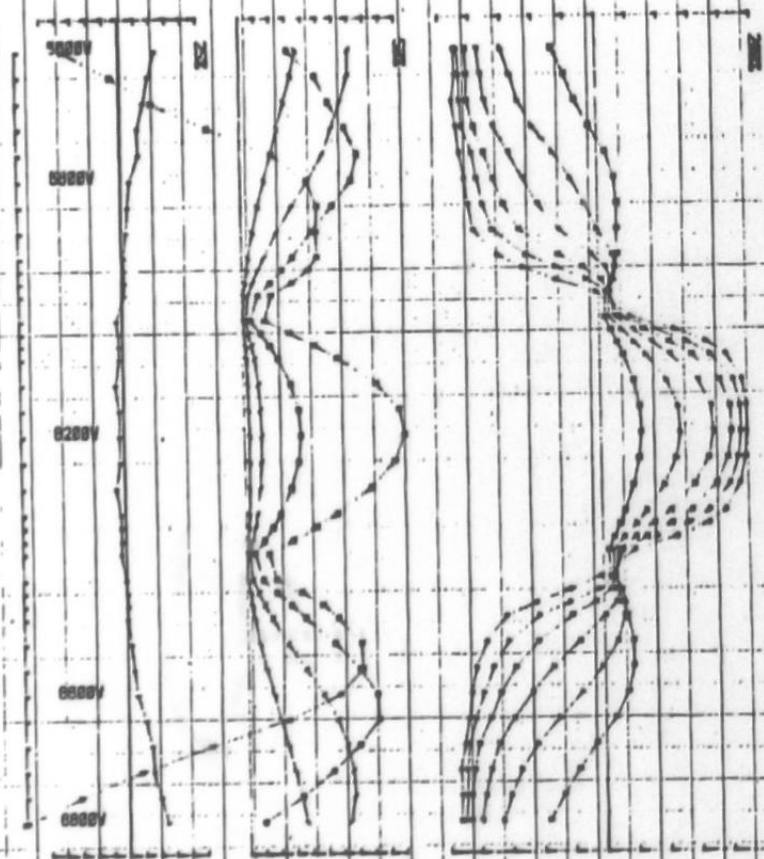
UTEX SURVEY conducted by LAMONTAGNE GEOPHYSICS Job 4882
 Project Area HANITOU LAKE Survey for BP Fractals 30.974
 Line 8250 Line B component Hz secondary Ch 1



UTEX SURVEY conducted by LAMONTAGNE GEOPHYSICS Job 4882
 Project Area HANITOU LAKE Survey for BP Fractals 30.974
 Line 8250 Line B component Hz secondary Ch 1



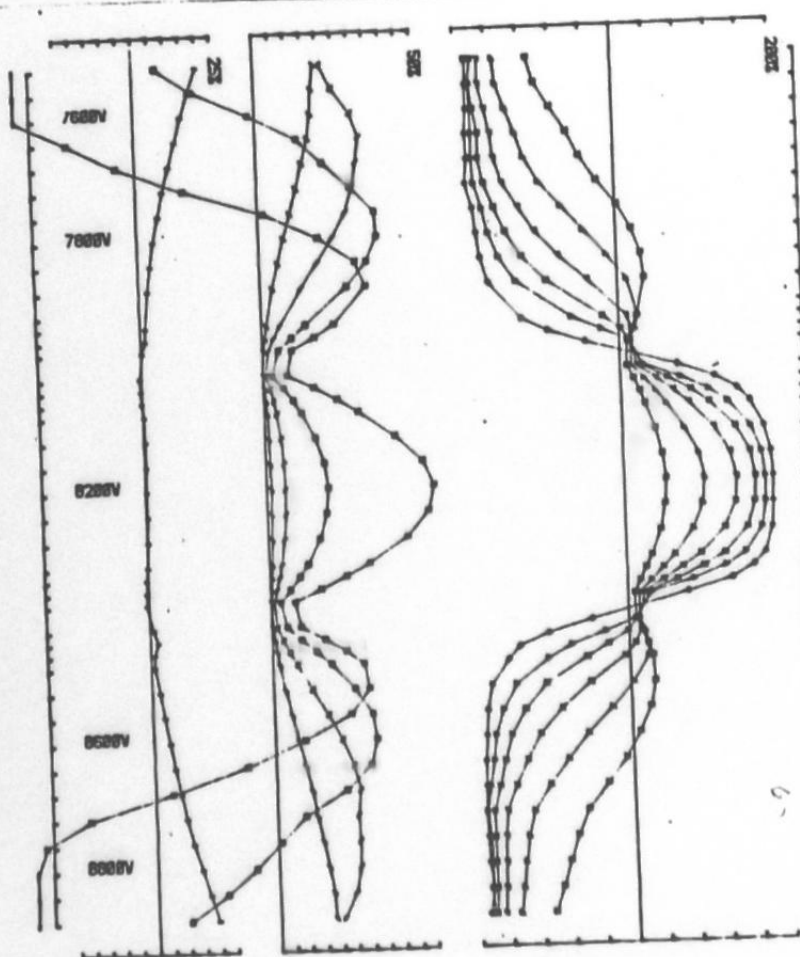
UTAH SURVEY conducted by LAMONTAGNE GEOPHYSICS Job 4882
 Project Area MONITOR LAKE Survey for BH fractional 38.974
 Lines 8258 Line 8 constant Hz secondary On 1



UTAH SURVEY conducted by LAMONTAGNE GEOPHYSICS Job 4882
 Project Area MONITOR LAKE Survey for BH fractional 38.974
 Lines 8257 Line 8 constant Hz secondary On 1

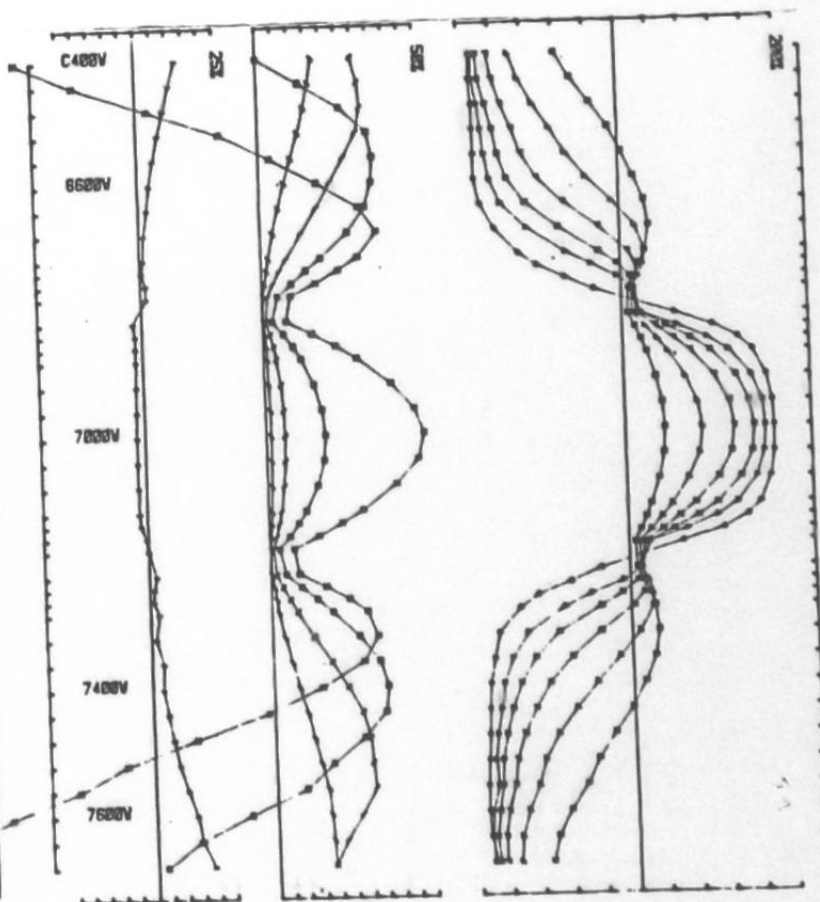
LOOP 0260

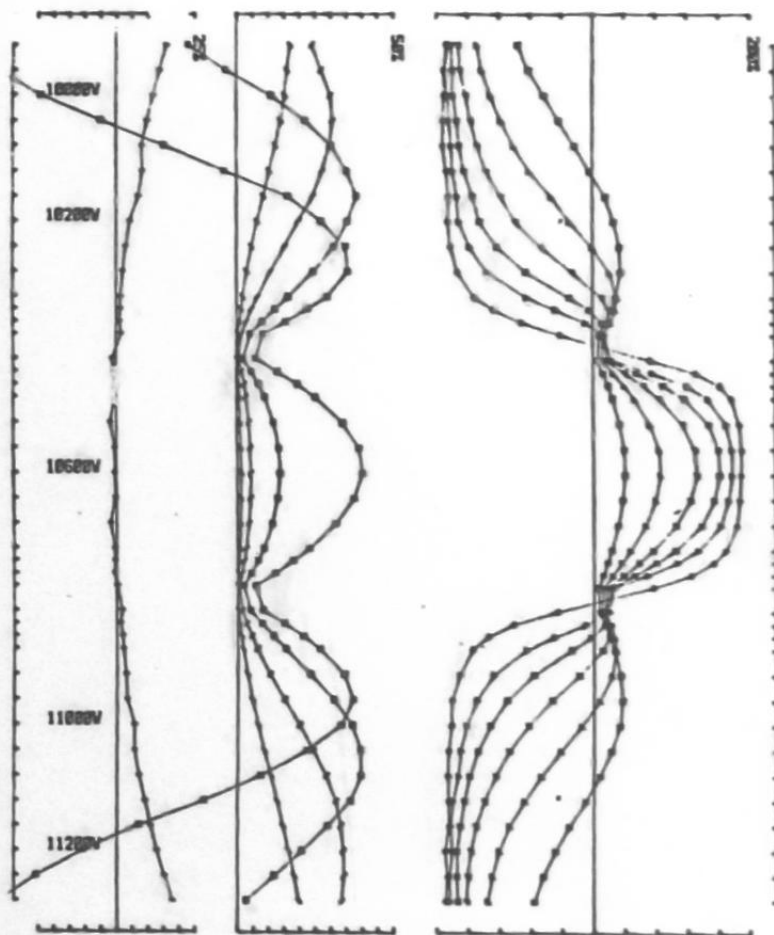
line B



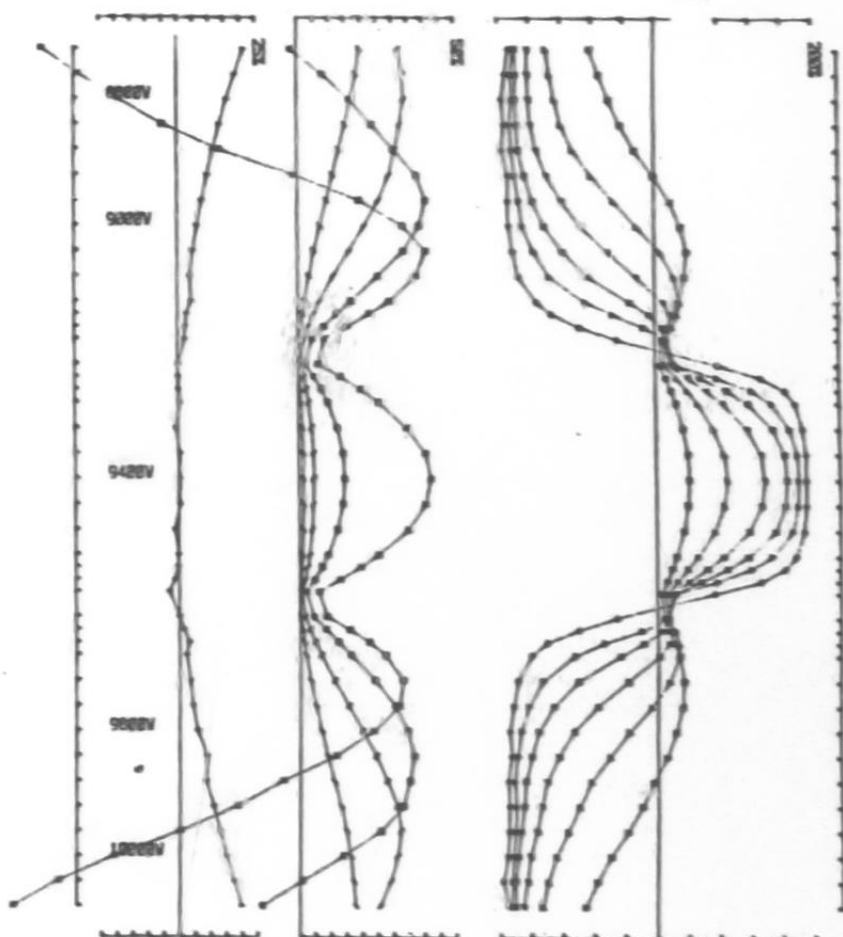
LOOP 0259

LINE B

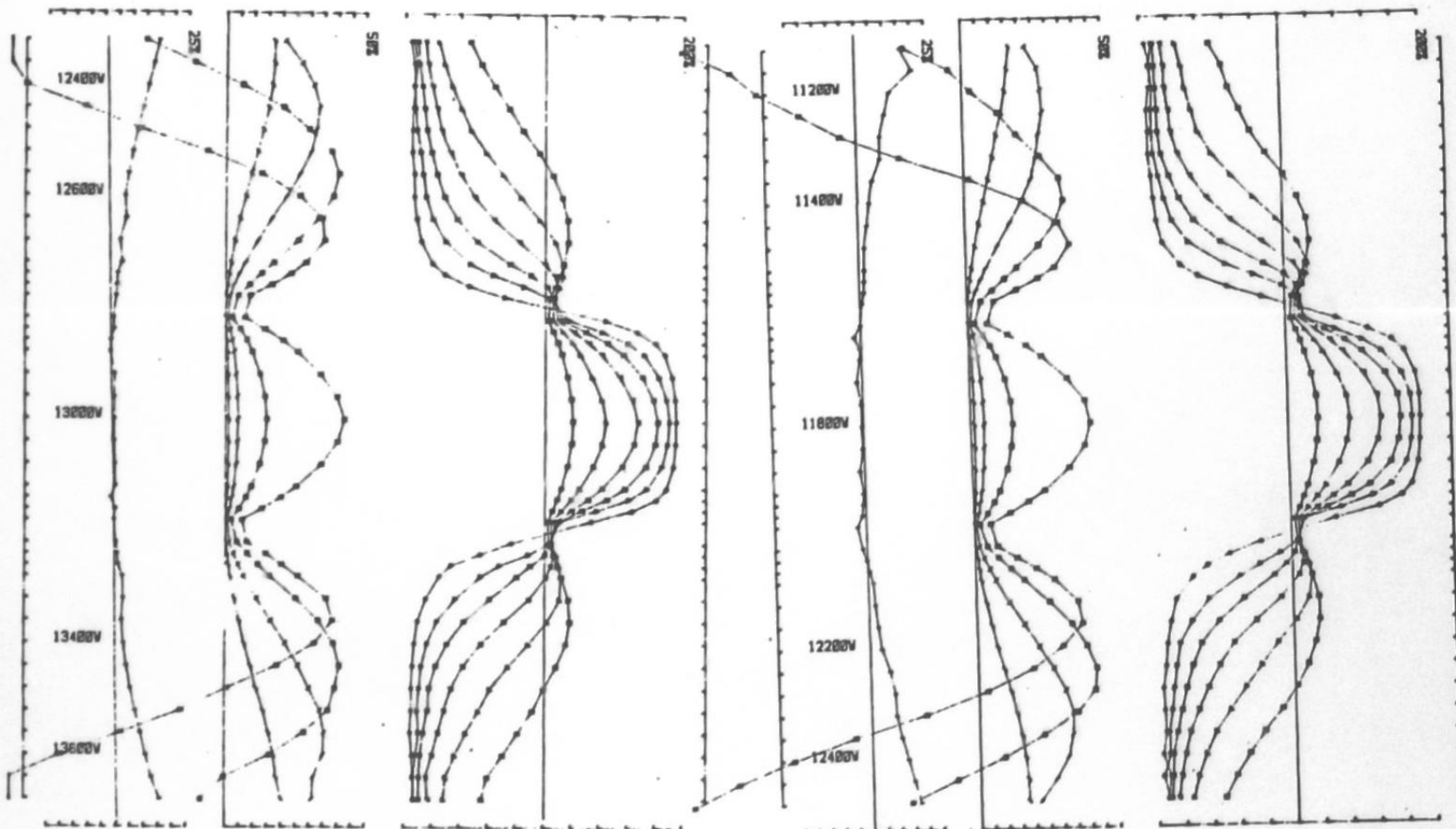




UTAH SURVEY conducted by LAMONTAGNE GEOPHYSICS Job 4802
 Project Area HANITOU LAKE Survey for BP frequency 30.974
 Loop 0202 Line B component Hz secondary Ch 1

