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Interpretation of Frequency Domain Airborne Electromagnetic Data

Final report

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SUMMARY

The results of multifrequency airborne electromagnetic surveys can be interpreted to yield a terrain map which faithfully reflects the surficial geology. This report presents a method for doing so, in an automatic fashion, on a digital computer. Although the present material refers specifically to the data obtained with the Scintrex TRIDEM AEM system it is expected that the concepts described here will be applicable to the interpretation of other frequency domain AEM data. The interpretation method presented here, first of all includes the application of an altitude correction to the survey data. It then translates the three-frequency secondary field data into an apparent conductance and/or conductivity of the overburden.

1 - INTRODUCTION

The Geological Survey of Canada has actively pursued the evaluation of the usefulness of airborne electromagnetic systems for the purpose of mapping surficial geology since 1963. The earliest studies (Collett, 1966) were aimed at an appraisal of the INPUT^R system with respect to aquifer detection. Although the results were but of a qualitative nature, they were sufficiently encouraging that the study was continued with an INPUT^R survey of the Ottawa region in 1967. The data obtained here was quantitatively interpreted by Dyck, Becker and Collett and the techniques for doing this were published (Dyck et al., 1974).

This work is a continuation of the same programs. The system under present consideration however, is the Scintrex TRIDEM. This three frequency (500 Hz, 2000 Hz, 8000 Hz) coplanar, inphase-quadrature, fixed wing (17.3 meter coil separation) installation is described by Bosschart and Seigel (1974) and in the Scintrex report attached here as Appendix I. In order to appraise this system the Geological Survey of Canada contracted with Scintrex for the survey of a large area near Timmins, Ont. and of a smaller area southeast of Hawkesbury, Ont. near the town of Alfred (Figure 1). A preliminary report on the interpretation of the Timmins data was published by Sinha (1976). This report consequently only deals with the interpretation of the Alfred data.

2 - THE SURVEY AREA

The geology of the survey area was mapped by Wilson (1946). The bedrock consists of limestones of the Trenton, Chazy and Beekmantown formations typical of eastern Ontario. It is overlain by bog deposits, glacial tills, sands, and, marine clays of varying thickness (Gwyn and Thibault, 1975, 1973). Ground control was provided by a number of DC resistivity soundings (Andrieux, 1968) and a very limited seismic survey (St-Hilaire, 1976). The location of the control stations is superimposed on the TRIDEM flight line map shown in Figure 2. The ground control data indicates a rough bedrock topography which is covered by the surficial deposits. Electrically, there appear to be three distinct layers. The dominant of these is the highly conductive Champlain Sea clay whose thickness ranges from zero to nearly 100 meters. It reposes on a highly resistive bedrock and is overlain by a relatively thin (1 - 10 m) cover of glacial drift which is again much more resistive.

As shown in Figure 2, a total of some 250 line kilometers of 3 frequency TRIDEM data were obtained by Scintrex in 1974 in the survey area. This data was submitted, in digital form to MERI for interpretation, early in 1975. The line spacing was of the order of 400 meters while the nominal survey altitude was 53 meters or 175 feet.

3 - DATA PROCESSING

Typical original survey data which was submitted to MERI is shown in Figure 3. Upon receipt it was corrected for excessive zero drift, high frequency and altitude variations. A typical corrected data set is shown in Figure 4. Finally, as shown in Figure 5, for the purposes of interpretation, the data set was converted from an inphase-quadrature presentation to an amplitude-phase presentation. The details of the filtering and data correction procedures are given in the Institute's Report Number 1 which is enclosed here as Appendix 2. The original and corrected data sets are attached to this report in Appendices 3, 4 and 5 respectively.

Before going on to a discussion of the interpretation techniques it is perhaps of interest to demonstrate the effectiveness of the altitude correction method which was used here. Figure 6 shows the 2000 Hz inphase and quadrature data obtained, for this purpose, along line 8, at two different altitudes. The flights were made at a nominal altitude of 150 and 200 feet. It can be seen that the average 50 foot elevation difference can result in amplitude differences as great as 1000 ppm and phase differences of up to 0.15 radians. Once the data is corrected for elevation differences however, as shown in Figure 7, the amplitude difference is reduced to less than 100 ppm on the average, while the average phase difference is of the order of 0.02 radians. These residual differences are probably attributable to the system noise and small spatial deviations between the two flight paths.

4 - INTERPRETATION

The objective of the various procedures which are outlined below is to translate the six individual corrected secondary field parameters, which constitute the TRIDEM output, into the physical parameters of the overburden such as layer thicknesses and conductivities. Furthermore, because of the amount of data to be processed, the interpretation procedures had to be computerized and held uniform throughout the survey area. It is this constraint which above all dictated the use of a "table look-up" approach in conjunction with a simple predetermined model. In particular it was assumed that all the conduction took place in a single layer which rests on a non-conductive bedrock and which in turn is covered by a variable thickness of non-conductive drift. The computer program then needed only to output the parameters (i.e. depth to top, conductance and where possible thickness and conductivity) for this hypothetical layer as a function of the secondary field characteristics.

The interpretation program (Appendix 6) is built around eight pairs of precomputed tables that are stored on tape. Each pair of tables corresponds to a given phase of the secondary field which constitutes the principal entry into the tables. In particular the tables are prepared for a secondary field phase of 0.33, 0.40, 0.49, 0.60, 0.73, 0.90, 1.10 and 1.35 radians. Table A of each pair yields an apparent layer thickness as a function of its depth of burial and the rate of change of secondary field phase with frequency. On the other hand, Table B of each pair, yields the

layer conductance and/or conductivity and depth of burial as a function of secondary field amplitude and layer thickness. Since the depth of burial is initially unknown a trial value is assumed and a number of iterations are made between the two tables until a consistent set of results is obtained.

The first step in the interpretation procedure is to determine which of the eight preselected phases is closest to the phase of the 2000 Hz secondary field. This phase value is called the "operating phase". Once it is determined, the exact frequency at which the secondary field would have that operating phase is obtained by interpolation in the available multi-frequency data. The next step consists of a determination, once again by interpolation, of the secondary field amplitude and rate of phase change with frequency at the operating phase. These two quantities are then read into the stored A and B tables and the layer parameters are read out directly. If the evaluated layer thickness exceeds the "thick" limit (e.g. 40 meters at 0.6 radians) the program output consists of an "apparent" half space conductivity and its depth of burial. When the evaluated layer thickness is inferior to the "thin" limit (e.g. 0.5 meters at 0.6 radians) the program outputs the "apparent" layer conductance. Finally, if the layer thickness falls between those two limits the computer program evaluates both the apparent conductivity and the apparent conductance. Evidently the layer thickness can be obtained from these two quantities.

The program contains a number of tests which evaluate the consistency of the data with the assumed model. In particular

the program ensures that the secondary field phase decreases with frequency and that the corresponding amplitudes exceed 200 ppm. It also ensures that the rate of phase change with frequency lies within the range allowed for the assumed model. Should the data seriously violate any of these criteria a diagnostic is indicated and no interpretation is made.

A typical graphical output of the interpretation program, for line 21, is shown in Figure 8, while the corresponding digital output follows the program listing in Appendix 6. The program outputs the apparent conductivity, and, where appropriate, the layer conductance. If a homogeneous half space is interpreted, its depth of burial is also indicated. This is not done in the layered case as it was found that in this circumstance the depth of burial estimates are not reliable. Finally, as a validity check, the program also outputs, on the lowest trace, the frequency at which the interpretation is made.

5 - RESULTS

The results for the whole test area are presented in Appendix 7 on a line by line basis and in a format identical to that shown in Figure 8. The data is of sufficient quality and quantity to perhaps warrant the presentation of contour maps of the three interpreted quantities. When this was attempted however, it was found that such presentations appeared to be of limited geological usefulness. This was so for a number of reasons. Foremost among them seem to be the ruggedness of the bedrock topography, the

departure of the actual overburden layering from the assumed model, and, the small but nevertheless finite conductivity of the bedrock.

After a careful study of the results and all other available information it was elected to present only geologically significant data which was extracted from the results shown in Appendix 7. Thus it was found that one could construct a terrain map for the area which contained two principal units and a transitional unit between these. Such a map is presented in Figure 9. The first unit which is defined by an apparent conductance contour of ten mhos corresponds to an area where the apparent conductance equals or exceeds this value. Here, the Champlain Sea clay has a thickness of thirty meters or more and is overlain by a drift cover whose thickness ranges from zero to ten meters and averages about five meters. The second unit is defined by an apparent conductivity contour of 0.03 mhos/meter and encloses areas where the apparent conductivity equals or is less than this value. In these regions we have a virtual absence (less than 3 m) of conductive clay and the surficial materials consist of sand, till and, limestone outcrop. It is more difficult to make any such categorical statements about the transitional layer. One would expect however, that here we have a varying thickness of clay (the principal conductor) which is covered by a 5-10 meter thickness of drift. It appears that the average clay conductivity is of the order of 0.3 mhos/meter so that reasonable estimates of the clay thickness (in meters) in the transitional region can be obtained by simply multiplying the apparent conductance values (as shown in Appendix 7) by a factor of three.

Because of the abundance of peripheral data it is easy enough to demonstrate the validity of the interpreted results. First of all one might look at the internal consistency of the interpretation. This can be best done by comparing the two southbound overflights of line 8 (lines 108 and 208) one of which was done at 150' nominal altitude while the other one was at 200' nominal altitude. The appropriate data is found in Appendix 7 and its inspection reveals that the two independent interpretations are consistent with each other with a tolerance of about 20%.

One can next compare the results of the automatic interpretation with those obtained at a number of ground stations (located as shown on Figure 2) where dc resistivity sounding data was available. This is done in Table 1 below where we compare apparent conductance values obtained through surface measurements with those obtained by interpreting airborne data.

TABLE 1

Comparison of surface and airborne data

STA	Surface value mhos	Airborne value mhos
21	17	>10
22	25	>10
23	0	< 1
24	1.5	2
25	2	2
26	13	10
31	18	>10
32	25	>10
33	20	>10
34	1.5	-
35	12	10
36	15	10
37	20	>10
42	16	>10
44	0	< 1

It must be noted that once the clay conductance exceeds 10 mhos (clay thickness greater than 33 meters) the Tridem system does not resolve the bottom of the conductive layer. On the other hand, if this quantity is inferior to 1 mho the system response amplitude is low and does not permit a highly accurate interpretation. Unfortunately one or the other of these two conditions prevailed at the majority of ground stations available for the data comparison. Because of this the two data sets in Table 2 can only be compared on a qualitative basis. Within this restriction however, one cannot help but appreciate the nearly perfect correlation between the two data sets. This is not too surprising because one would expect that the apparent conductance to be the most reliable interpreted quantity as its evaluation mainly depends on the secondary field phase.

Finally one can gain further confidence in the use of the interpreted terrain map of Figure 9 by noting that all outcrops indicated on the ODM drift map (Gwyn & Thibault, 1973) fall within the sand, till and rock zone. On the other hand, the two wells that are indisputably situated within the indicated thick clay zone show an overburden thickness in excess of thirty meters.

6 - CONCLUSION

On the basis of the foregoing discussion and the results presented in Appendix 7 one can conclude that multifrequency airborne electromagnetic surveys can be useful, within limits, for the purpose

of mapping the surficial geology of a given area. The automatic method of interpretation presented here is efficient and quite accurate as long as the actual layering in the overburden does not appreciably differ from the assumed simple one layer model.

Although no detail interpretation was done in the context of the present work, it can be done, using a similar technique to that described here, in regions where suitable geological conditions exist. An example of such a detail interpretation is shown in Figure 10. Here we have interpreted a section of line 8 which was also covered by a detail seismic survey (St-Hilaire, 1975) and by a number of D.C. resistivity soundings (Andrieux, 1968). It can be seen that the depths of the bottom of the conductive layer as interpreted from the TRIDEM results compare very favourably with the seismic data while the estimates of depth to top of the layer which was not indicated by the seismic data agree well with those obtained from the resistivity soundings.

In conclusion we recommend to the Geological Survey the continuation of its research in mapping surficial geology with airborne em. Surely the quality of the data presented here justifies this recommendation. It is certain that with the development of new em systems endowed with a much greater range of frequencies the shortcomings of the present survey and interpretation can be overcome.

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Wilson, A.E. (1946) "Geology of the Ottawa-St.Lawrence Lowland, Ontario and Quebec"; Geol. Surv. Can. Memoir 241, 66p. Accompanied by 3 maps.