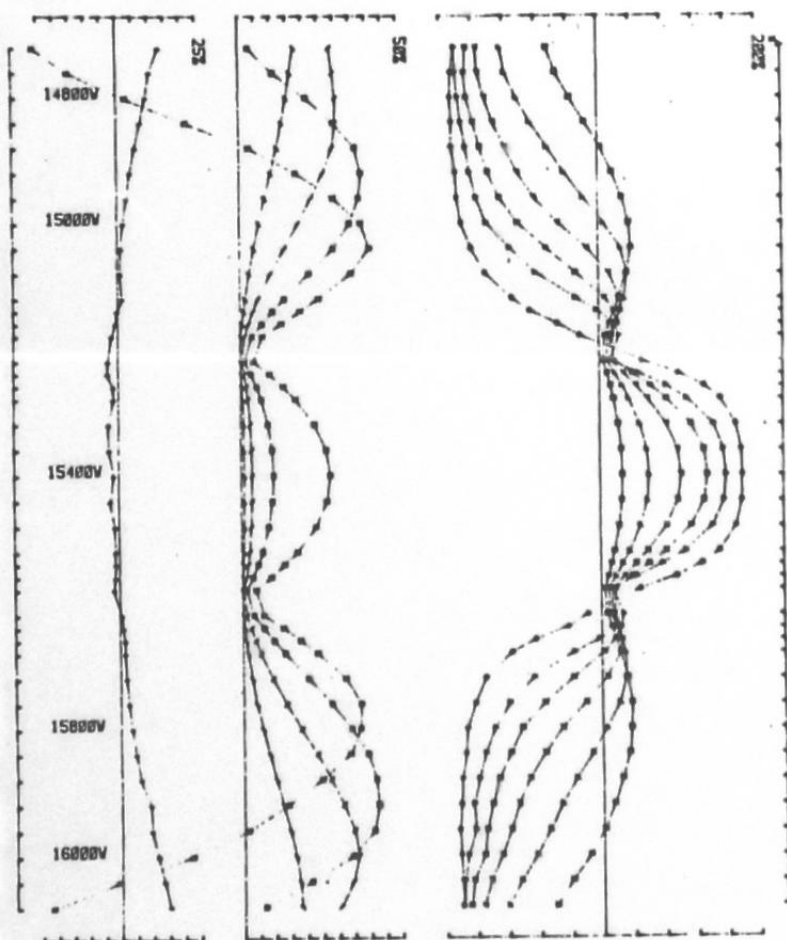


UTAH SURVEY conducted by LAMONTAGNE GEOPHYSICS Job 4802
 Project Area HANITOU LAKE Survey for BP frequency 30.974
 Loop 0201 Line B component Hz secondary Ch 1

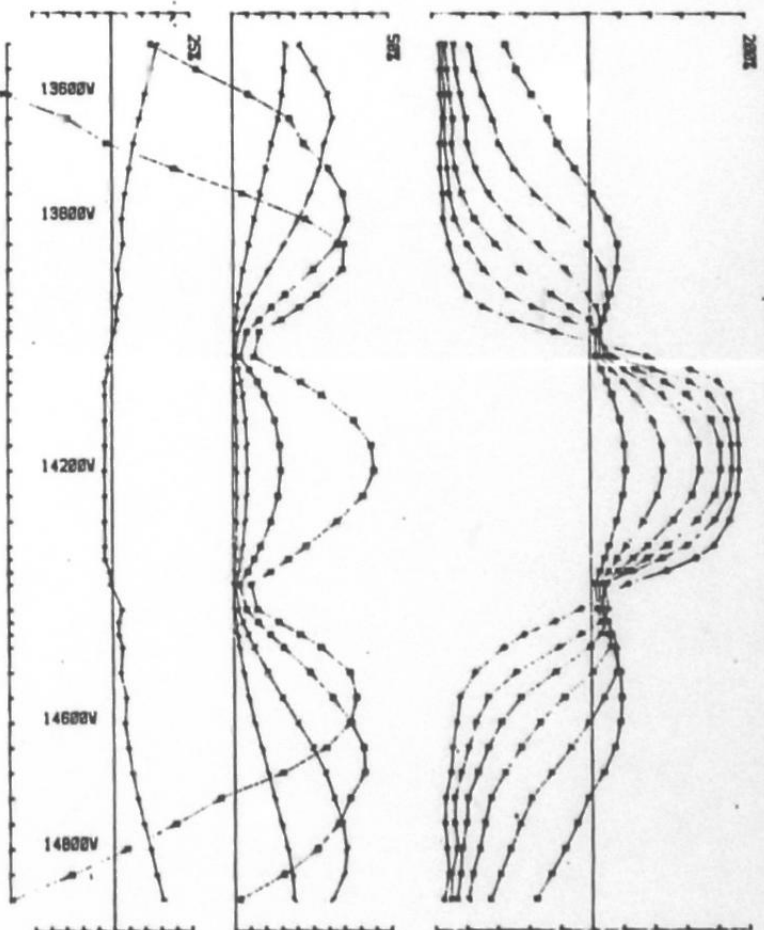


UTEH SURVEY conducted by LAMONTAGNE GEOPHYSICS Job 4882
 Project Area MANITOU LAKE Survey for BP frequency 38.974
 Loop 0264 Line B component Hz secondary Ch 1

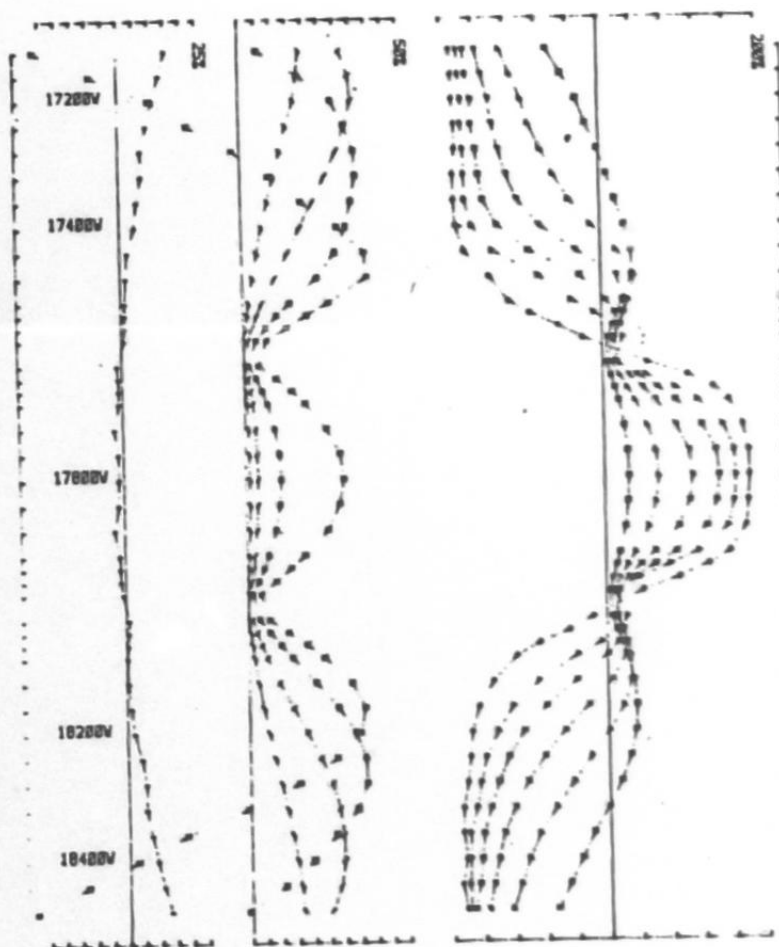
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 Project Area MANITOU LAKE Survey for BP frequency 38.974
 Loop 0263 Line B component Hz secondary Ch 1



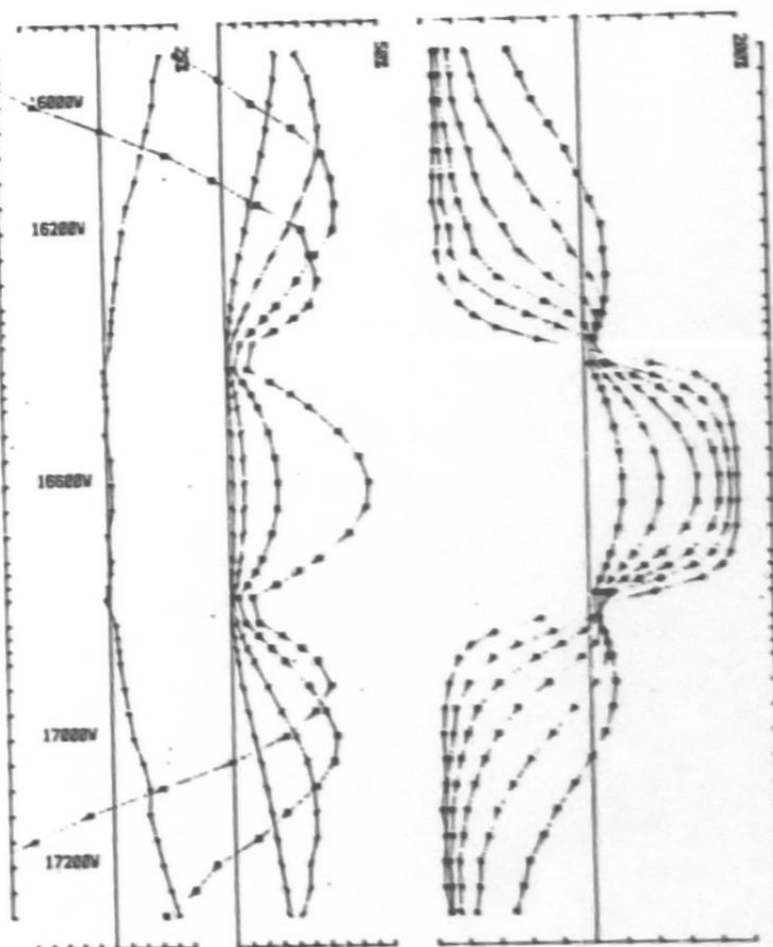
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 Project Area MANITOU LAKE Survey for BP frequency 30.974
 Loop 0266 Line B component Hz secondary Ch 1



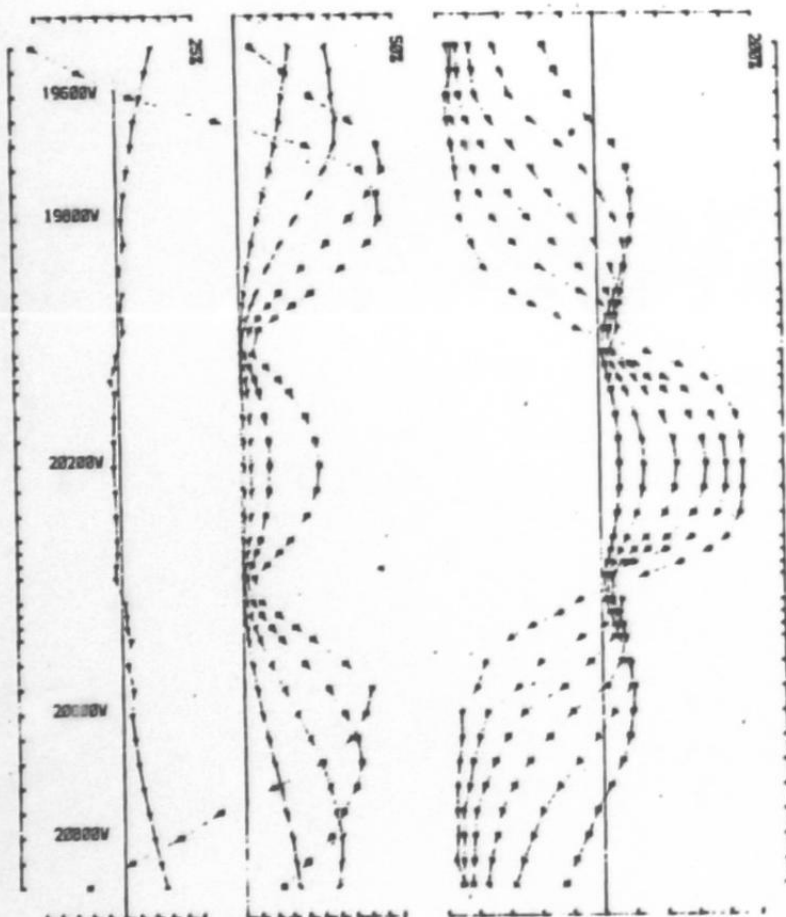
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 Loop 0265 Line B component Hz secondary Ch 1



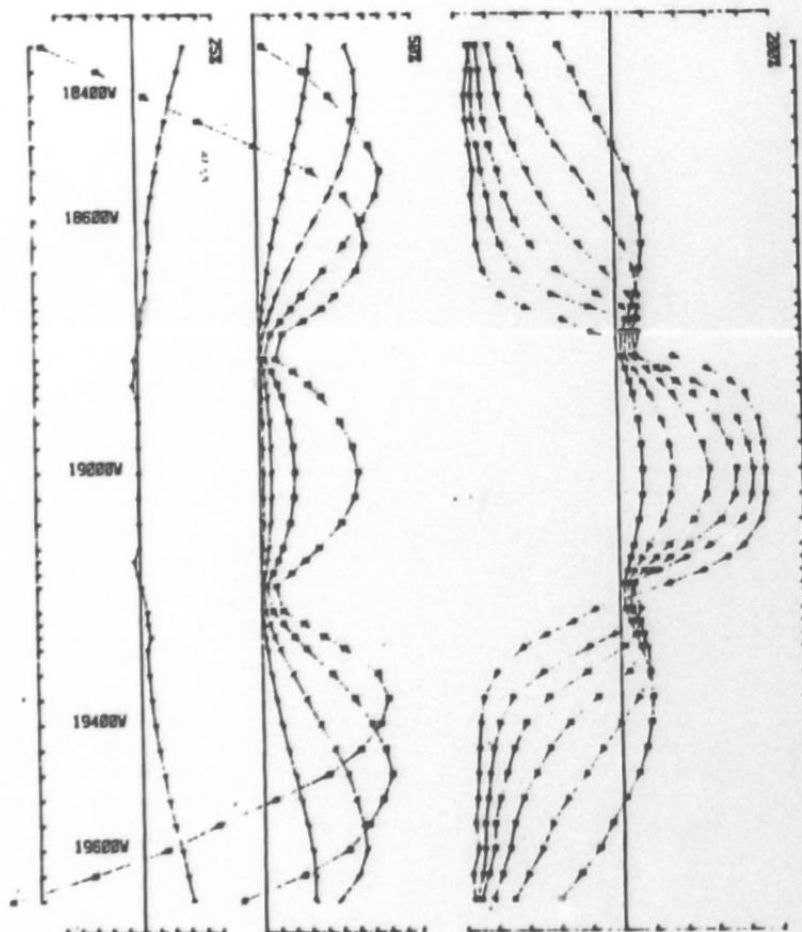
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 Loop 8268 Line B component Hz secondary Ch 1