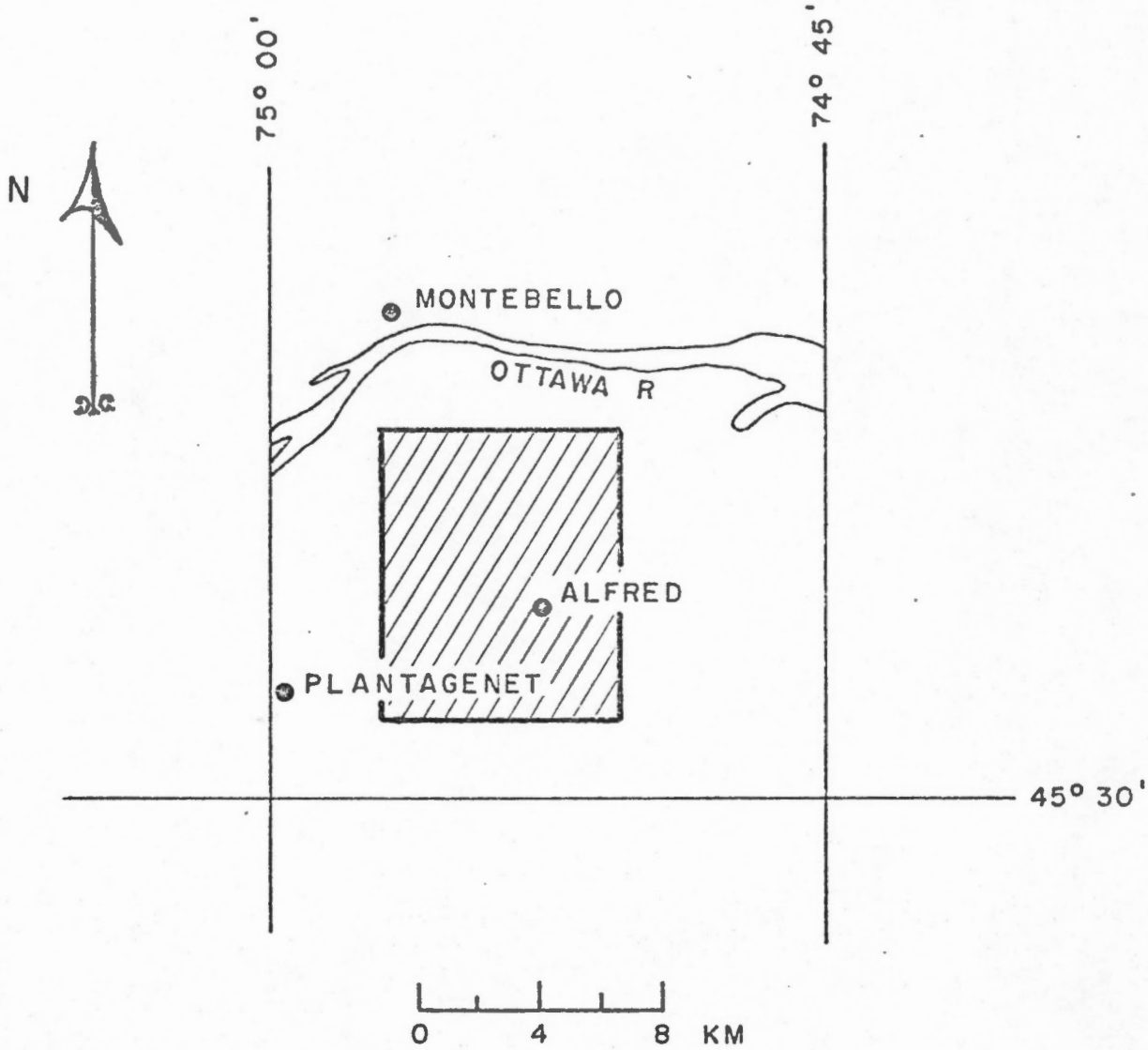

FIGURE-1 : LOCATION MAP

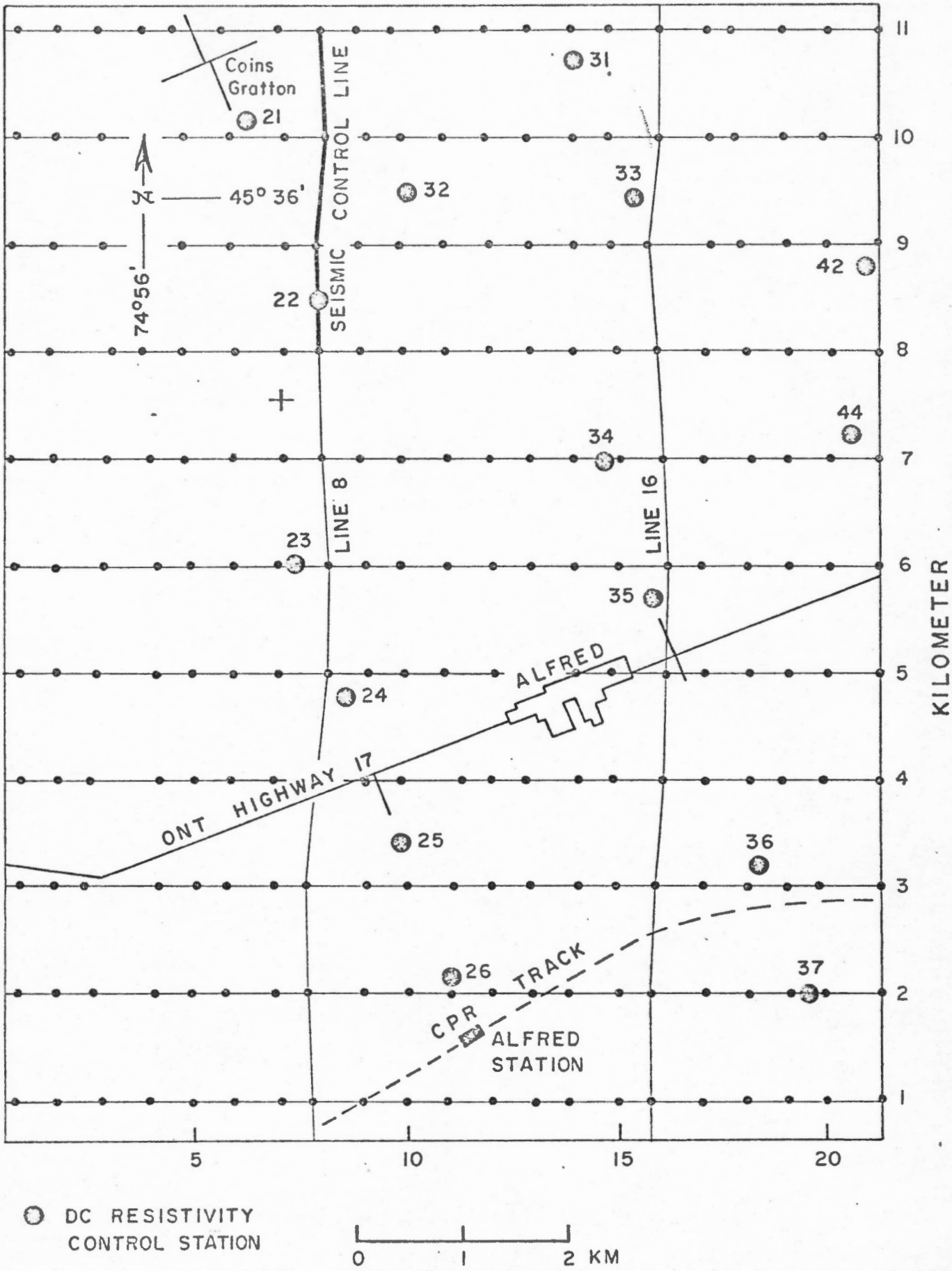

FIGURE-2: TRIDEM FLIGHT LINE MAP

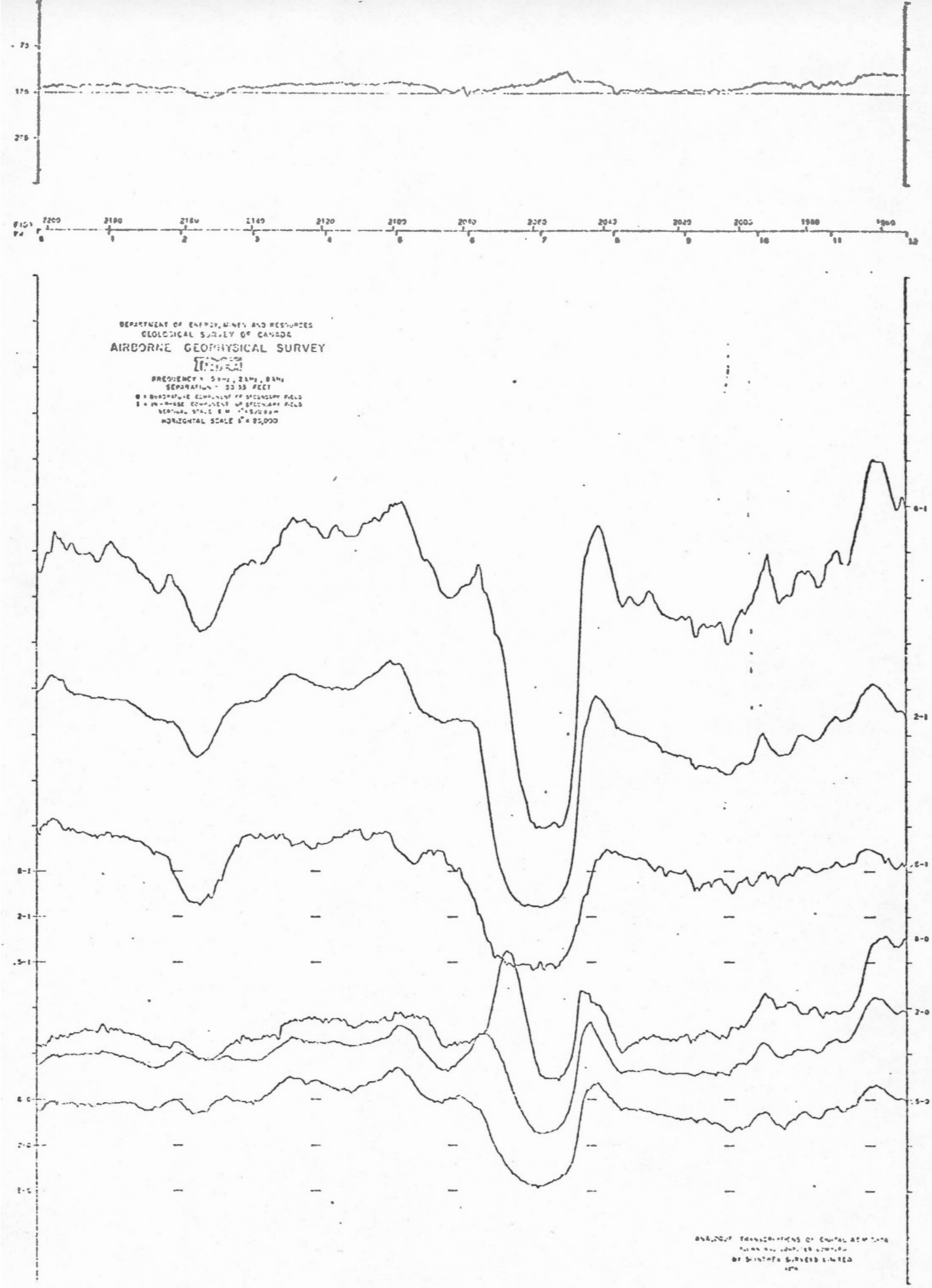

FIGURE-3 : ORIGINAL DATA

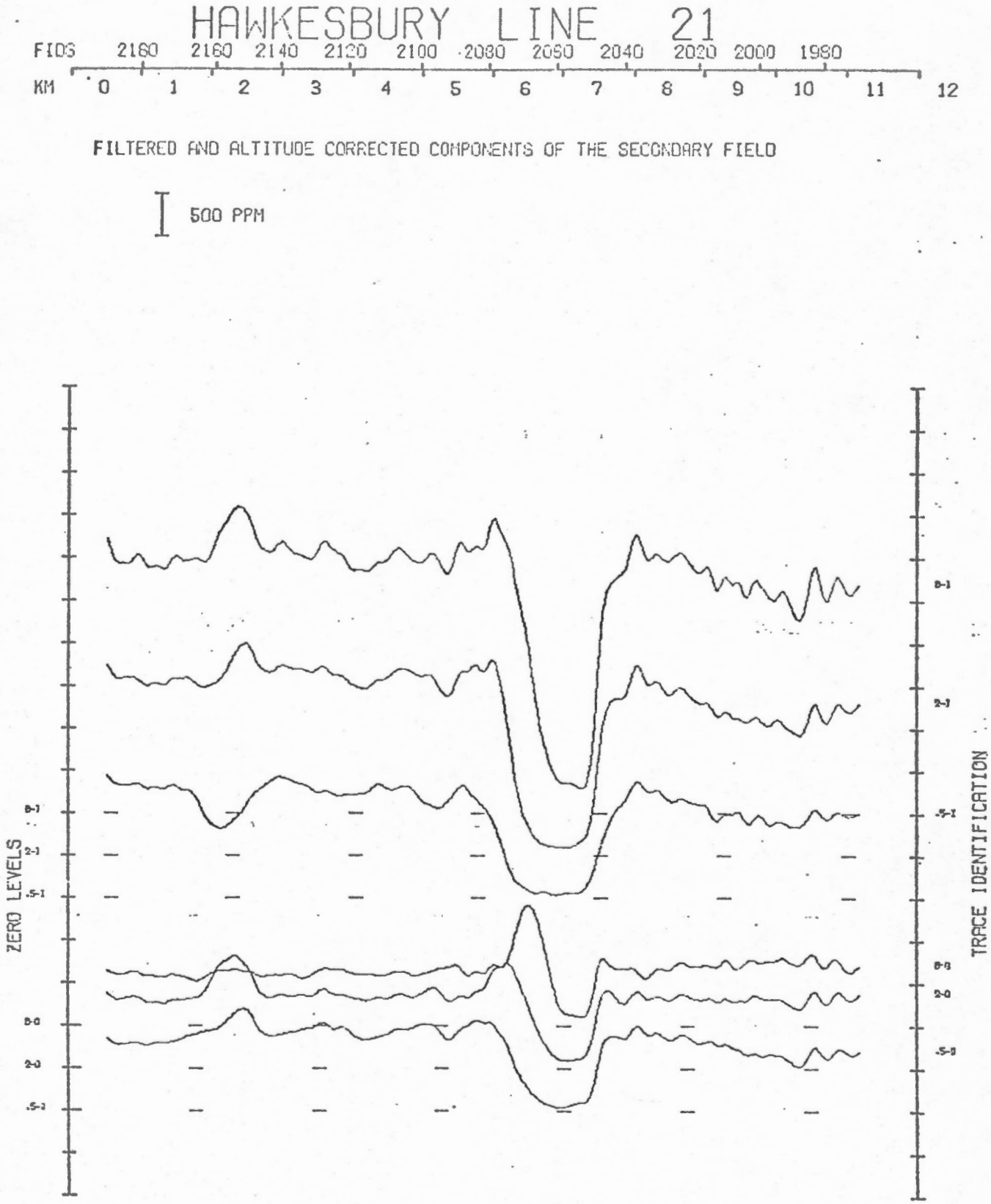

FIGURE-4 : CORRECTED DATA

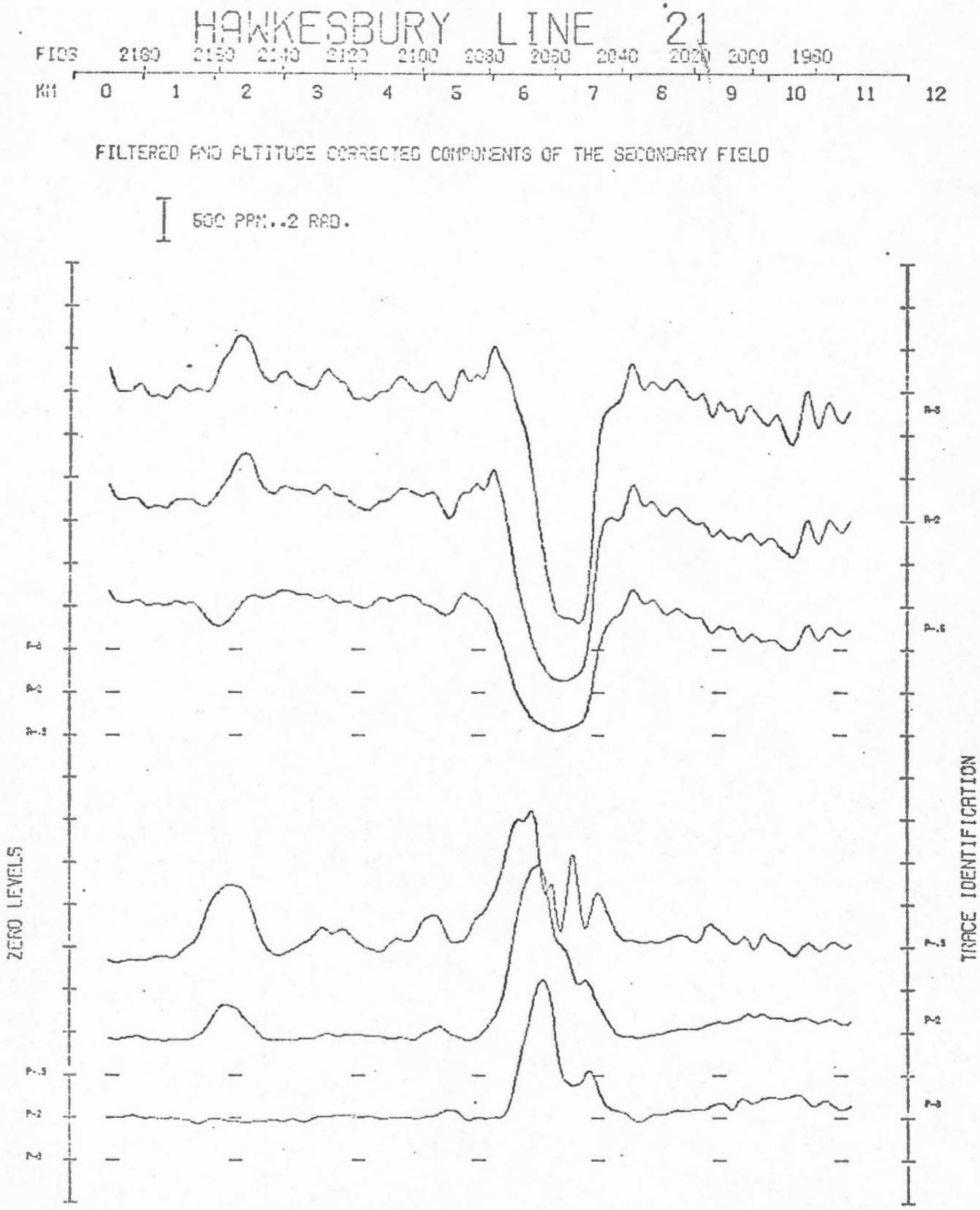

FIGURE-5 : AMPLITUDE-PHASE DATA

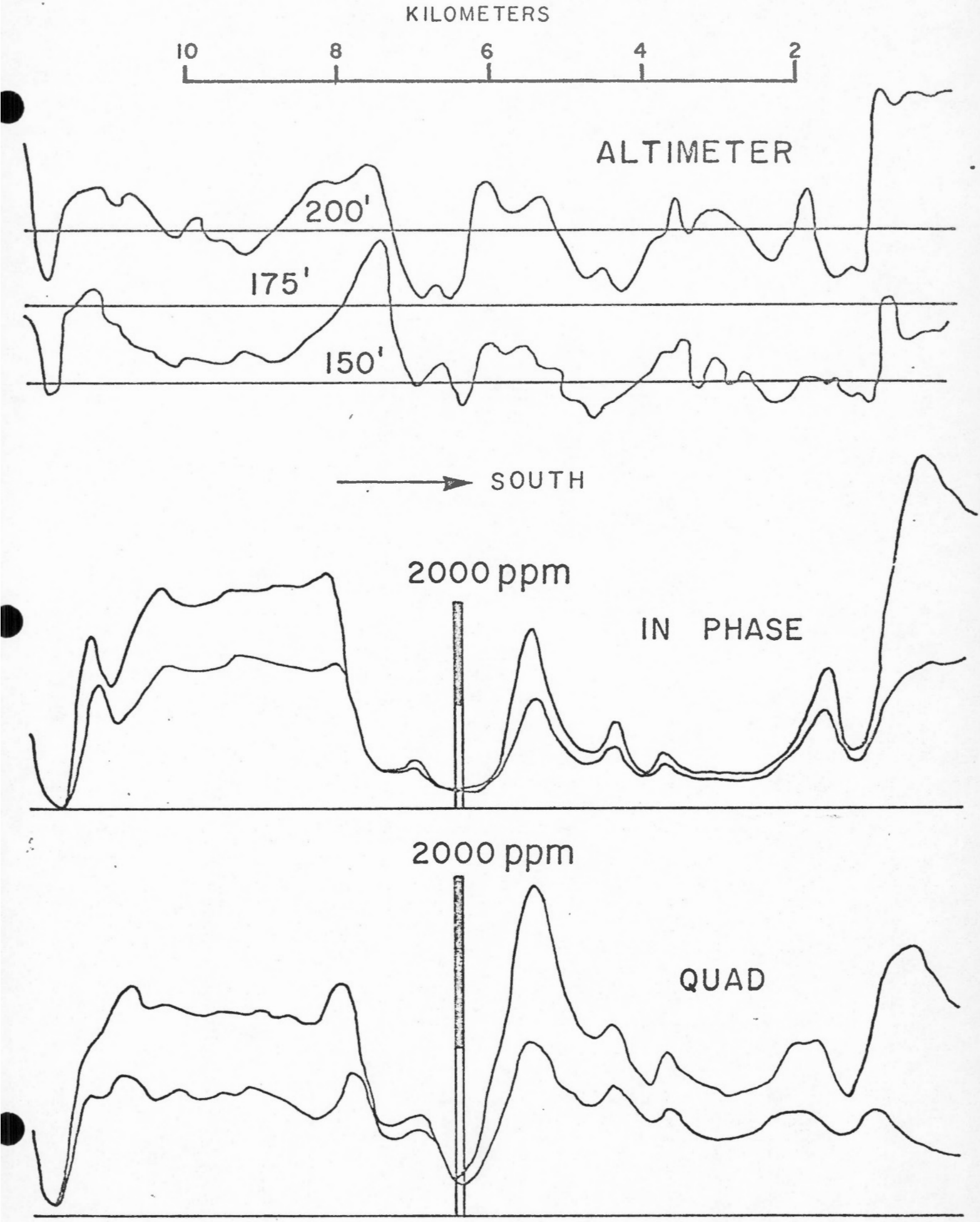

FIGURE-6: 2000 Hz UNCORRECTED DATA LINE 8

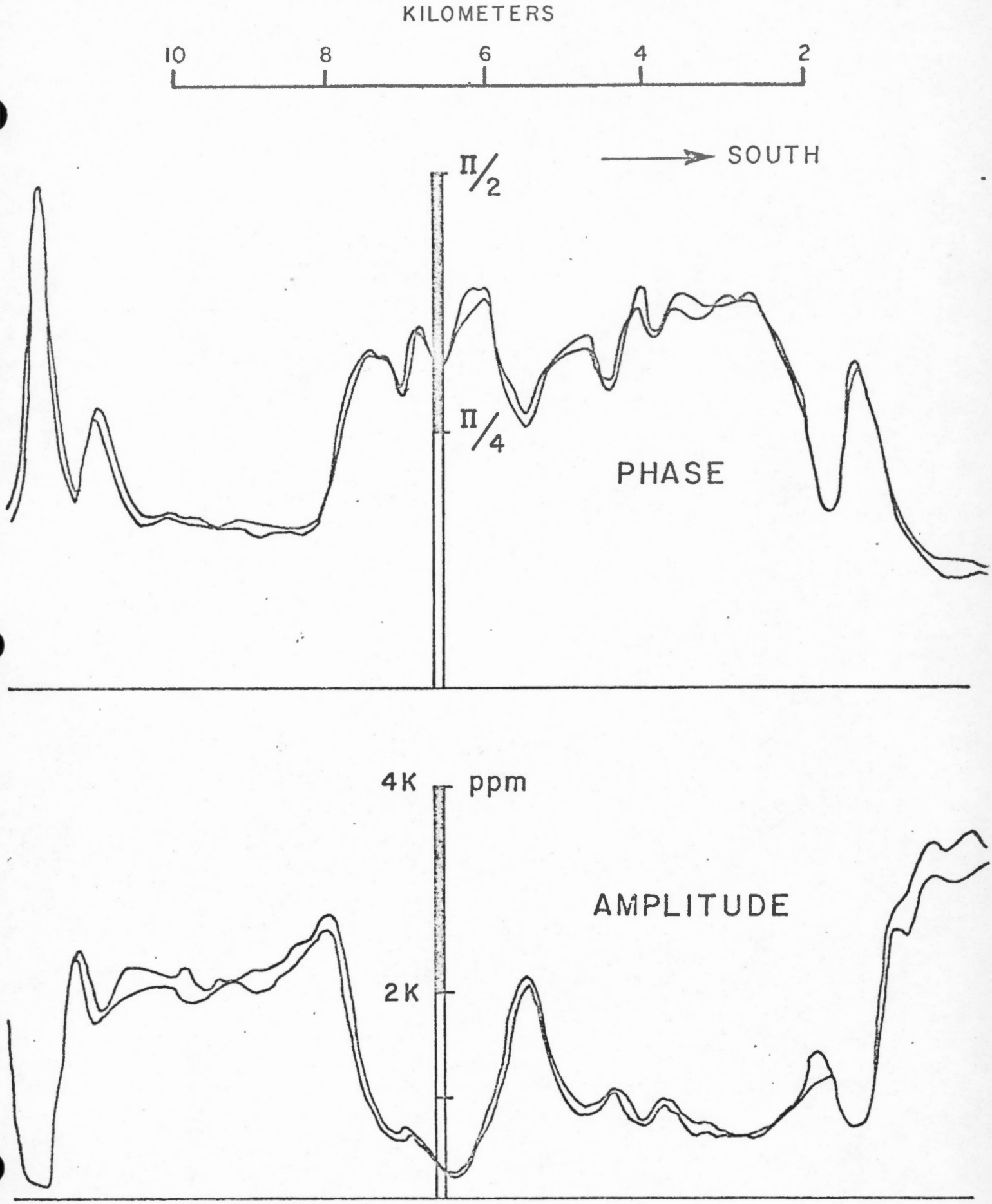

FIGURE - 7 : 2000 Hz CORRECTED DATA LINE 8

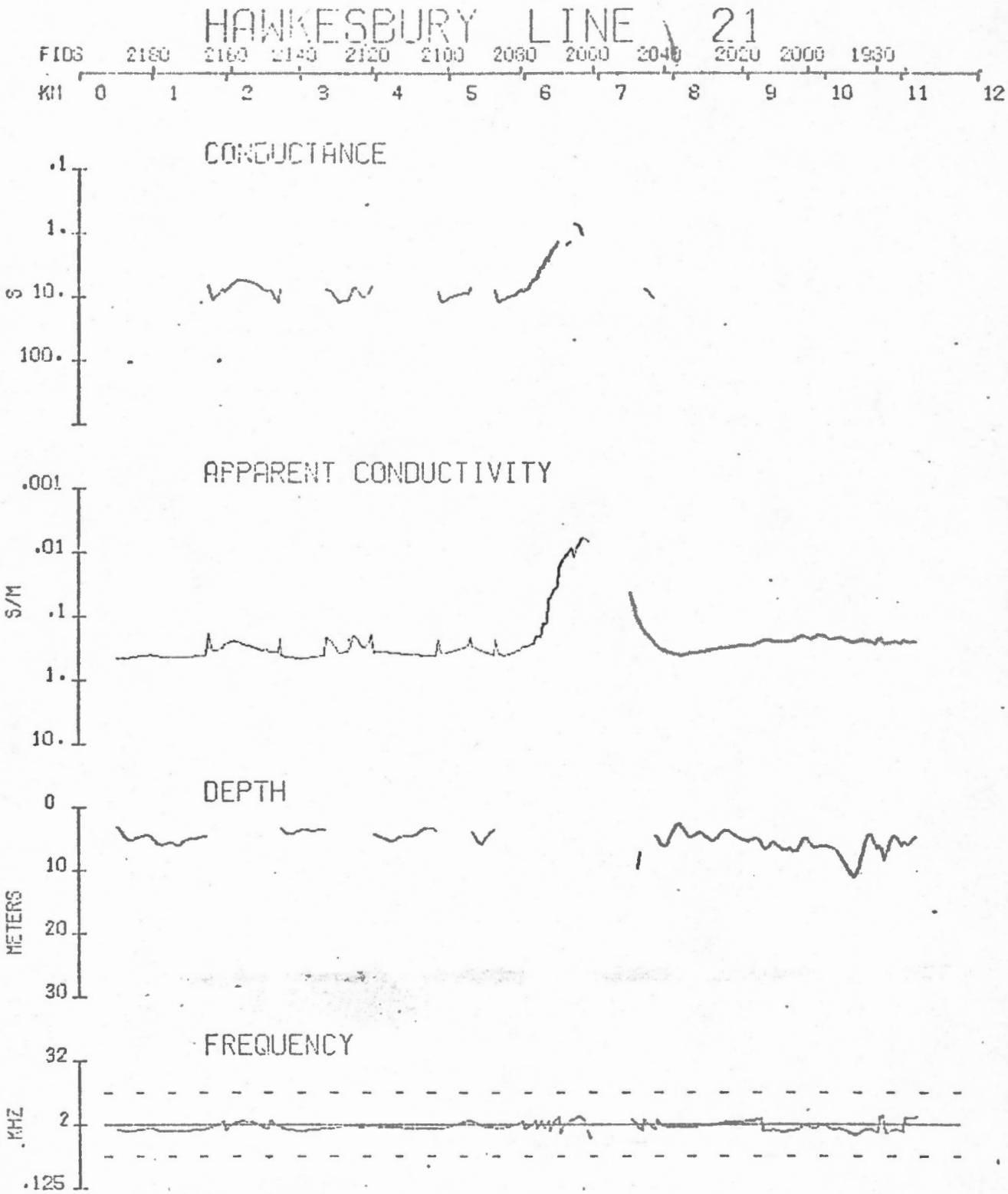

FIGURE-8 : INTERPRETATION GRAPHICAL OUTPUT LINE 21

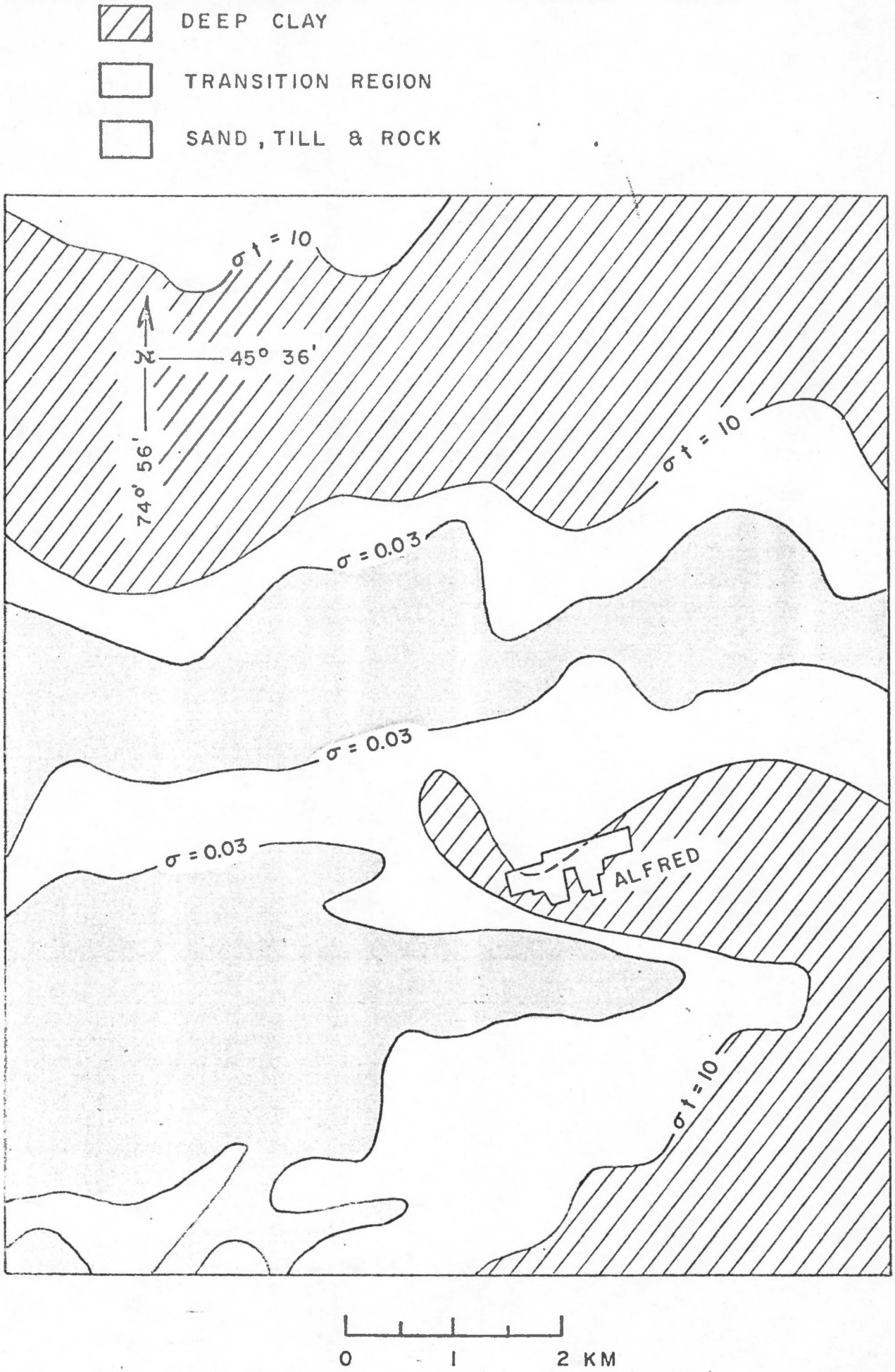

FIGURE - 9 : TERRAIN MAP

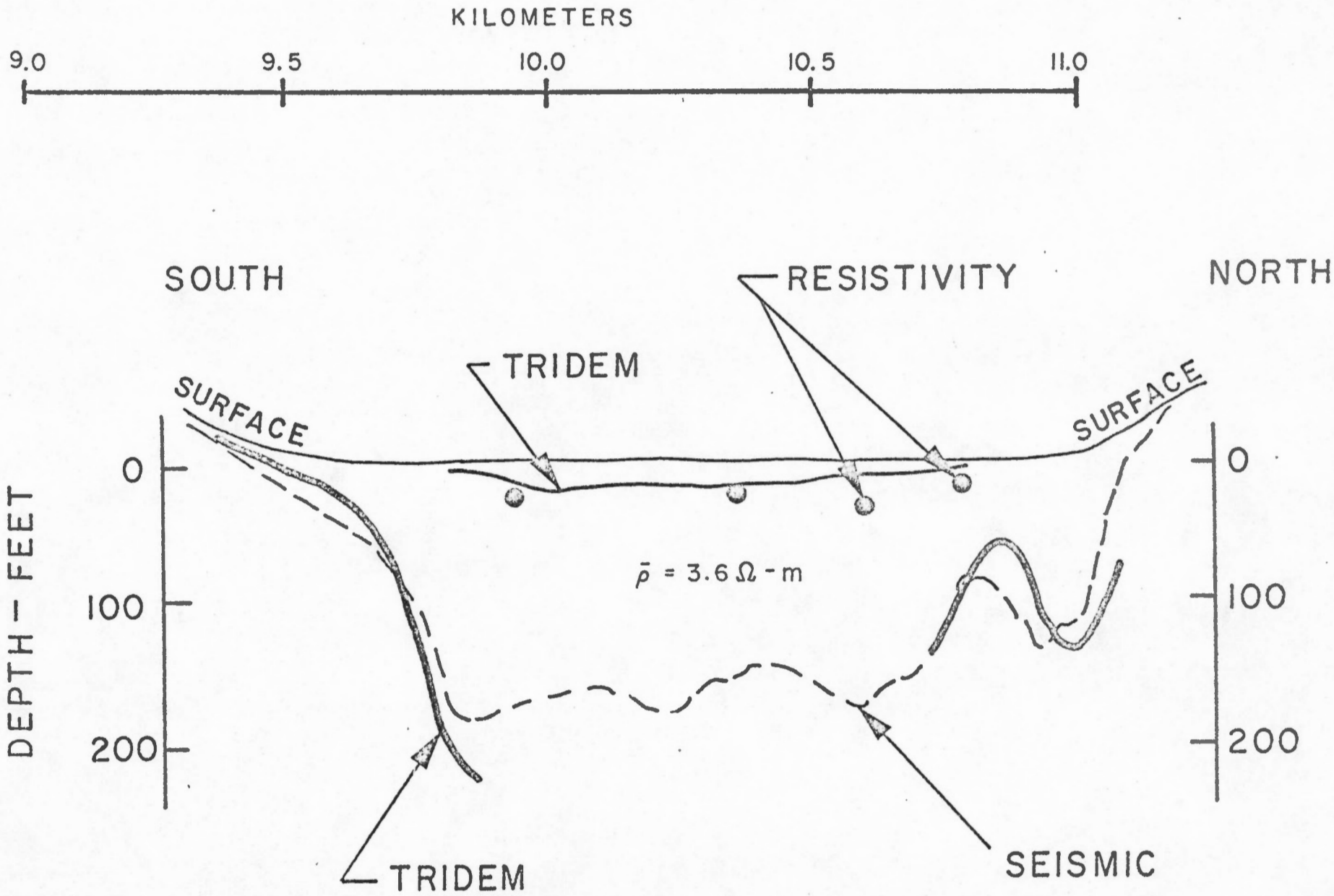

FIGURE - 10 : DETAIL INTERPRETATION LINE 8

Appendix 1

REPORT ON
AIRBORNE GEOPHYSICAL SURVEYS
IN HAWKESBURY AND TIMMINS AREA
FOR
THE GEOLOGICAL SURVEY OF CANADA