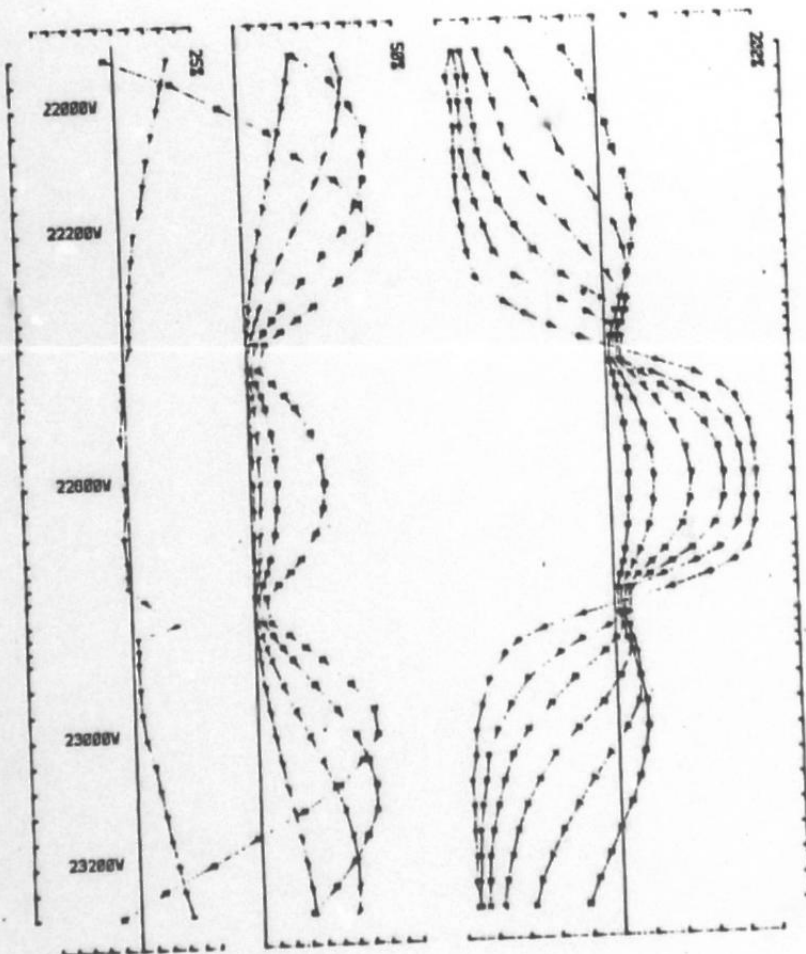
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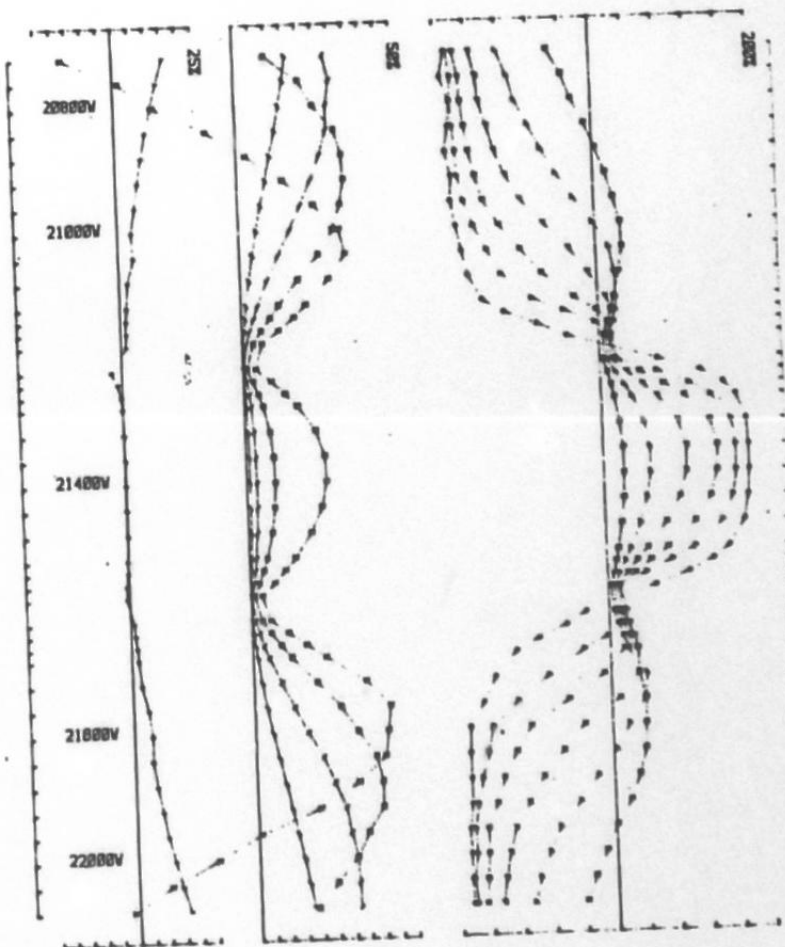
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 Project Area MANITOU LAKE Survey for BP Fractals 38,974
 Loop 0270 Line B component Hz secondary Ch 1



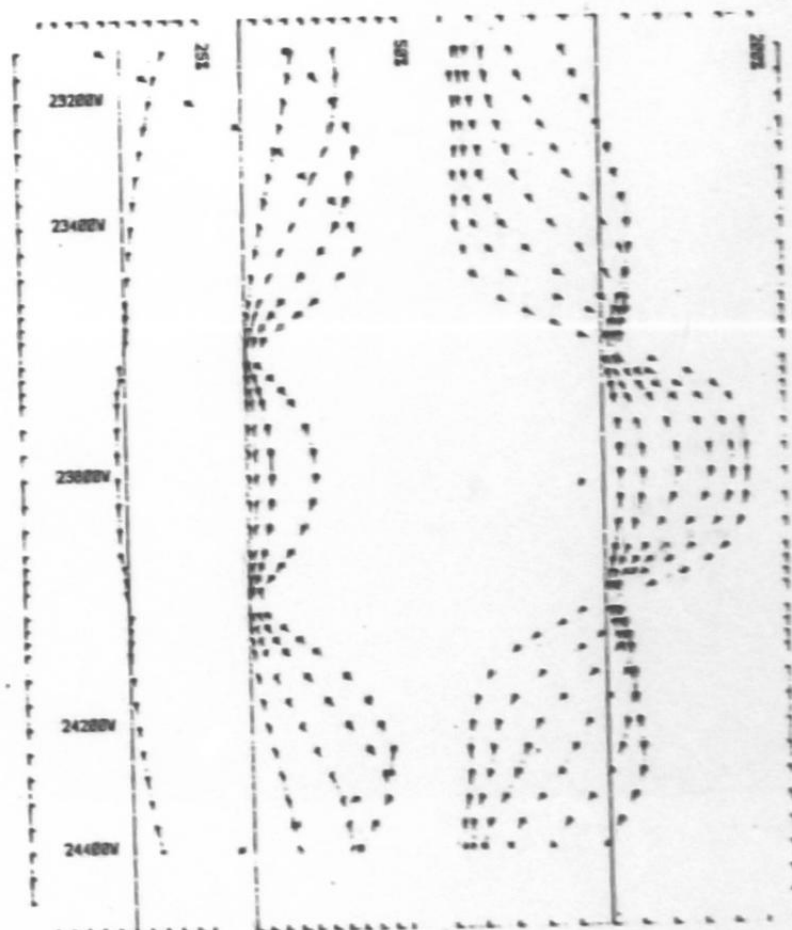
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 Project Area MANITOU LAKE Survey for BP Fractals 38,974
 Loop 0269 Line B component Hz secondary Ch 1



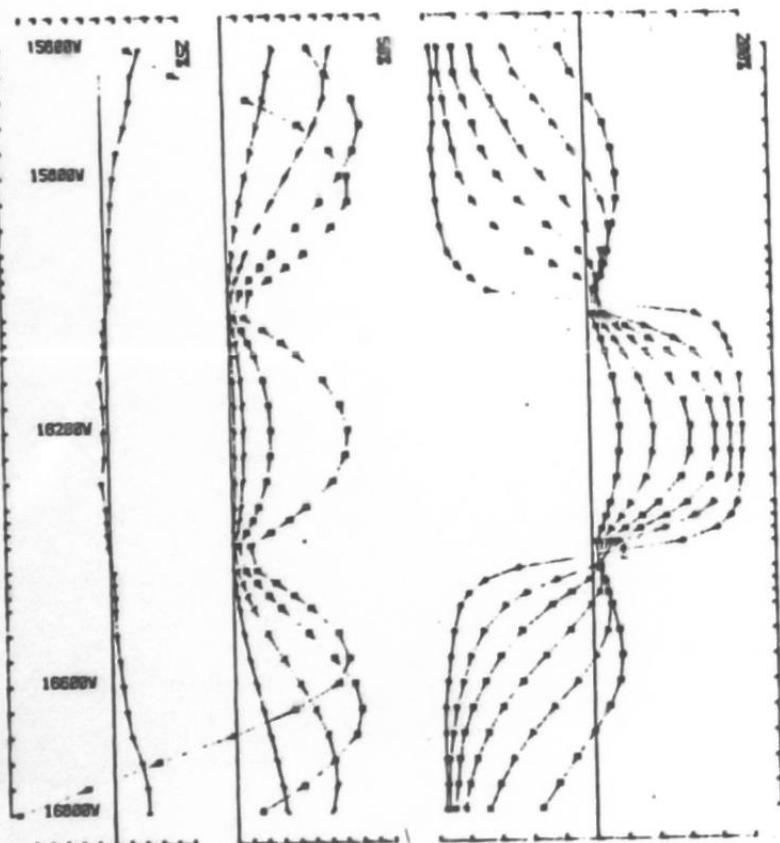
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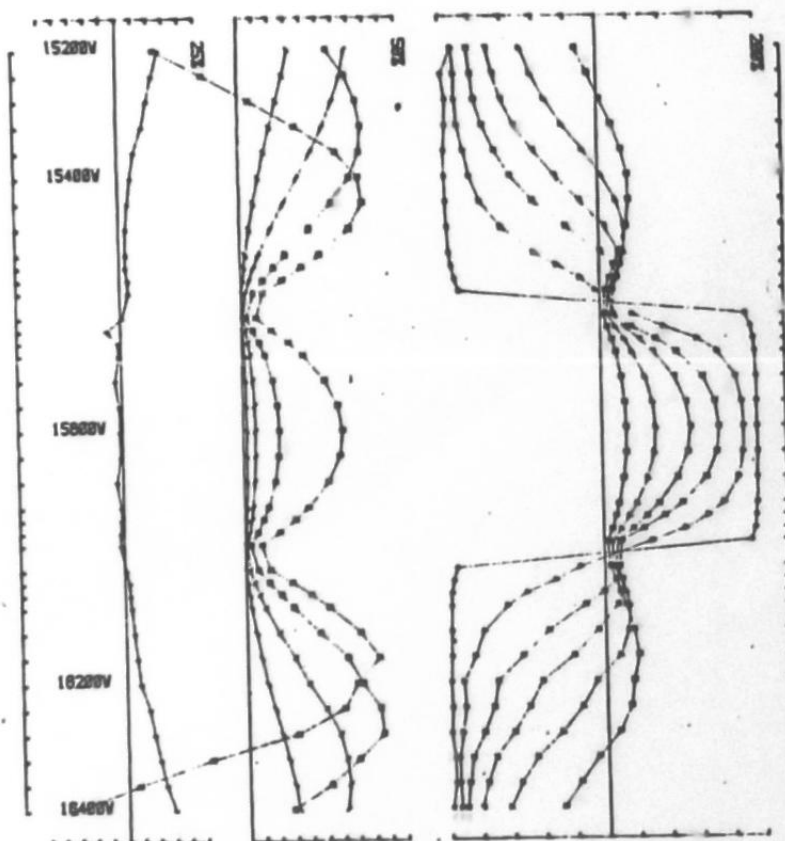
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 Loop 0271 Line B component Hz secondary Ch 1



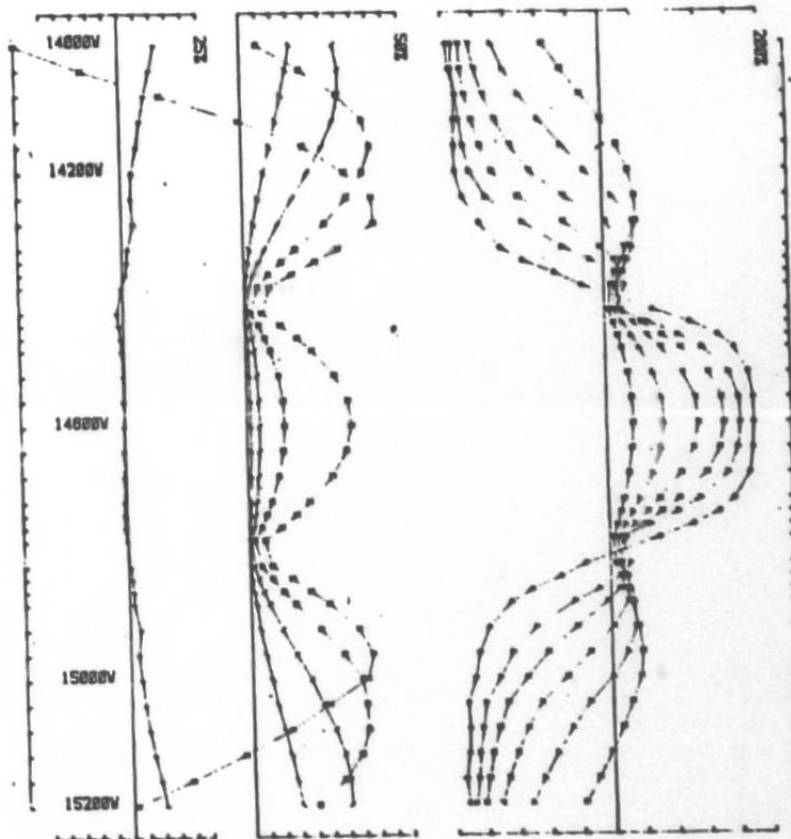
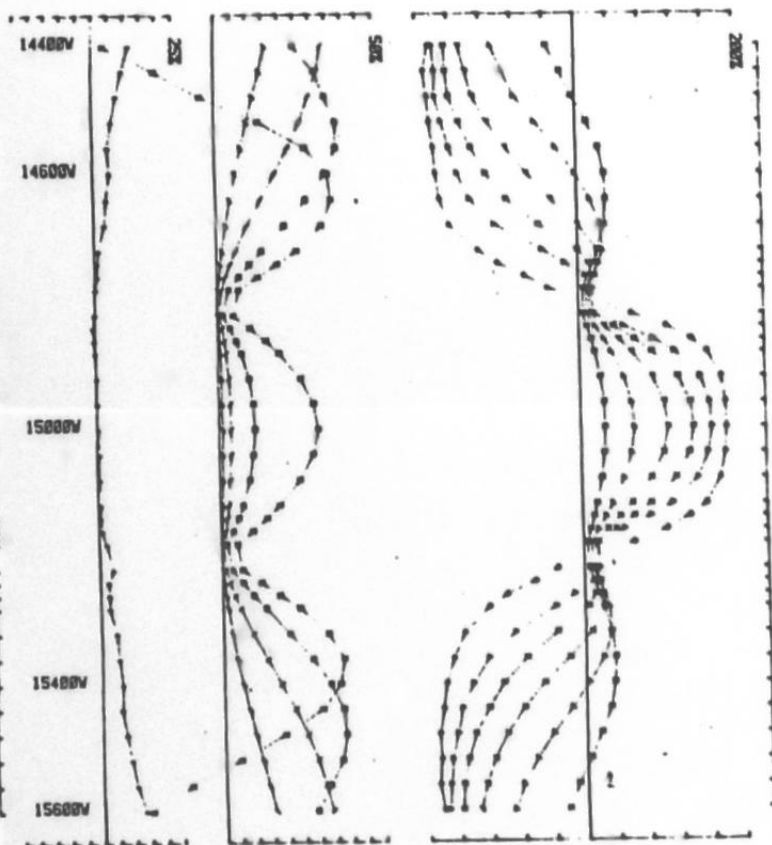
UTEH SURVEY conducted by LAMONTAGNE GEOPHYSICS Job 4002
 Project Area HANITOU LAKE Survey for BP fractal 30.974
 Legno 0273 Line 0 constant Hz secondary Ch 1



UTAH SURVEY conducted by LAMONTAGNE GEOPHYSICS Job 4882
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 Loop 8274 Line B component Hz secondary Ch 1

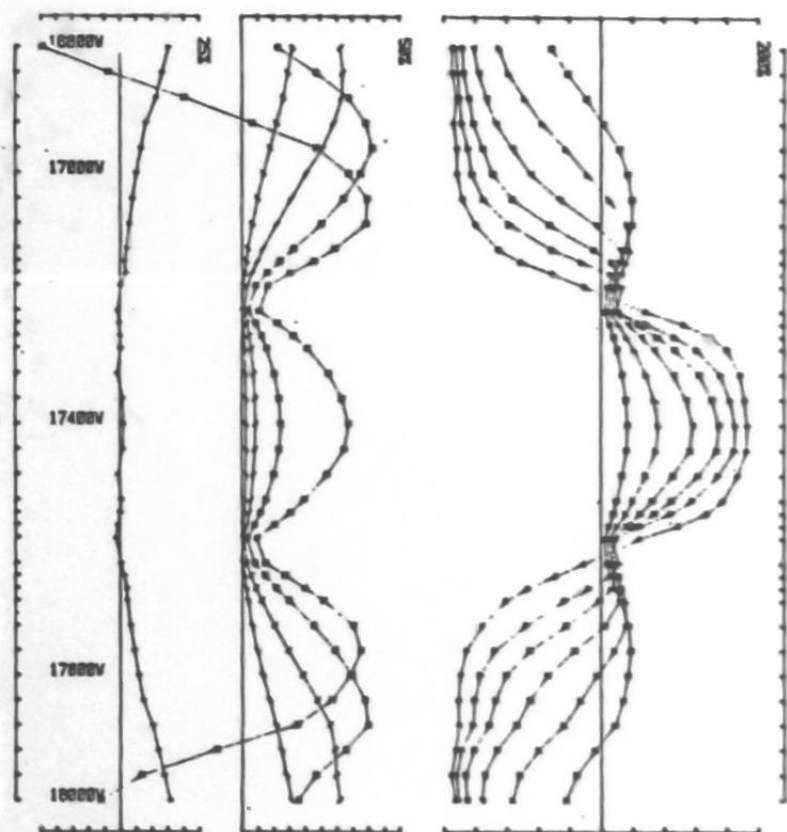


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 Project Area MANITOU LAKE Survey for BP fiscal 38.974
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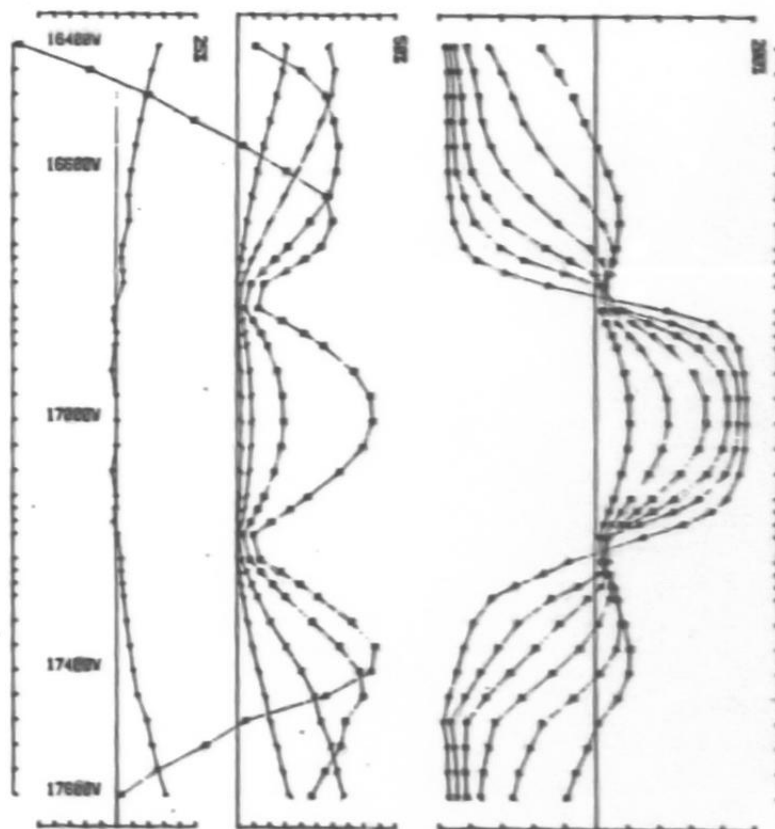


UTAH SURVEY conducted by LAMONTAGNE GEOPHYSICS Job 4882
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 Loops 8276 Line B component Hz secondary Ch 1

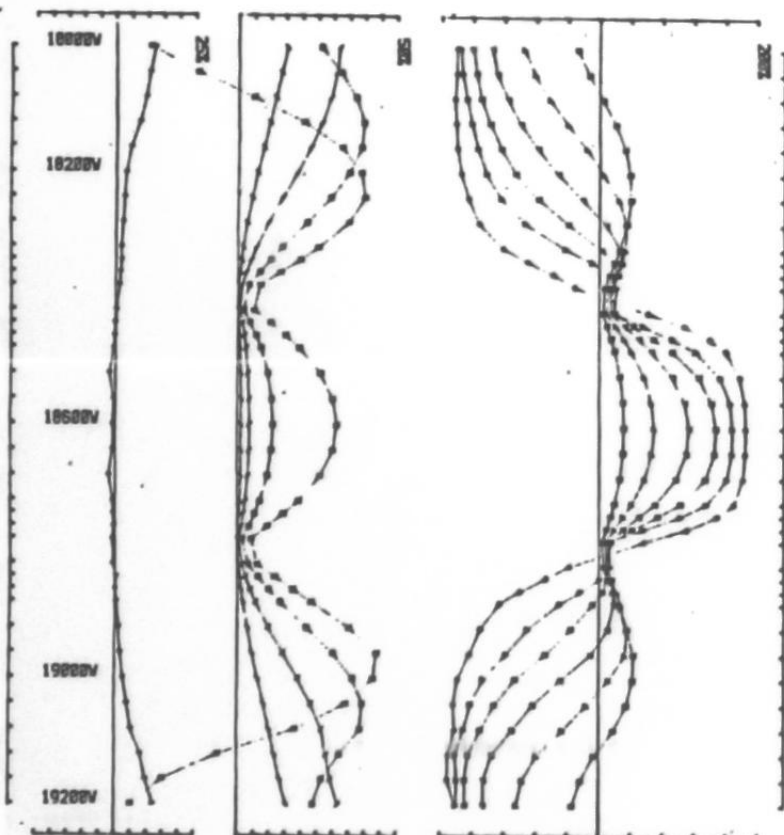
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 Project Area MANITOULAKE Survey for BP freq(Dal) 38.974
 Loops 8277 Line B component Hz secondary Ch 1



UTEM SURVEY conducted by LAMONTAGNE GEOPHYSICS Job 4802
 Project Area WINNIPEG LAKE Survey for BP Project 50,974
 Loop 0279 Line 0 component Hz secondary Ch 1



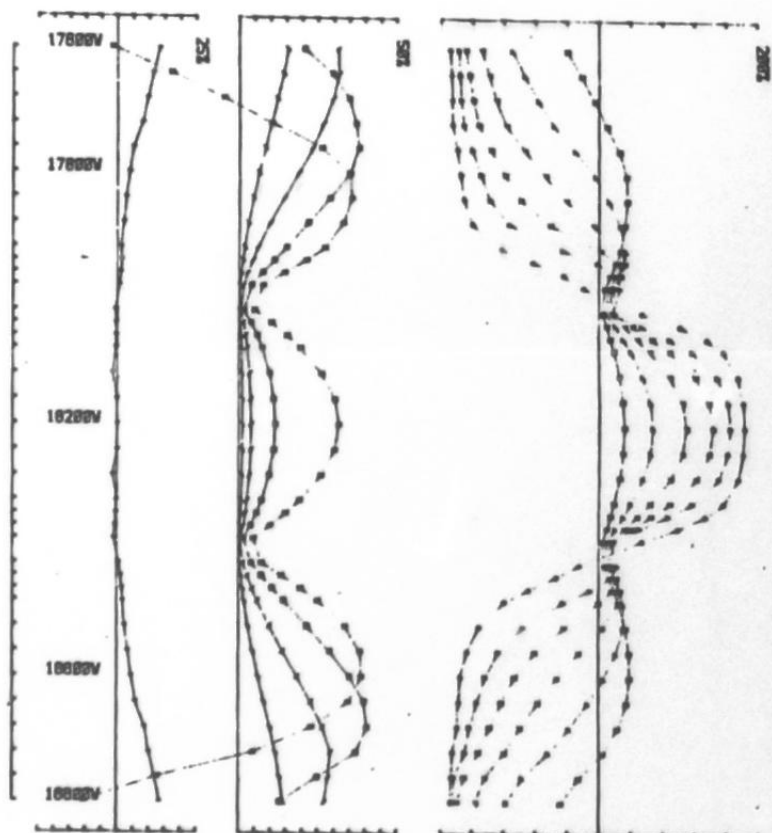
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 Project Area WINNIPEG LAKE Survey for BP Project 50,974
 Loop 0278 Line 0 component Hz secondary Ch 1



UTAH SURVEY conducted by LAMONTAGNE GEOPHYSICS Job 4882

Project Area HWITOU LAKE Survey for BP, frequency 38.974

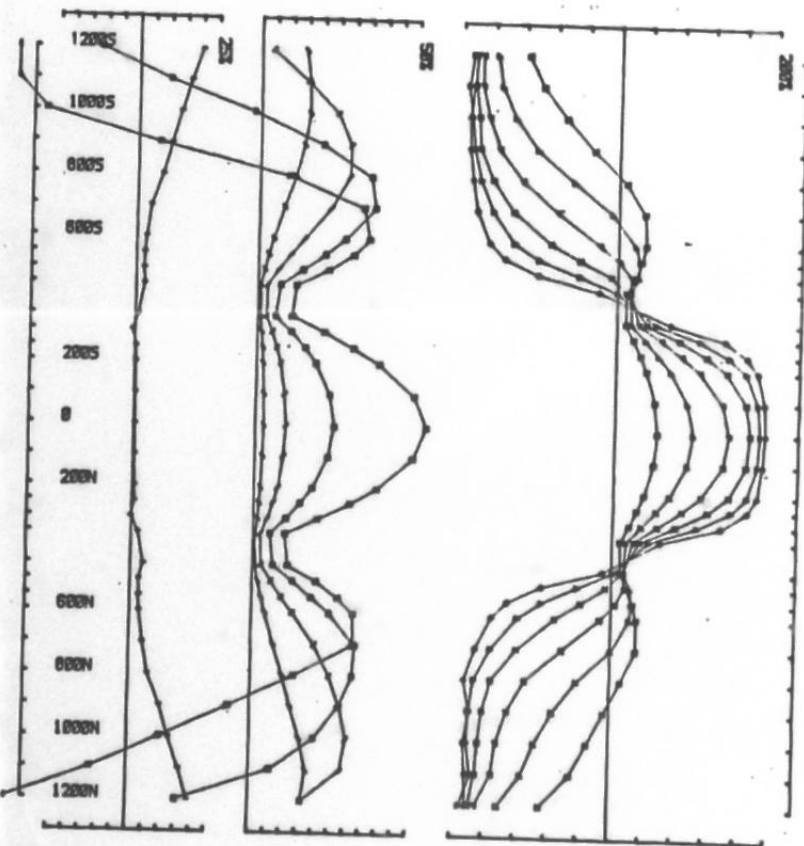
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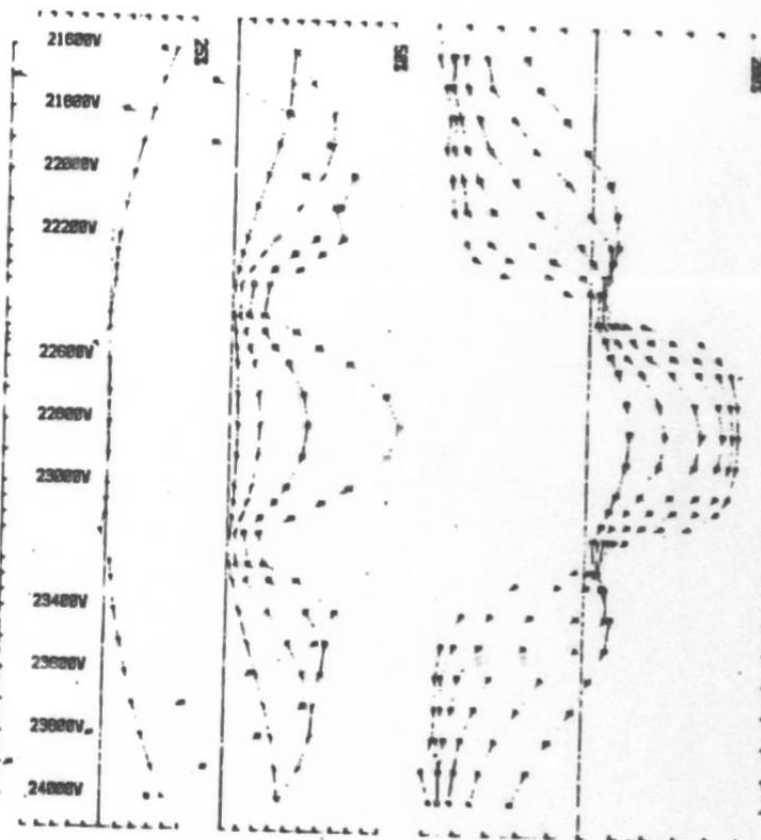
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Project Area HWITOU LAKE Survey for BP, frequency 38.974

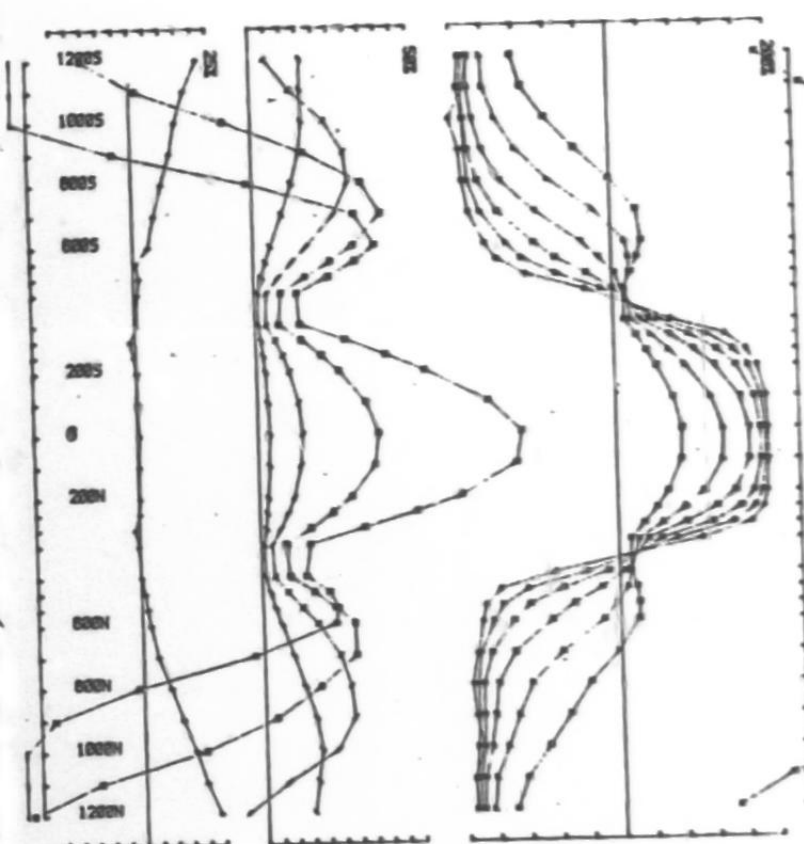
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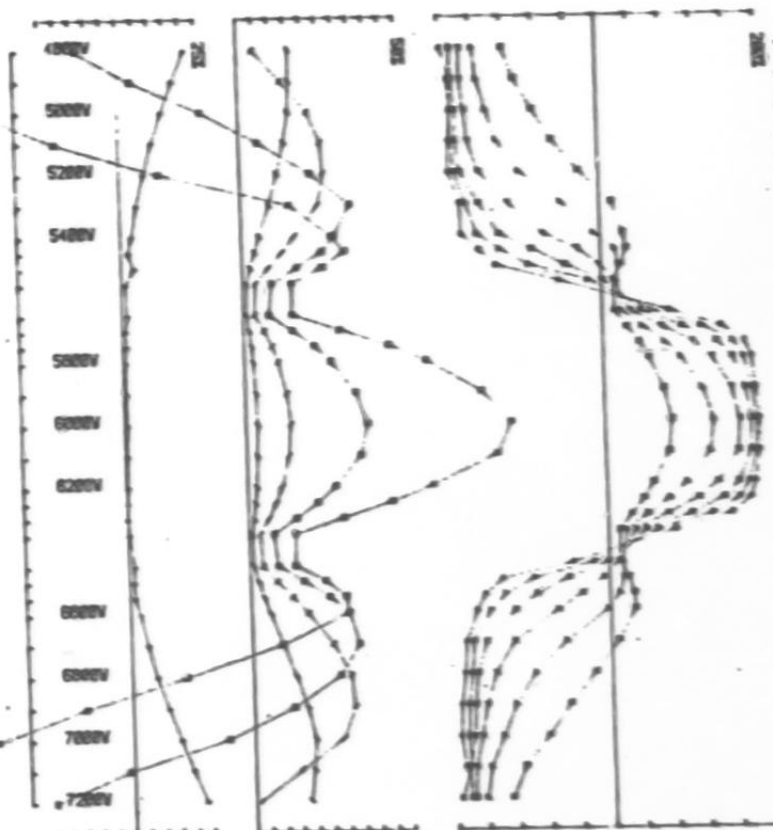
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 Loop 8289 Line 22000V component Hz secondary Ch 1