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Timmins: (1) Electromagnetic Anomaly Plan

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REPORT ON
AIRBORNE GEOPHYSICAL SURVEYS
IN HAWKESBURY AND TIMMINS AREA
FOR
THE GEOLOGICAL SURVEY OF CANADA

INTRODUCTION

An airborne geophysical survey using the Scintrex Tridem system has been executed during the months of October and November 1974 for the Geological Survey of Canada. The survey was flown in two distinct areas identified as Hawkesbury and Timmins. Over 600 line miles were surveyed, digitally processed and displayed by computer controlled plotter. The purpose of the survey was to evaluate the system as a mapping tool.

SURVEY EQUIPMENT AND PROCEDURES

1. Survey System: Scintrex IUZ Otter

The aircraft used for Tridem surveys is a DeHavilland Otter DHC-3 (CF-IUZ). This STOL aircraft is a versatile geophysical platform having a gross weight of 8000 pounds. According to loading, range and areas to be surveyed it could be fitted with wheels, skis or floats. The basic platform is equipped with the Scintrex Tridem units, a 1γ resolution fluxgate magnetometer (Gulf MK-III), a linear sweep radar-altimeter working on a 9 Ghz carrier (Collins ALT-50) and a 35 mm frame camera (Automax) for flight path recovery purposes equipped with fiducial number printing counter and a 17.5 mm wide angle lens. An accelerometer is also installed on one of the wing tips. An inter-valometer-intercom system (Scintrex IITC-2) is used to generate the synchronization signals for the fiducial counters (navigator, operator, camera, analogue recorder) and to control the camera operation. The intercom system is used for in-flight communication by the survey crew. The recording system is built around two independent recorders: one of them is an analogue recorder, recording up to 24 channels of information also equipped with fiducial number, printing counter and vertical and horizontal grid system (Visicorder 1508B). The second recorder is a 7 track IBM compatible incremental digital system (Incredata Mk II) recording the following information at every scan with a scan rate of two per second: fiducial number, time, total magnetic field intensity, altitude, and the 6 channels of Tridem data. At every 20 scans a header is also recorded giving the day, the mode of operation and the line number. To this basic package the following equipment could be added without modifications to the aircraft: a VLF unit which measures the in-phase and out-of-phase vertical field relative to the horizontal field and a gamma ray spectrum analyser (Scintrex GAD-5) with sensors

of over 1500 cu. in. crystals volume (Scintrex GSA-64, GSA-77). The analogue and digital recording systems record all these extra channels.

2. EM System: Scintrex Tridem

The Tridem system is a 3 frequency in-phase, out-of-phase airborne EM system operating at nominal frequencies of .5, 2 and 8 Khz. The actual frequencies during the survey were .524, 1.948 and 8.127 Khz. The coil configuration is coplanar with coil axis parallel to the aircraft roll axis and the coil separation is 58-1/3 feet. The recorded parameters are the in-phase and out-of-phase components of the secondary field, the field generated in the aircraft being bucked-out by the system. The calibration of the system consists of momentarily altering by a known fraction (usually 500 ppm for .5 and 2 Khz and 1000 ppm for 8 Khz) the value of the bucking supply to show a deflection in the recorded parameters of known amplitude relative to the primary field. The value in parts per million of this alteration is not dependent upon any attenuator setting; it is applied before any type of signal processing.

3. Mag System: Gulf MK-III

The Gulf MK-III system is a fluxgate servo-orienting unit measuring the total magnetic field intensity. The measuring fluxgate element is continuously maintained in the direction of the local field by two servo-motors and a gimbal system controlled by two mutually perpendicular auxiliary fluxgate elements maintained in a null field by the servo-loop. The field intensity is digitally measured and recorded on the digital recording system. The digital magnetic data is also converted to analogue data with a full scale of 100 or 1000 γ and recorded on the analogue recorder.

4. Procedures

Prior to the airborne survey the system is warmed-up for a period of a minimum of 30 minutes. A survey flight begins by a calibration period at a minimum altitude (h) of 1000 feet above ground. The system is then flown at survey altitude (h = 175 feet, nominal) for a period of approximately 30 minutes along the planned flight lines. Following each 30 minute period, the survey is interrupted for a calibration sequence done at a calibration altitude ($h \geqslant 1000$ feet) during which zero levels are readjusted whenever necessary. Any such readjustment is identified on the flight log by the operator. The flight log also lists each line surveyed, its direction, the beginning and end fiducial number and any problems encountered during the survey. The information recorded on these flight logs is subsequently used during the flight path recovery and the data processing.

The flight path recovery is done during the night following a given flight using a recovery mosaic, the navigator's mosaic and the developed flight path recovery film: each frame is identified by its fiducial number as already mentioned. The recognizable points on the mosaic are labeled with their corresponding fiducial number as observed on the 35 mm frames. The flight path is obtained by joining the recovered points. On the mosaic such a point is shown by a small circle while an extrapolated point is shown with an x.

The exact calibration circuits and procedures together with the phase relationship of the Tridem signals were described to the GSC representative, Dr. A. Becker, during the survey period at Pendleton Airport on November 3, 1974. An overall check of the phasing of all the components of this electromagnetic system could be observed when the system flew over a low conductivity magnetic body (Flight No. 5, Line No. 27S, Fiducial No. 2494, Area: Timmins). As expected in such a situation the quadrature channels show negligible response while the in-phase channels have negative response. The altimeter trace shows that the topographic expression of this magnetic feature is a small hill with a half-width of about 800 feet.

The polarity of the response is now defined: if the secondary field has the same polarity, at the receiver coil, as the primary field it is defined as positive. The positive direction on the field analogue records is in the direction of the trace identification numbers. In the final computer display the positive direction is in the direction of the altimeter trace while the final digital data tape has a polarity inverse to the one defined here.

FIELD REPORT

1. Hawkesbury

The base in the Hawkesbury area was established in Plantagenet where use was made of the Pendleton Airport. The survey period was between November 2 and 8, 1974. Two test flights were made to optimize the dynamic range with resolution compromise while the survey itself was done with flight No. 3, 4, 5 and 6. At the end of this period the field analogue records were transferred to the GSC office for examination. They were later transferred back to Scintrex for the evaluation of gain and zero levels drifts.

2. Timmins

In this area the survey crew was operating from the Timmins airport. The survey was made during the period from November 21 to 30, 1974. Following a test flight in the survey area only one attenuated channel

(8 Khz in-phase) was left on the analogue records since the amplitudes of the responses were smaller than on the first area. The removal of the other attenuated traces on the record produce a simpler record without any loss of information in this area.

ANALOGUE RECORD DESCRIPTION

1. Channel Identification

There are 13 recorded traces (10 at Timmins) on the analogue records which are tabulated here.

Parameter	Trace No.	Nominal Scale
Accelerometer	1	10 G/inch
.5 Khz Q	2	500 ppm/inch
2 Khz Q	3	500 ppm/inch
8 Khz Q	4	500 ppm/inch
Magnetic field intensity	5	280 γ/inch
.5 Khz I	6	500 ppm/inch
2 Khz I	7	500 ppm/inch
8 Khz I	8	500 ppm/inch
Altimeter	9	130 feet/inch
2 Khz QA	10	2500 ppm/inch
8 Khz QA	11	2500 ppm/inch
2 Khz IA	18	2500 ppm/inch
8 Khz IA	12	2500 ppm/inch

The identification of each trace is written once for each line and is also done systematically by the sequential interruption of each trace in synchronism with the printing of the corresponding channel number at the bottom of the analogue record. The I, Q and A symbols stand for, respectively, in-phase, out-of-phase and attenuated. The deflection factors and the zero level positions could be measured at regular intervals; the calibration is done in the same order each time and a description of it follows.

2. Calibration Sequence and Description

A deflection corresponding to 2G is first recorded on the accelerometer trace. Two deflections corresponding to a difference in altitude of 100 feet are then recorded on the altimeter trace followed by a deflection giving the position of a 50 feet radar-altitude. The coil's altitude is 5 feet lower than the indicated altitude. This display is linear to 500 feet where there is a discontinuity in the slope of the response function; the altimeter is linear again from 500 to 2000 feet but with a slope equal to 15% of the slope between 0 and 500 feet. Using the 500 feet discontinuity and the 50 feet mark a slightly more precise evaluation of height above ground could be made:

$h \leqslant 500$ feet $\qquad h = \left[\frac{(l_n - l_{50}) \times 450}{(l_{500} - l_{50})}\right] + 45$

l = distance of trace from arbitrary datum
n = any station
50 = during calibration of ALT-50
500 = at 500 feet discontinuity
h = altitude in feet

The Tridem traces are calibrated in the following order with the corresponding deflection magnitude in parts per million: .5 Khz Q (533), 2 Khz Q (508), 8 Khz Q (1050), .5 Khz I (502), 2 Khz I (505), 8 Khz I (1009). The attenuated channels are thus calibrated at the same time as the normal channels. As already explained to the GSC representative only the in-phase deflection has accurate phase and could be used for checking receiving coil phasing.

The magnetic field display has a resolution of 1 γ, a sampling interval of 0.5 seconds and a dynamic range of 0 to 999. Each change in the 4th digit is displayed by interrupting during about 0.5 seconds the normal display and having the 4th digit recorded on a 0 to 9 scale. In addition to the geophysical traces the fiducial numbers (every tenth) are printed on the upper edge of the record; thick lines are recorded every 10th fiducial and light lines at every fiducial number.

FIELD DIGITAL RECORD

The in-flight digitally recorded parameters have already been identified in the system description. Two types of input are recorded in this system: digital and analogue. All the information already in digital form is sent to the system's digital multiplexer controlled by the formatter; this includes header, fiducial number, time, magnetic field intensity and, when added to the basic platform, gamma ray spectrum analyser. This type of data is recorded and read back as it is: the processing of these data at a later stage will therefore start with the data directly without any scale factor. The information in analogue form which includes the altimeter signal, all the Tridem channels and the VLF channels when used are sent to an analogue multiplexer also controlled by the formatter and to an unsigned analogue to digital converter. Each of these signals therefore has a particular offset value and a scale factor associated with its conversion in digital form. The recorder limitations of the resolution and dynamic range are as follows:

Parameter	Resolution	Dynamic Range
Fiducial number	1	0 - 9999
Time	.5 sec	0-23h 59min 59.8 sec
Magnetic field	1	0-99999
Altitude	1 foot	6-404 feet
Tridem	Variable 1-50 ppm	0 ± 500 ppm to 0 ±25000 ppm

DIGITAL DATA PROCESSING

The digital processing of this airborne geophysical survey consisted of the following steps: digitization of the flight path recovery, transformation of the recorded altimeter data in feet and the Tridem data in parts per million of the primary field. The Tridem data were corrected for zero level drift, gain drift and were laterally shifted to correct for low-pass filter time lag. The corrected data were then displayed at constant scale on a computer controlled plotter.