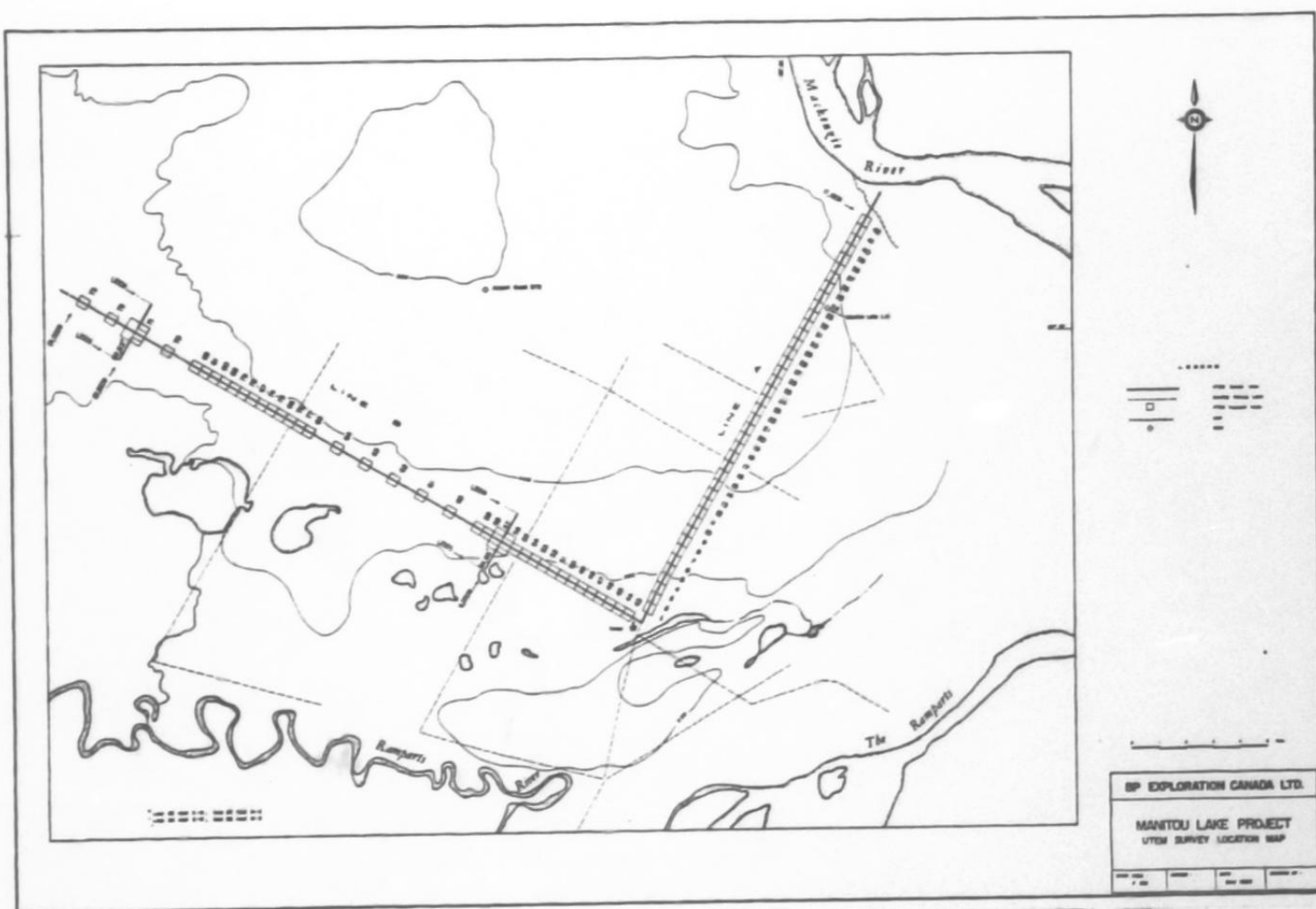
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 Project Area MANITOU LAKE Survey for BP Freshet 15,988
 Loop 8282 Line B component Hz secondary Ch 1



UTAH SURVEY conducted by LAVENTAGNE GEOPHYSICS Job 4002
 Project Area MONTICLOSA Survey for BP Project 15,900
 Loop 8205 Line 8000V component Hz secondary Ch 1



UTAH SURVEY conducted by LAVENTAGNE GEOPHYSICS Job 4002
 Project Area MONTICLOSA Survey for BP Project 15,900
 Loop 8204 Line 8000V component Hz secondary Ch 1



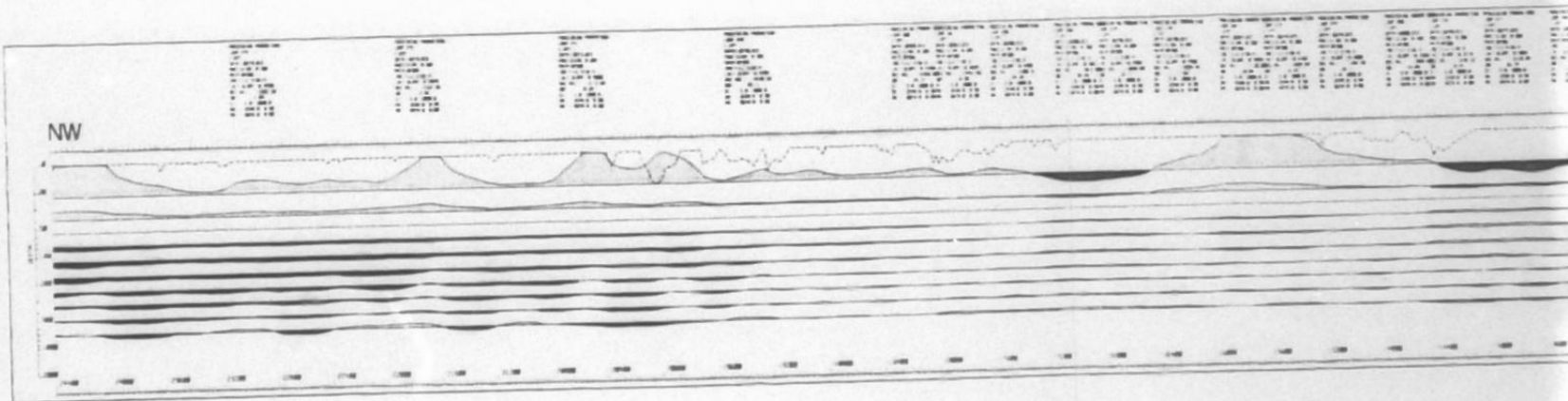
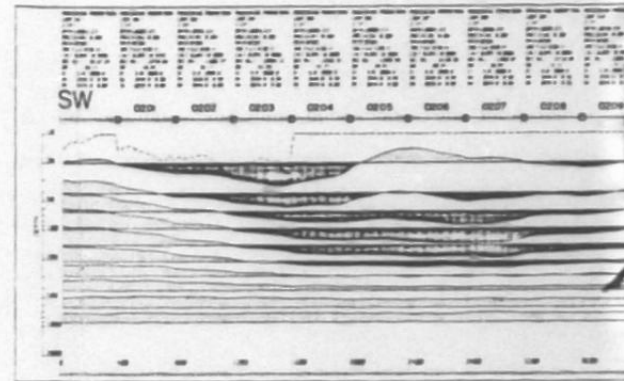


Figure 5A. ASD section line A.

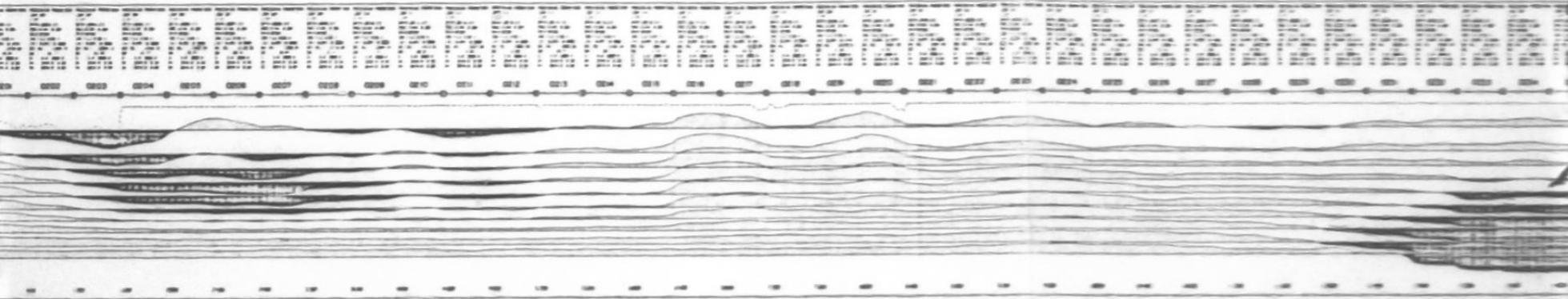


Figure 5B. EASD section line B.

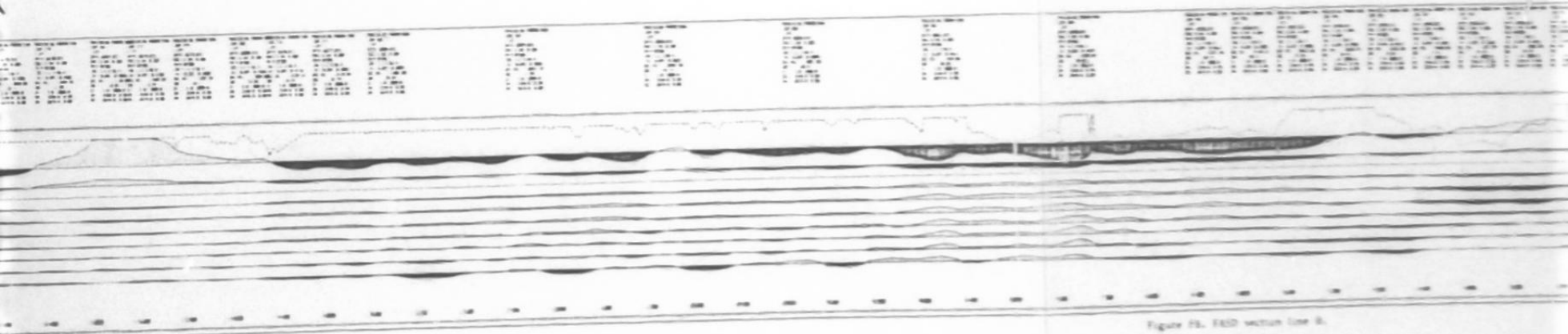


Figure 5A. ASD section line A.

Figures 5A and 5B. DIP data line A.

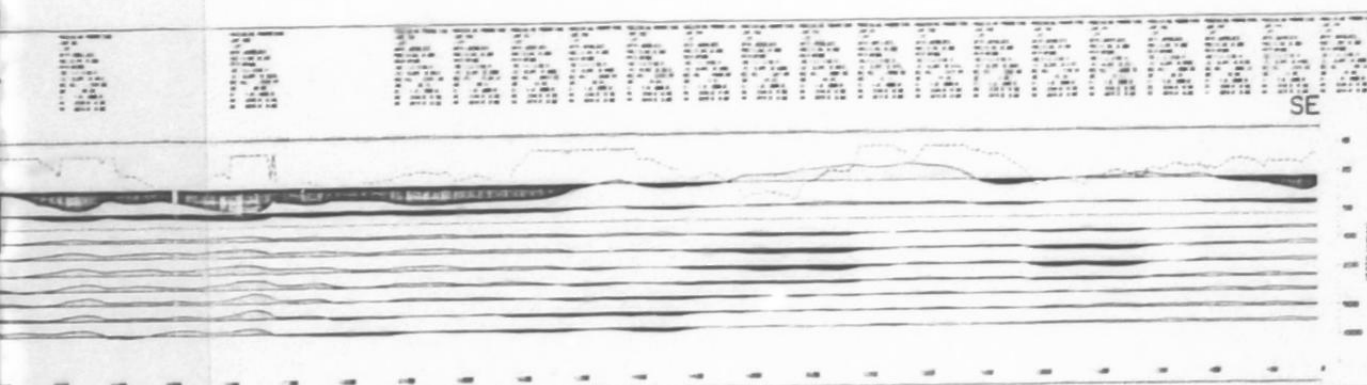
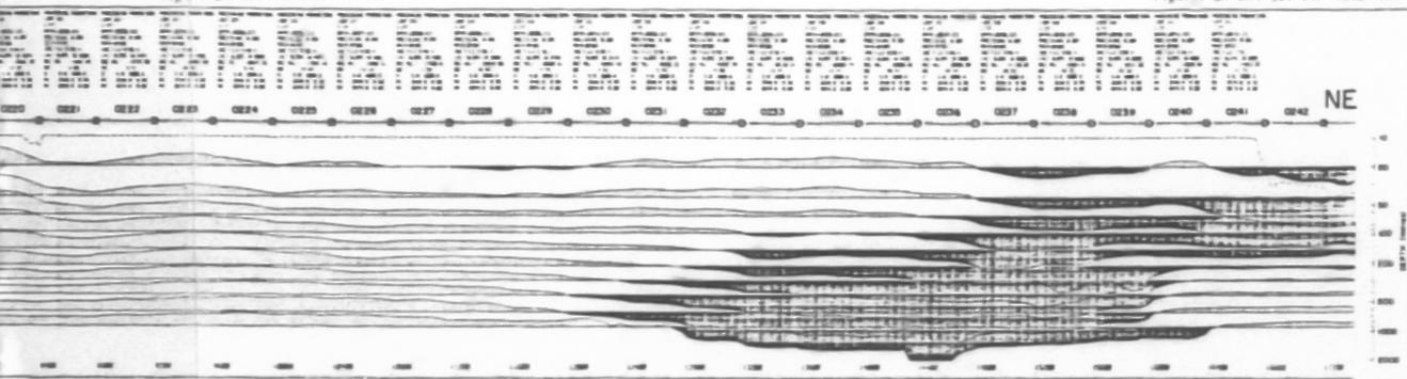
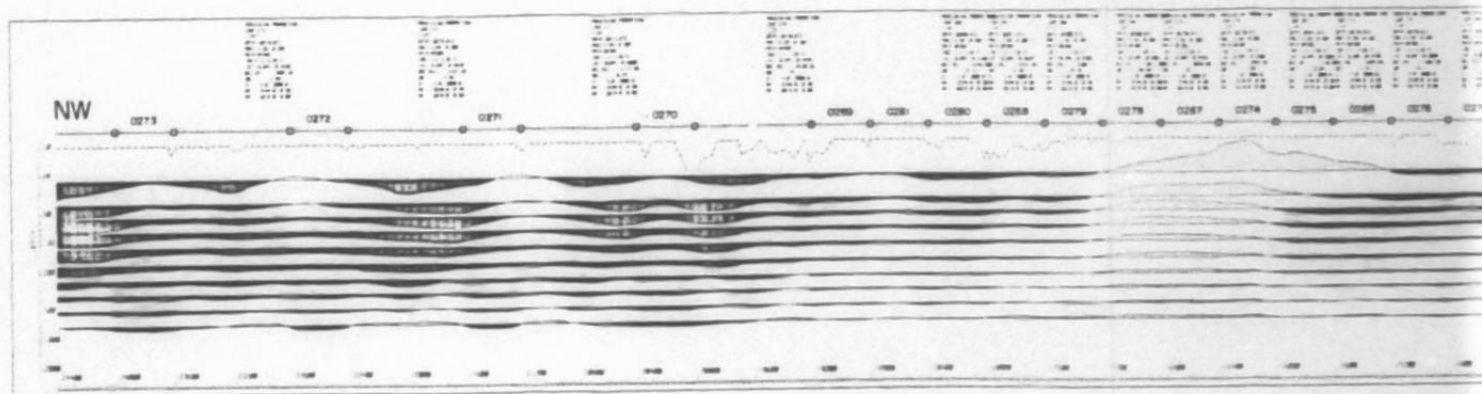
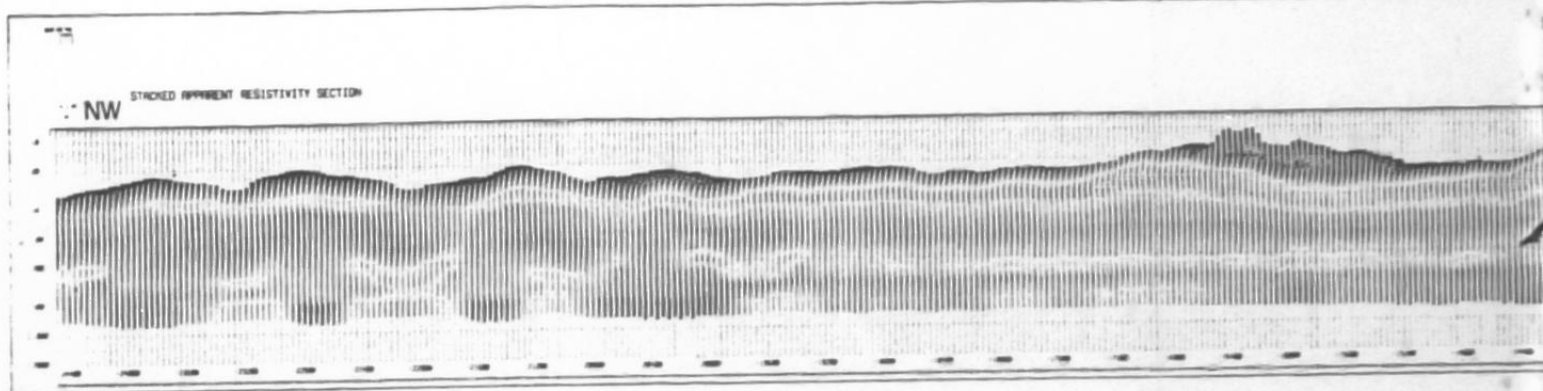


Figure 5B. FASD section line B.



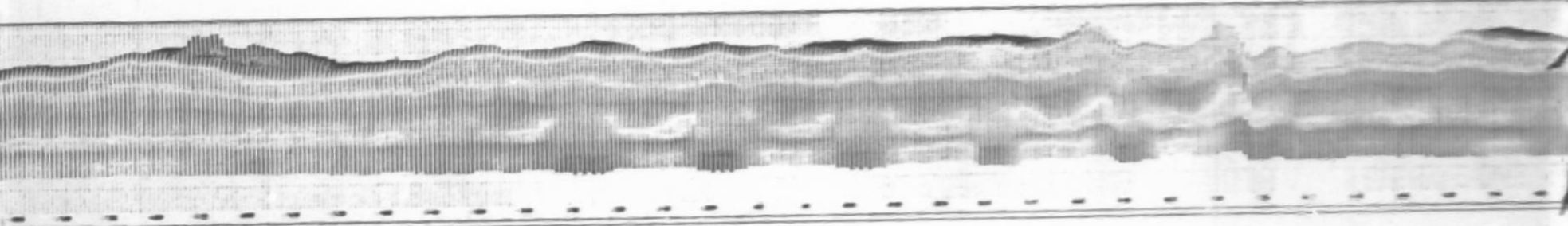
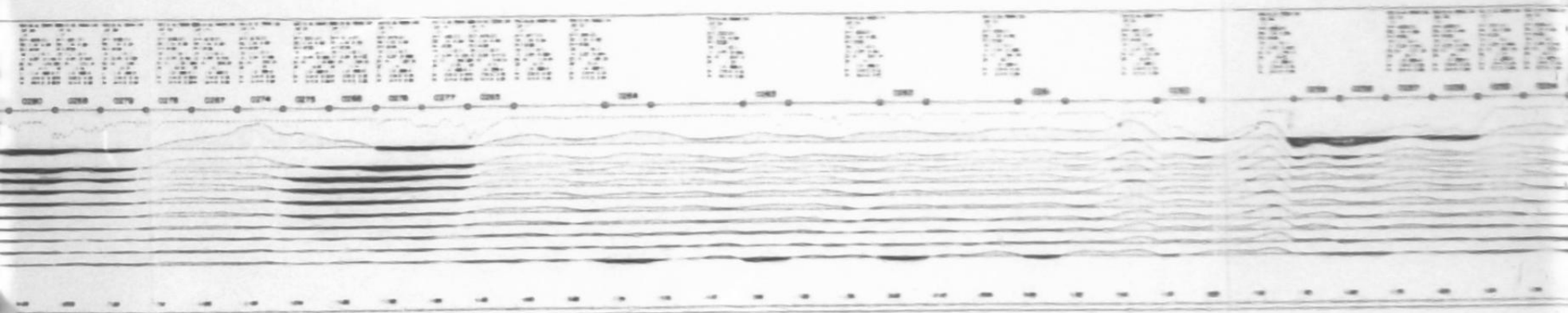


Figure 14. 800 section line 2.



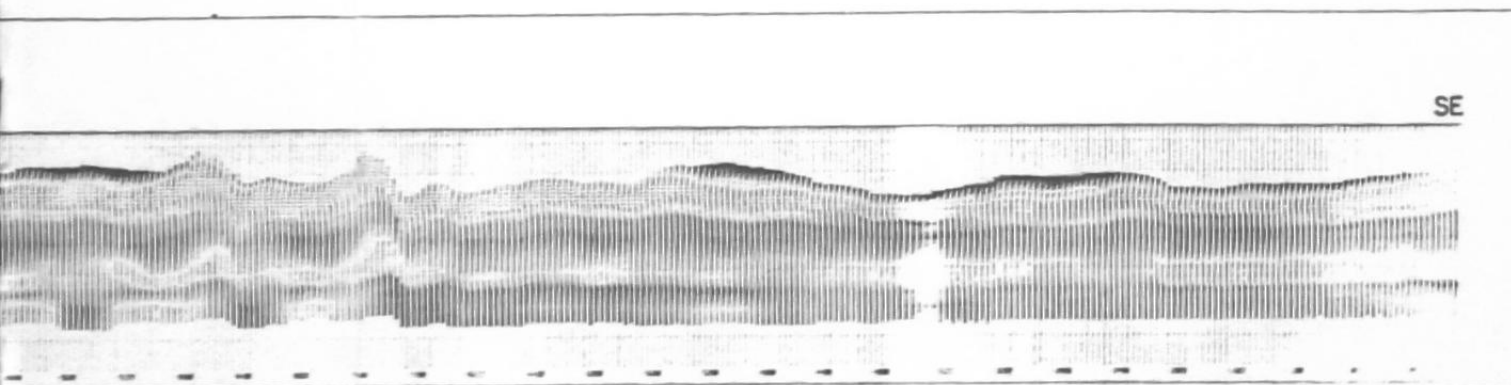
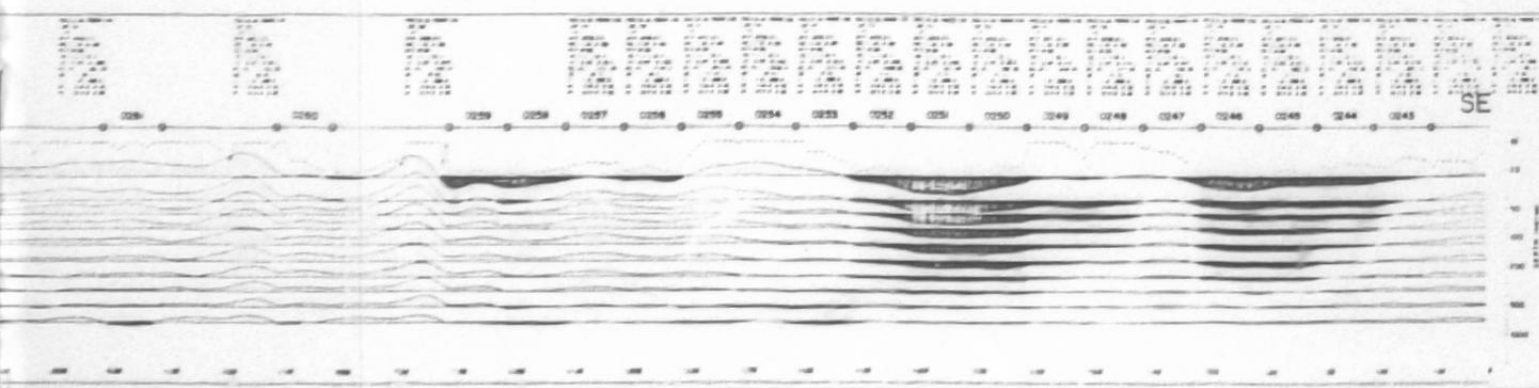
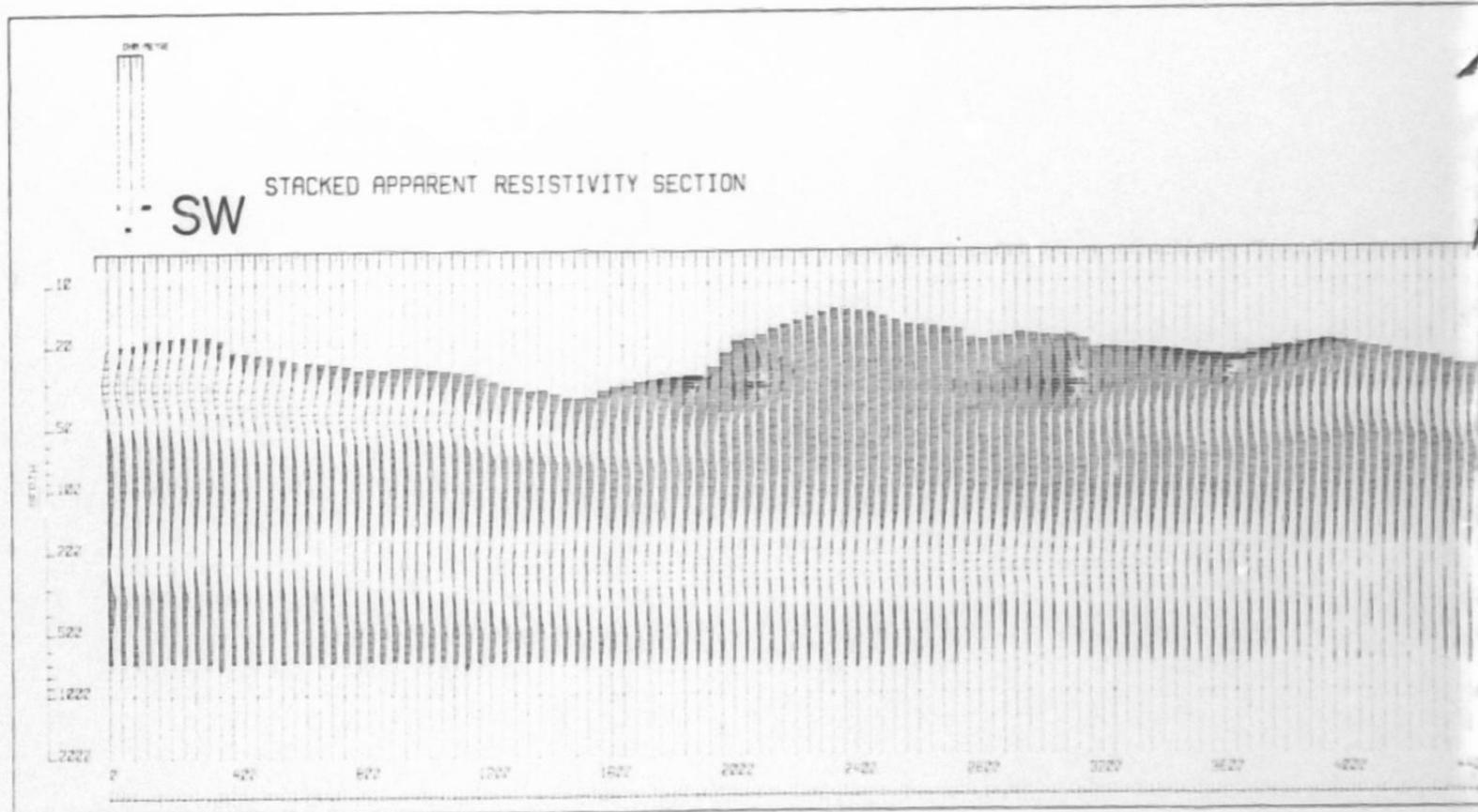
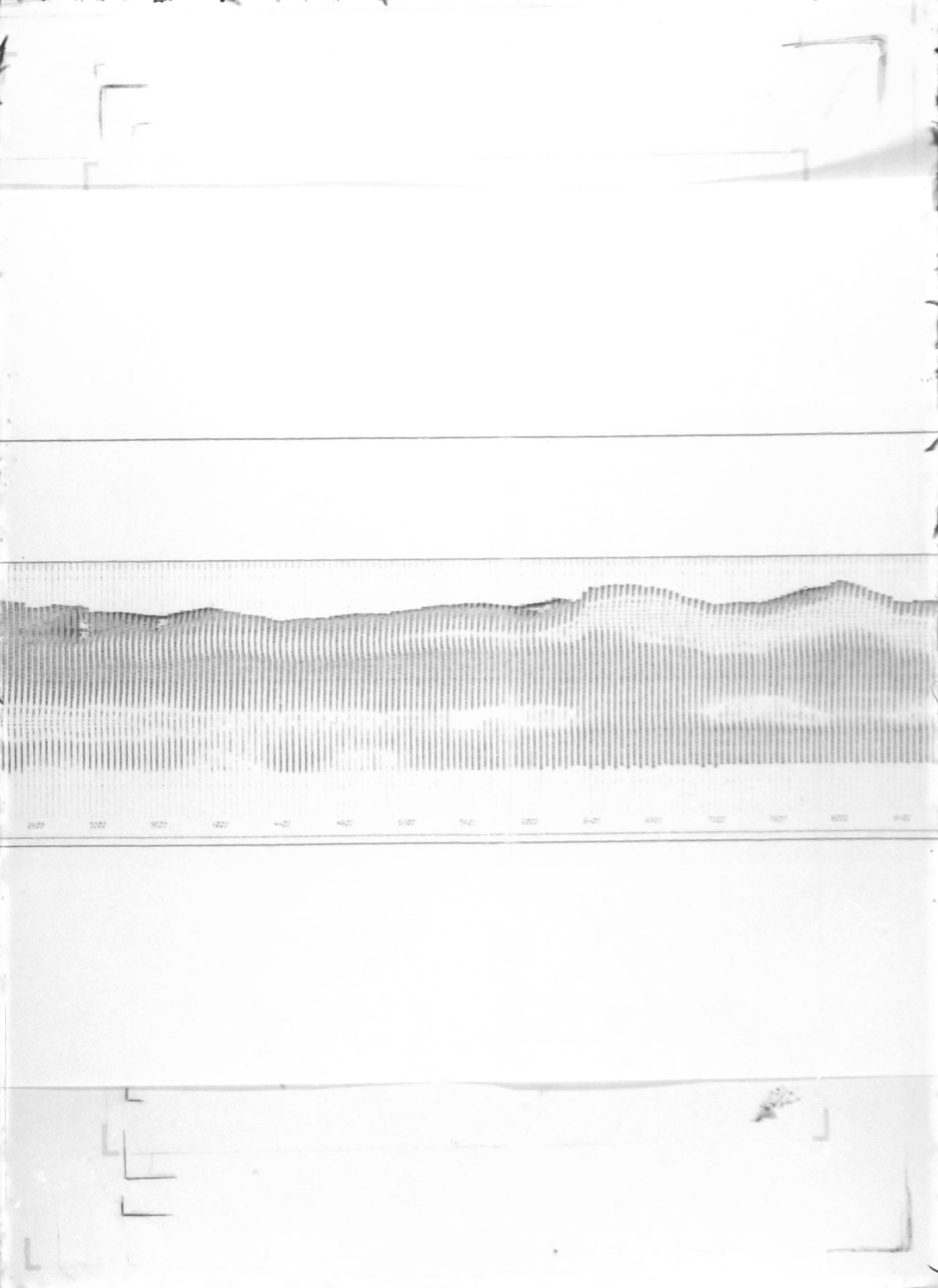


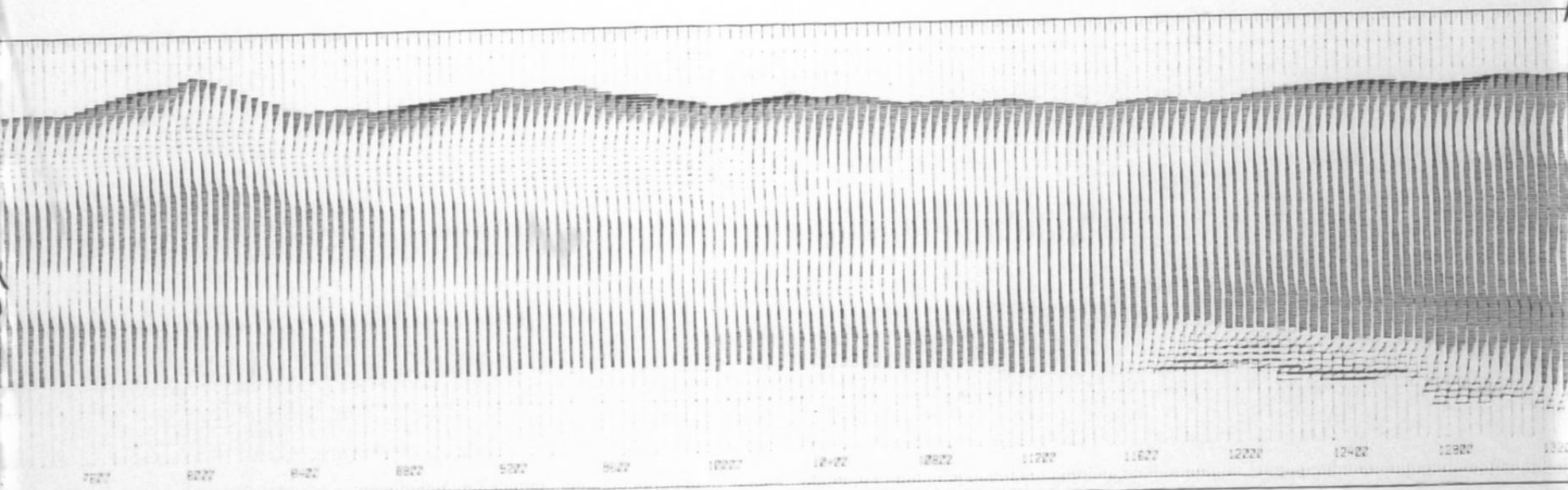
Figure 8A. 810 section line 8.

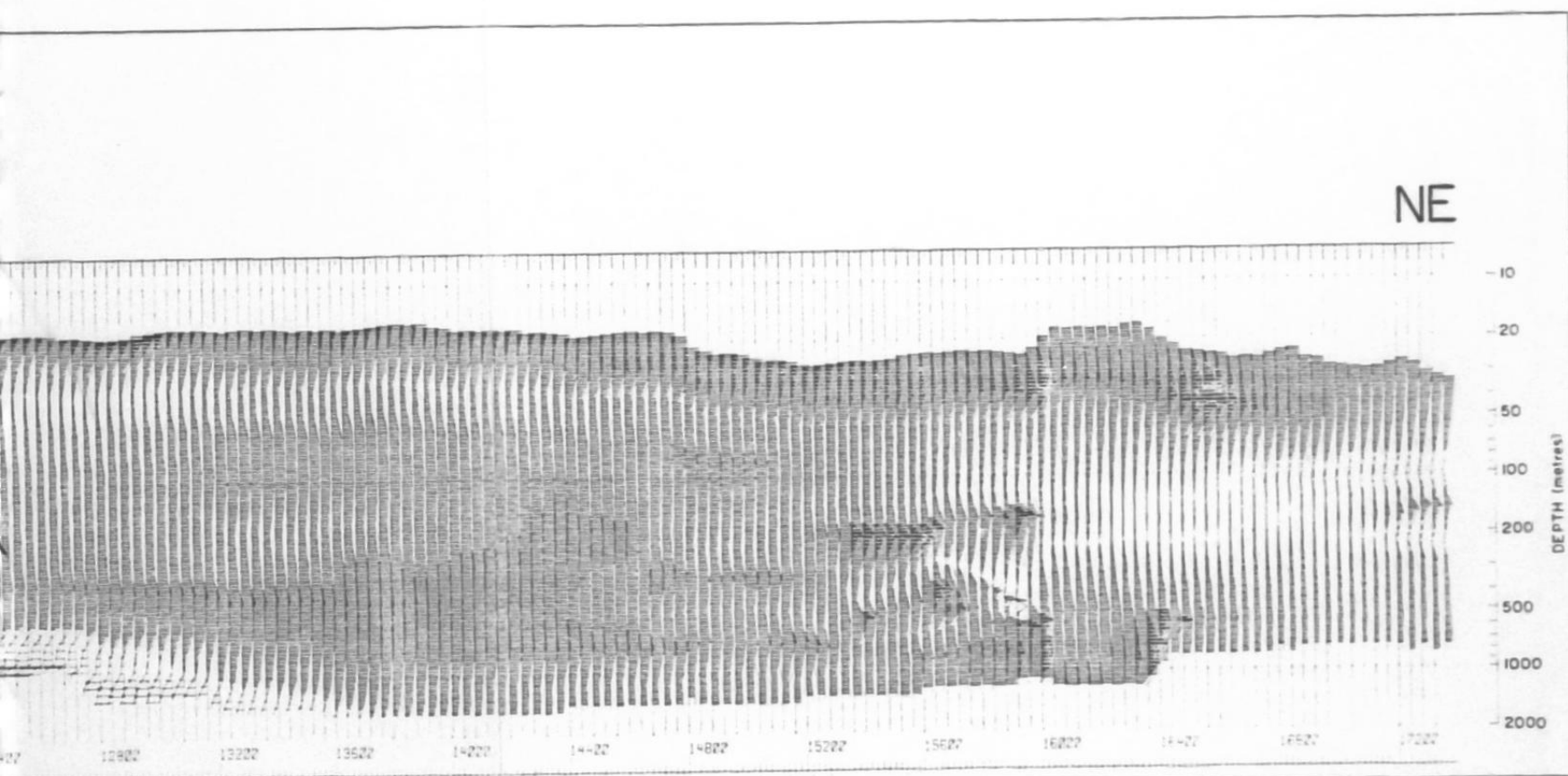
Figures 8A and 8B. Dip data line 8.

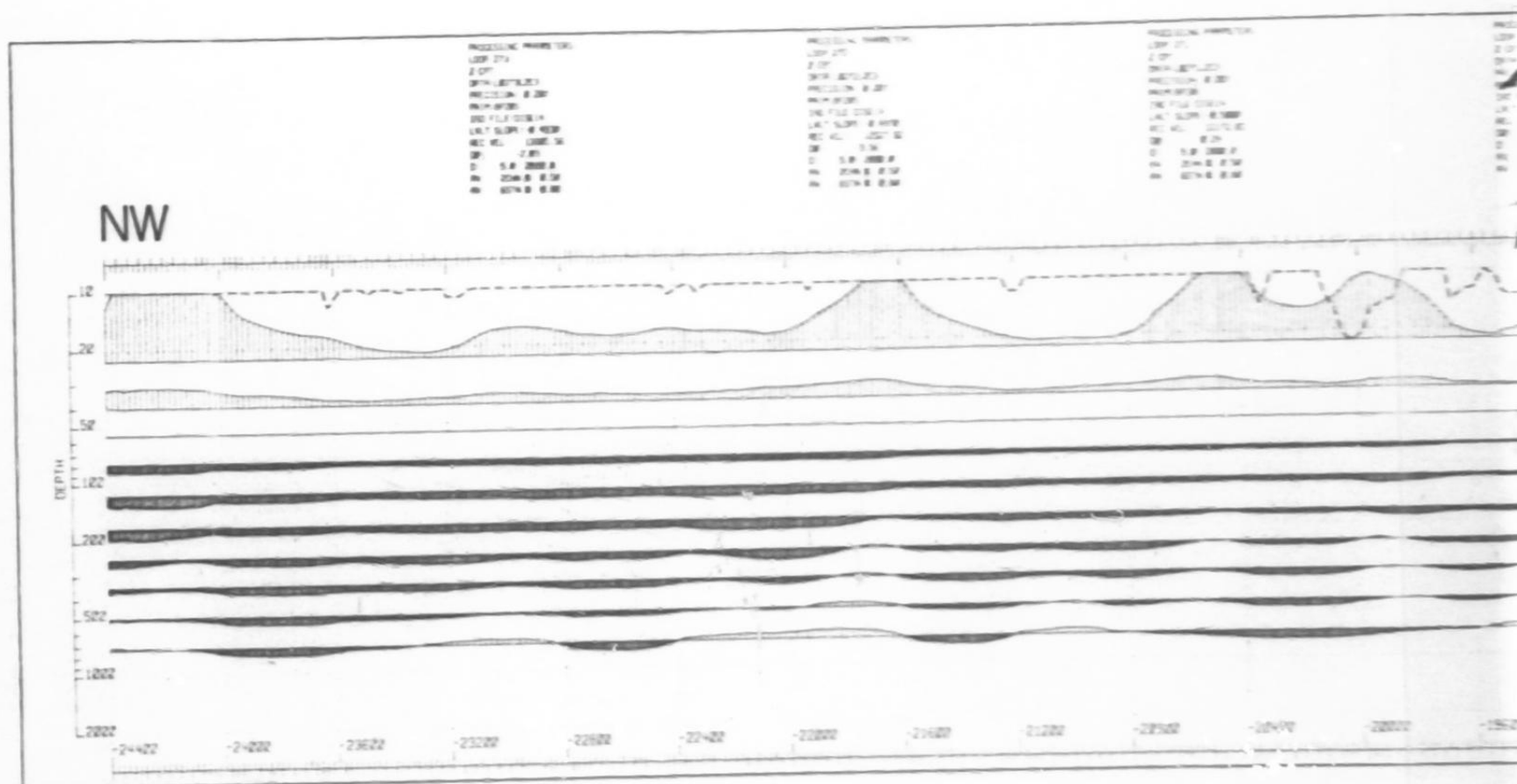












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PRECISION: 0.200
PRM: 100%
END FILE 000014
LVLT SLOPE: 0.5000
REC VEL: 100%
DP: 0.20
DI: 5.0 2000.0
AV: 2046.0 0.50
AV: 6074.0 0.50

PROCESSING PARAMETERS
LOOP 272
Z-CP
DATA: 100%
PRECISION: 0.200
PRM: 100%
END FILE 000014
LVLT SLOPE: 0.5000
REC VEL: 100%
DP: 0.20
DI: 5.0 2000.0
AV: 2046.0 0.50
AV: 6074.0 0.50

PROCESSING PARAMETERS
LOOP 273
Z-CP
DATA: 100%
PRECISION: 0.200
PRM: 100%
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REC VEL: 100%
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AV: 6074.0 0.50

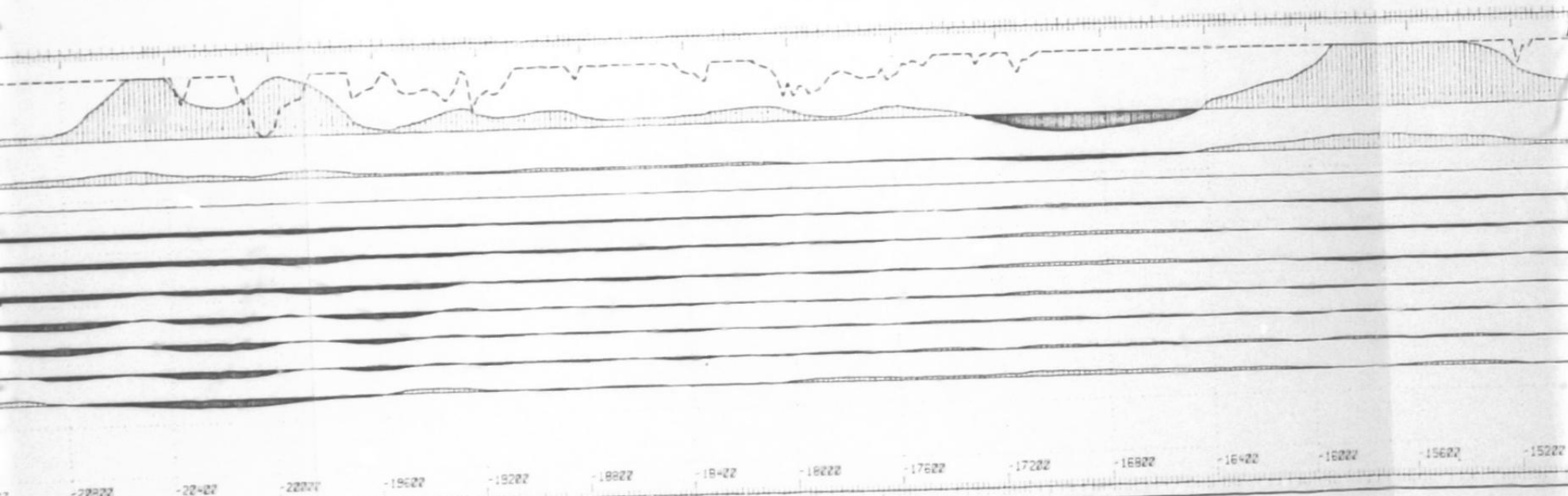
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PROCESSING PARAMETERS
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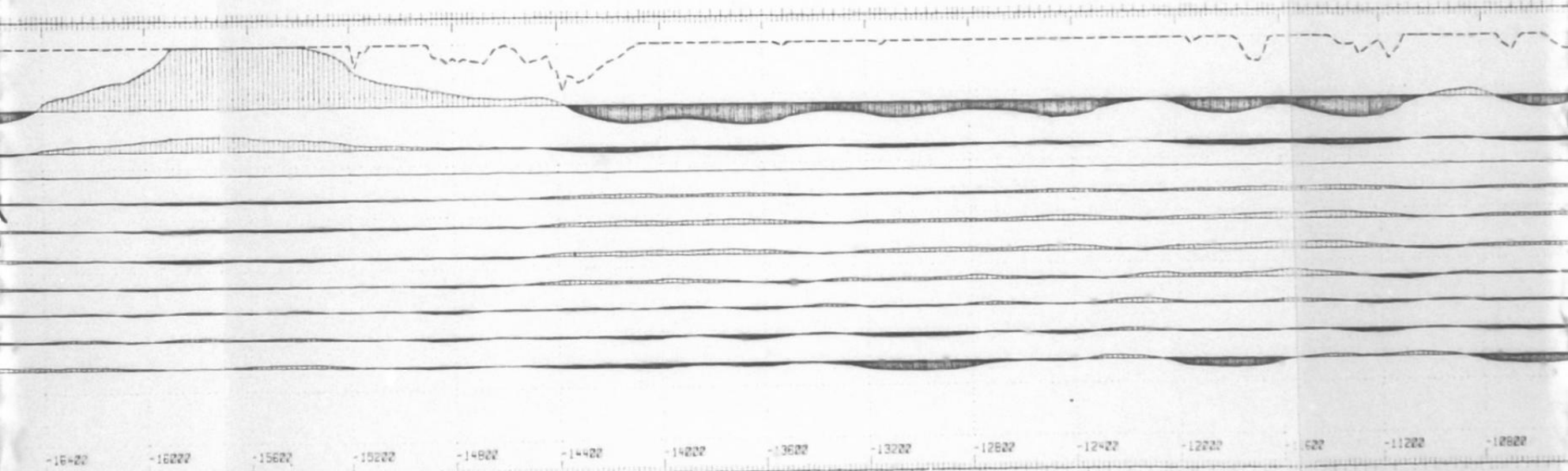
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PROCESSING PARAMETERS
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Z-CP
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PRECISION: 0.200
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LVLT SLOPE: 0.5000
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AV: 6074.0 0.50

PROCESSING PARAMETERS
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Z-CP
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LVLT SLOPE: 0.5000
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DP: 0.20
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AV: 2046.0 0.50
AV: 6074.0 0.50



PROCESSING PARAMETERS	PROCESSING PARAMETERS	PROCESSING PARAMETERS	PROCESSING PARAMETERS	PROCESSING PARAMETERS	PROCESSING PARAMETERS	PROCESSING PARAMETERS	PROCESSING PARAMETERS	PROCESSING PARAMETERS	PROCESSING PARAMETERS
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DATA: 18276.203	DATA: 18276.203	DATA: 18276.203	DATA: 18276.203	DATA: 18276.203	DATA: 18276.203	DATA: 18276.203	DATA: 18276.203	DATA: 18276.203	DATA: 18276.203
PRECISION: 0.201	PRECISION: 0.201	PRECISION: 0.201	PRECISION: 0.201	PRECISION: 0.201	PRECISION: 0.201	PRECISION: 0.201	PRECISION: 0.201	PRECISION: 0.201	PRECISION: 0.201
PRM: 89200	PRM: 89200	PRM: 89200	PRM: 89200	PRM: 89200	PRM: 89200	PRM: 89200	PRM: 89200	PRM: 89200	PRM: 89200
END FILE: 010014	END FILE: 010014	END FILE: 010014	END FILE: 010014	END FILE: 010014	END FILE: 010014	END FILE: 010014	END FILE: 010014	END FILE: 010014	END FILE: 010014
LVLT SLOPE: 0.4400	LVLT SLOPE: 0.4400	LVLT SLOPE: 0.4400	LVLT SLOPE: 0.4400	LVLT SLOPE: 0.4400	LVLT SLOPE: 0.4400	LVLT SLOPE: 0.4400	LVLT SLOPE: 0.4400	LVLT SLOPE: 0.4400	LVLT SLOPE: 0.4400
REC VEL: 14294.35	REC VEL: 14294.35	REC VEL: 14294.35	REC VEL: 14294.35	REC VEL: 14294.35	REC VEL: 14294.35	REC VEL: 14294.35	REC VEL: 14294.35	REC VEL: 14294.35	REC VEL: 14294.35
DP: 11.91	DP: 11.91	DP: 11.91	DP: 11.91	DP: 11.91	DP: 11.91	DP: 11.91	DP: 11.91	DP: 11.91	DP: 11.91
D: 5.0 2000.0	D: 5.0 2000.0	D: 5.0 2000.0	D: 5.0 2000.0	D: 5.0 2000.0	D: 5.0 2000.0	D: 5.0 2000.0	D: 5.0 2000.0	D: 5.0 2000.0	D: 5.0 2000.0
PA: 2046.0 0.50	PA: 2046.0 0.50	PA: 2046.0 0.50	PA: 2046.0 0.50	PA: 2046.0 0.50	PA: 2046.0 0.50	PA: 2046.0 0.50	PA: 2046.0 0.50	PA: 2046.0 0.50	PA: 2046.0 0.50
AV: 6574.0 0.00	AV: 6574.0 0.00	AV: 6574.0 0.00	AV: 6574.0 0.00	AV: 6574.0 0.00	AV: 6574.0 0.00	AV: 6574.0 0.00	AV: 6574.0 0.00	AV: 6574.0 0.00	AV: 6574.0 0.00



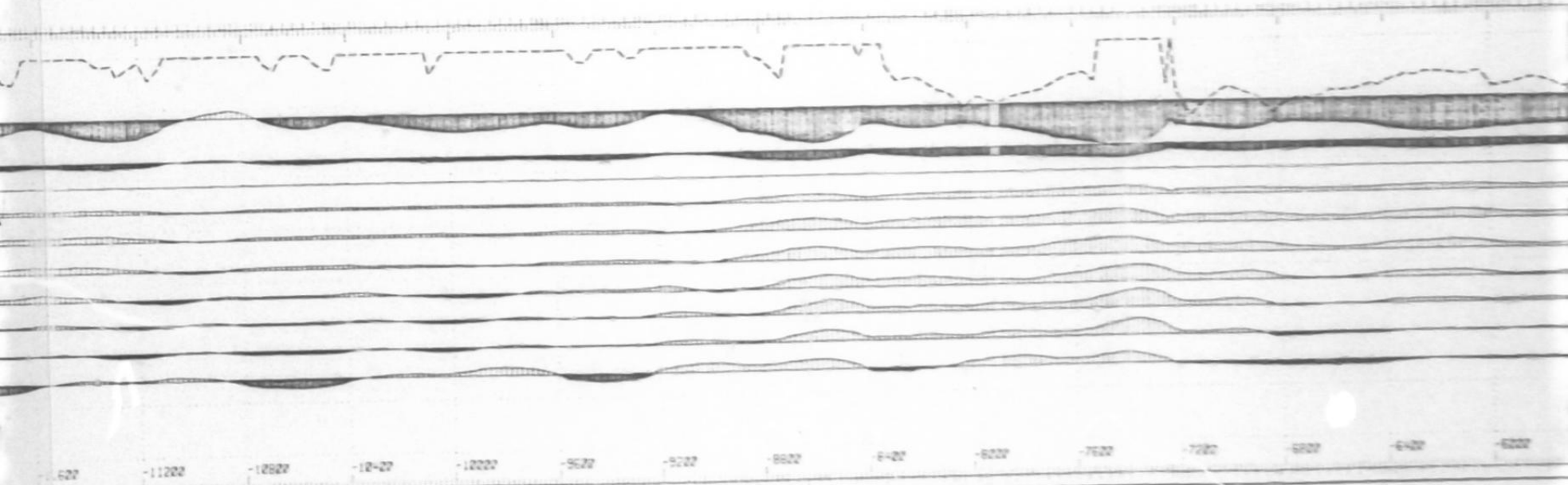
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REL. VEL. 0.0000
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D 5.0 2000.0
AN 2000.0 0.00
AN 0000.0 0.00

PROCESSING PARAMETERS
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DATA UNLOADED
PRECISION 0.200
FROM 000000
END FILE 000000
UNIT SLOPE 0.0000
REL. VEL. 0.0000
DB 20.00
D 5.0 2000.0
AN 2000.0 0.00
AN 0000.0 0.00

PROCESSING PARAMETERS
LOOP 200
Z OFF
DATA UNLOADED
PRECISION 0.200
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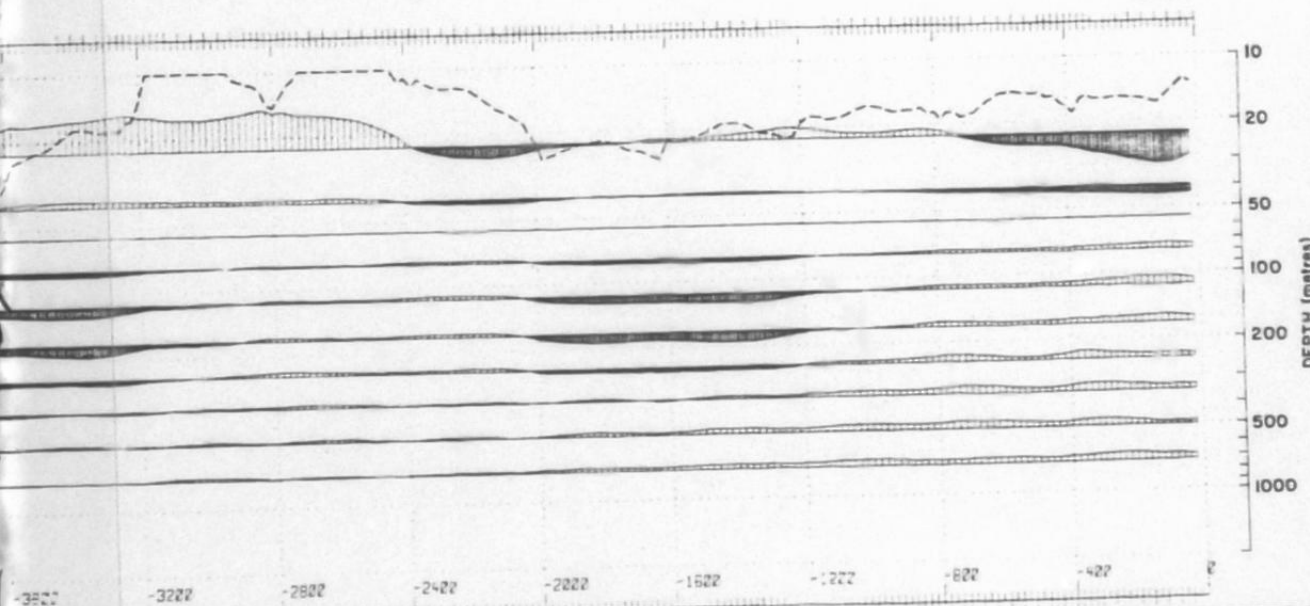
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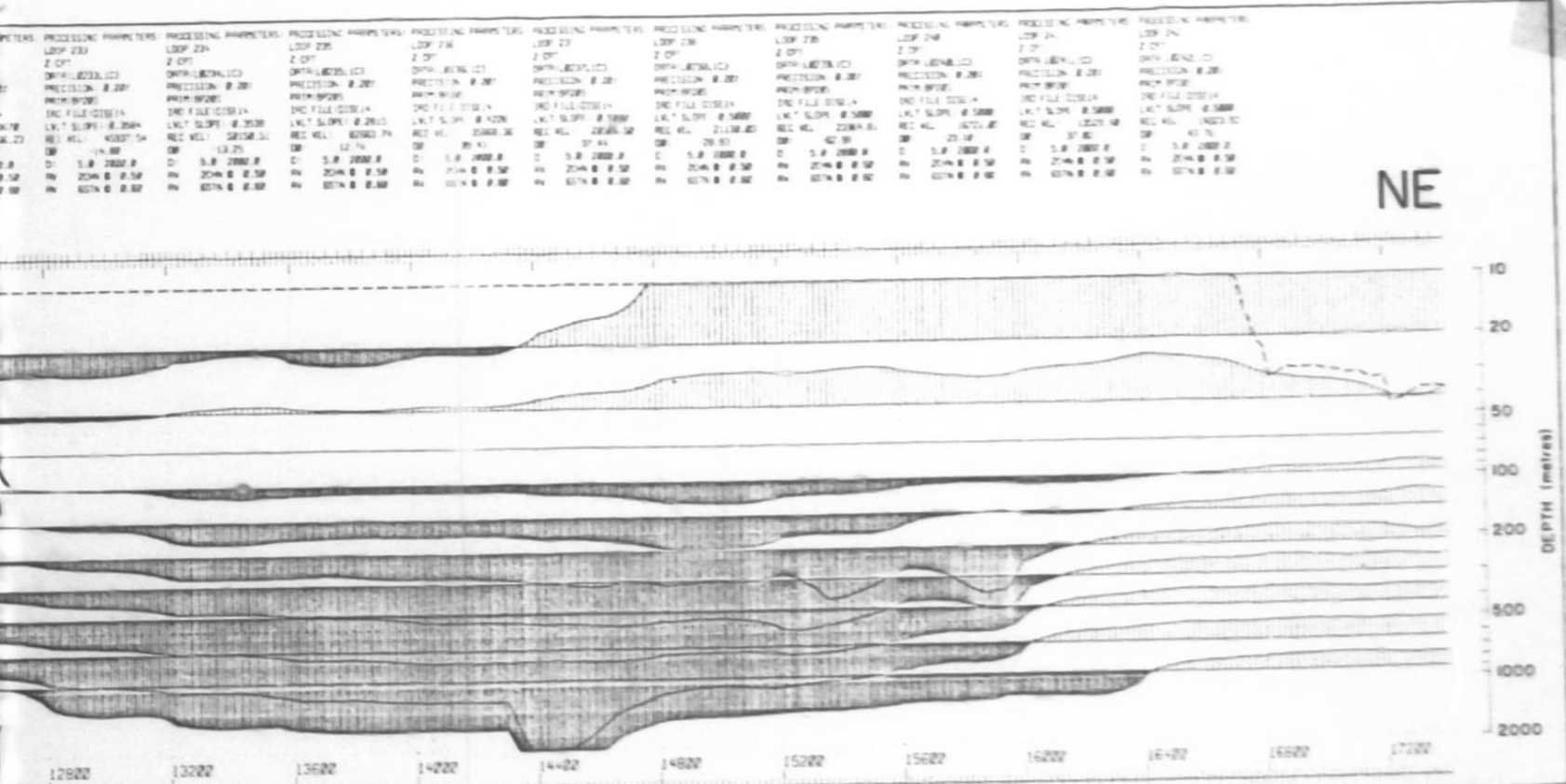
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D 5.0 2000.0
AN 2000.0 0.00
AN 0000.0 0.00



PROCESSING PARAMETERS	PROCESSING PARAMETERS	PROCESSING PARAMETERS	PROCESSING PARAMETERS	PROCESSING PARAMETERS	PROCESSING PARAMETERS	PROCESSING PARAMETERS	PROCESSING PARAMETERS	PROCESSING PARAMETERS	PROCESSING PARAMETERS
LOOP 250	LOOP 251	LOOP 252	LOOP 253	LOOP 254	LOOP 255	LOOP 256	LOOP 257	LOOP 258	LOOP 259
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PRECISION: 0.200	PRECISION: 0.200	PRECISION: 0.200	PRECISION: 0.200	PRECISION: 0.200	PRECISION: 0.200	PRECISION: 0.200	PRECISION: 0.200	PRECISION: 0.200	PRECISION: 0.200
PRM: 10000	PRM: 10000	PRM: 10000	PRM: 10000	PRM: 10000	PRM: 10000	PRM: 10000	PRM: 10000	PRM: 10000	PRM: 10000
END FILE: 010014	END FILE: 010014	END FILE: 010014	END FILE: 010014	END FILE: 010014	END FILE: 010014	END FILE: 010014	END FILE: 010014	END FILE: 010014	END FILE: 010014
LVL: 10000	LVL: 10000	LVL: 10000	LVL: 10000	LVL: 10000	LVL: 10000	LVL: 10000	LVL: 10000	LVL: 10000	LVL: 10000
REC: 10000	REC: 10000	REC: 10000	REC: 10000	REC: 10000	REC: 10000	REC: 10000	REC: 10000	REC: 10000	REC: 10000
DI: 10000	DI: 10000	DI: 10000	DI: 10000	DI: 10000	DI: 10000	DI: 10000	DI: 10000	DI: 10000	DI: 10000
AV: 10000	AV: 10000	AV: 10000	AV: 10000	AV: 10000	AV: 10000	AV: 10000	AV: 10000	AV: 10000	AV: 10000
AV: 10000	AV: 10000	AV: 10000	AV: 10000	AV: 10000	AV: 10000	AV: 10000	AV: 10000	AV: 10000	AV: 10000

SE





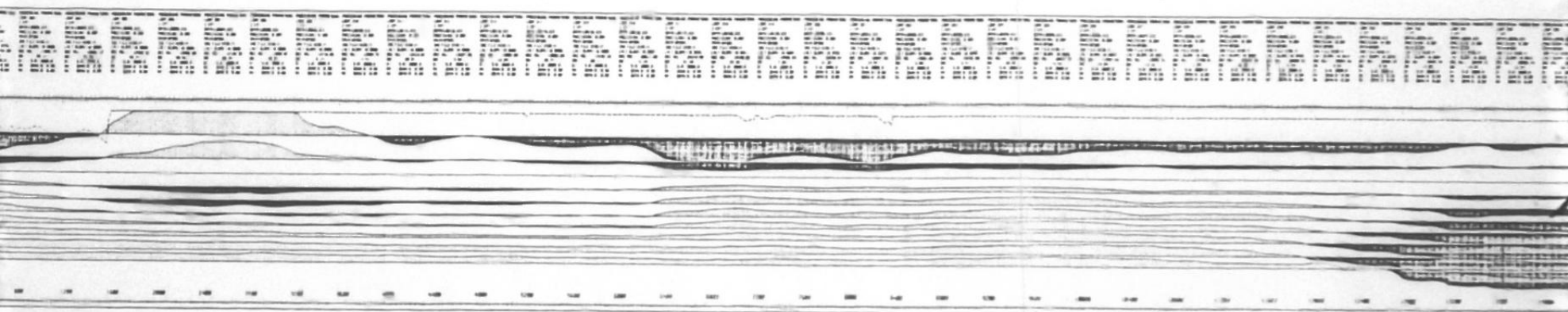
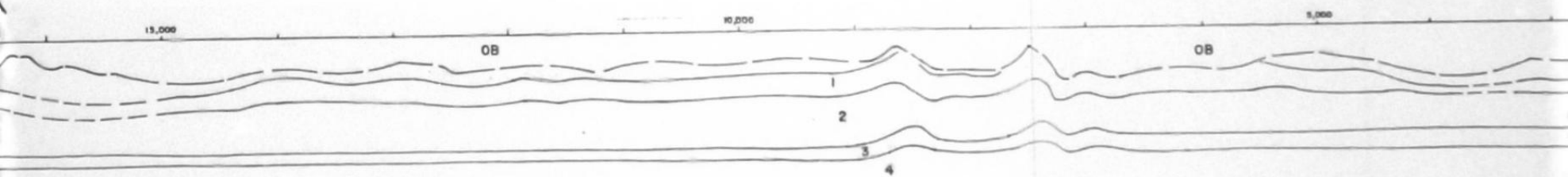


Figure 5B. TARD section line A.



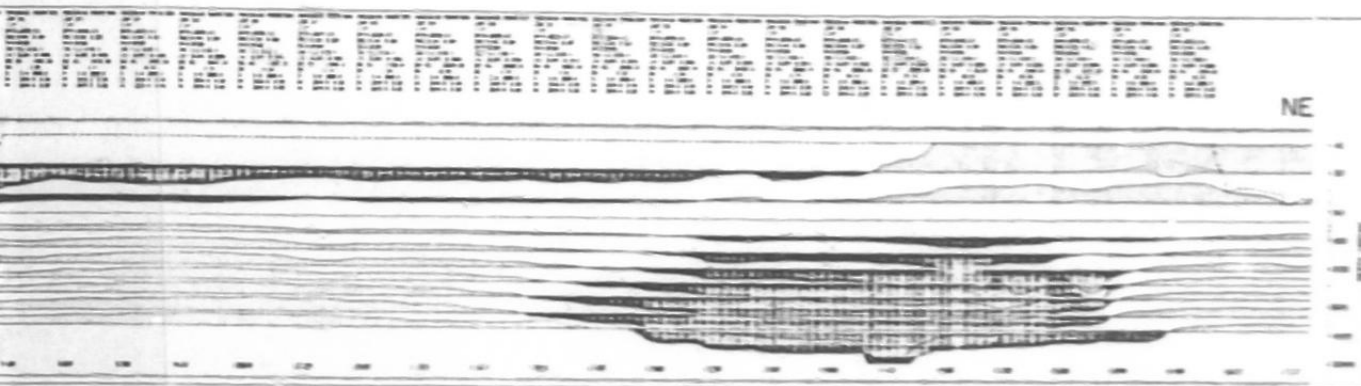


Figure 5B. FAD section line 8.

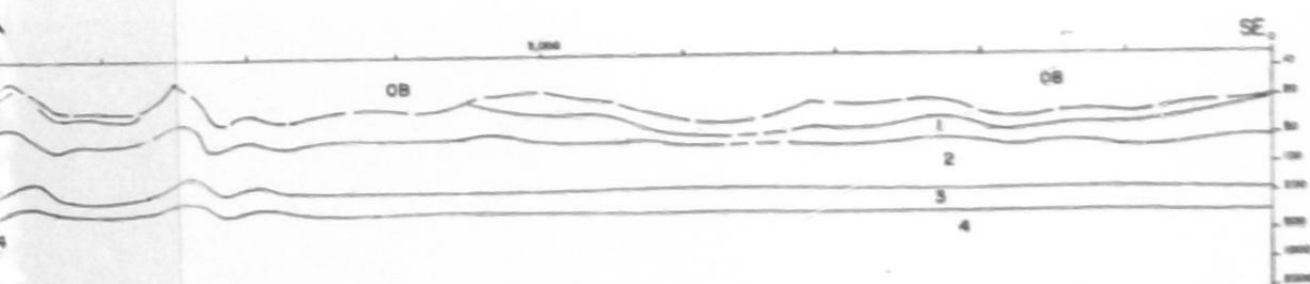


Figure 5A (top): SEAB section of line 8.

Figure 5A (bottom): Interpretation of line 8.