1. Digitization of Flight Path Recovery

Each of the recovered fiducial points in the two flight path recovery mosaics were transferred on a 1:50,000 N.T.S. map. They were then digitized on an arbitrary scale and converted to N.T.S. X-Y coordinates using the topographic maps as a grid reference. Each recorded station has then been assigned a pair of N.T.S. X-Y coordinates by linear interpolation between two digitized points.

2. Altimeter Data

The output of the altimeter was digitally recorded with an attenuation circuit giving one foot per digit. The processing thus consisted only in subtracting from the recorded value the fixed system offset taking into account the difference between the radar antenna location relative to the Tridem's coil location together with the initial delay in the installation of the radar altimeter.

3. Tridem Data

The determination of the zero levels and the sensitivities of the system were done using the records of the calibration periods. The .5 Khz and 2 Khz channels have sensitivities of the order of 10 ppm/digit while the 8 Khz channels were operating at 20-25 ppm/digit. Any zero level readjustment was also included in the processing data table giving zero levels and their time drift and sensitivities with their time drift for each of the Tridem channels between each calibration interval. The Tridem data has also been shifted by 3 scans to compensate for filter time lag: the evaluation of this time lag is now described.

4. Time Lag Evaluation

The time constant of the EM system is the same for the three frequencies and is 2 seconds; this could be measured during each calibration period. Each light vertical line as previously described is a 1 second mark on the analogue record. The exact instant of the step is easily observed in this type of record and thus provides a check with a single measurement. The time lag of the response is also a function of the shape of the anomaly;

the 8 Khz channels frequently give slightly less time lag in the record. Three types of target could be used for such an evaluation within the area of the survey: power line, magnetic dyke, outcrop or river valley cutting conductive formation. Because of their narrower responses, the first two cases give better estimates of the time delay expected over a conductive dyke. Typical examples of such estimates are:

Area	Flt. No.	Line No.	Geo. Loc.	Peak Loc.	Type
Timmins	2	10N	4980	4981.5	Pwr. Line
	2	5S	2497.5	2499	Pwr. Line
	5	27S	2493	2494.5	Mag dyke

Such a time lag has been estimated at 1.5 seconds $\pm$ .5 seconds.

5. Processed File

A processed file has then been recorded meshing the X-Y coordinates with the altimeter data in feet and the shifted Tridem data in parts per million corrected for drifts. This file has been used to produce the analogue displays.

What shift? response time delay?

see p.6 & 3

COMPUTER GENERATED ANALOGUE DISPLAYS

For each line or reflight portion of a line a display has been produced. All the displays have been drawn with constant scales; the horizontal scale is 1:25,000, the altimeter scale is 100 feet per inch and the Tridem scale is 500 parts per million per inch. In order to get a clear display, the Timmins in-phase zero-levels have been displaced relative to the Hawkesbury in-phase zero-level because the mean phase of the secondary field was different.

Each display is identified by a line number and the area where it was surveyed. The first trace on top of the display is the altimeter with higher altitudes down in order to have a non-inverted topographic signature. The next trace shows the fiducial numbers and the distance in kilometers from the datum line. All the Tridem traces are identified at the right side of the analogue display while their corresponding zero level is indicated at the left side. The Hawkesbury sheets are oriented N-S and the Timmins sheets are in the NE-SW direction. The stations are projected on these directions in order to maintain constant scaling from one display to the other.

The position of the zero levels for each channel has been systematically determined by the procedure outlined in the last section 3; while this procedure is theoretically correct and particularly suitable to computer data processing some care should be exercised in using these results. Taking into account the operating characteristic of the Tridem system when the survey was flown, some zero level checks have to be made on part of the data to measure accurately the ground electromagnetic response.

TIMMINS BEDROCK CONDUCTOR EVALUATION

1. Presentation of Results

The electromagnetic records are interpreted to determine the presence of subsurface bedrock conductors. Where field distortion occurs, the location and the approximate depth of the main current flow can be derived. The current axis is well defined when the current is concentrated,for instance, in thin, steeply dipping conductors. In wide or multiple banded conductors or in horizontal conductors such as overburden, the current is usually more dispersed and the anomalies yield less positive information. The peak location, conductor coding, conductance, depth of burial, magnetic correlation and spurious anomalies are indicated on the electromagnetic anomaly plan, Plate # 1, Timmins. For clarification purposes, each item is defined in this section and summarized in Table 1

TABLE 1

Category

Coding	Category	Remarks
⊙	1	Anomaly well defined, good conductivity
⊖	2	Anomaly well defined, low to medium conductivity
O	3	Anomaly poorly defined, low conductivity

Conductivity & Depth

O σt, S or D — Conductance (σt) of target conductor
Shallow (S), depth of burial $\leq$ 100 ft.
Deep (D), depth of burial $>$ 100 ft.

Magnetic Correlation

⊙ Direct Coincidence
o) Magnetic high offset to right
(o Magnetic high offset to left

Spurious Anomalies

⊗ Likely man-made conductors

a) Peak Location

The conductor peak location is shown on the map by a circle in the appropriate location. In the case of a broad conductor or closely spaced multiple conductor zones, there may be more than one peak, in which event, all major peaks are shown. A conductor which is likely man-made is indicated by an ⊗.

b) Conductor Coding

To facilitate the evaluation of the geophysical data shown on the plan, the electromagnetic anomalies are classified in three groups according to Table 1. Generally, category 1 anomalies, which represent well defined conductors of good conductivity, would constitute first order exploration targets; category 2 anomalies, due to well defined conductors of lower conductivity are second priority targets; and category 3, which covers all weaker and poorly defined anomalies, are targets which, on the basis of the geophysical data alone, are of questionable merit.

c) Conductance (mhos)

The conductivity-thickness (σt) product of steeply dipping individual conductors may be obtained using the in-phase and quadrature anomaly amplitudes at a given frequency. Using a typical response diagram of a coplanar coil configuration over a vertical thin sheet, (eg., Fig. 3.4.4, Ghosh, M.K. (1972), Interpretation of Airborne EM Measurements Based on Thin Sheet Models, Unpublished Ph. D. Thesis, University of Toronto. This diagram was corrected for the Tridem coil separation of 58-1/3 feet), the conductance can be determined. When a highly conductive cover is present the σt value of underlying conductors may be distorted as the result of mutual induction and cannot be reliably determined.

d) Relative Depth of Burial

The approximate depth of burial may be found using the in-phase and quadrature anomaly amplitudes at a given frequency and the response diagram of a coplanar coil configuration over a vertical thin sheet. The effect of conductive cover in the presence of underlying conductors is to yield an unreliable depth determination.

The relative depth of burial is indicated on the plan by a D or S according to Table 1. S is used to indicate an interpreted depth of burial of less than 100 ft. and D defines a conductor with an interpreted depth of burial in excess of 100 ft.

e) Magnetic Correlation

The relation between the electromagnetic anomalies and the magnetic intensity is indicated only when the latter is simultaneously recorded, when close and significant correlation is evident, ie., when both anomalies arise from sources at a comparable depth and are coincident or only slightly offset.

Direct correlation is indicated by a double concentric circle. When the anomalies are offset, half a concentric circle is shown on the side of the magnetic high.

f) Spurious Anomalies

Man-made conductors, including power lines, pipe lines, telephone lines, metal fences, railways, etc. may cause spurious anomalies and are indicated by an O on the plan.

2. Discussion of Results

In the Timmins area, the overburden conductance and the conductance of bedrock conductors is not appreciably different, which of course yields the recognition of bedrock conductors extremely difficult. A number of third category targets are located which have conductances of at least about 1 mho.

Some of these targets may be conductors of bedrock origin or local zones of relatively highly conducting overburden.

A number of man-made conductors are also defined which are due to power lines.

Because of the uncertainty involved in distinguishing these conductors from the overburden, the depth of burial and the conductance determinations may be in error in some cases.

FINAL TAPE FORMATTING, READING INSTRUCTIONS, PRINTOUT DESCRIPTION

1. Final Tape and Printout

The final data tape consists of two files. The first file contains Timmins data and the second file contains Hawkesbury data. The tape itself is no label, 9 track, 800 bpi, EBCDIC coded and formatted. It was created at IBM with fixed block records.

DCB = (RECFM = FB, LRECL = 80, BLK SIZE = 2000)

Each record contains processed data for one data point. No header records or any other special records appear on the tape.

The record format is: 3I6, 2I10, 7I6. The following parameters which appear on the tape are defined in Table II.

I AREA, LINE, IF10, IXUTM, IYUTM, IALT, IT5I, IT5Q, IT 2I, IT2Q, IT 8I, IT8Q.

TABLE II

PARAMETER	DEFINITION
I AREA	Area Location: I AREA = 1 for Timmins I AREA = 2 for Hawkesbury
LINE	Line Number
IFID	Fid Number: Fid Number appears twice for reading at each $\frac{1}{2}$ second.
IXUTM	Universal Transverse Mercator Grid- Easting Coordinate
IYUTM	" " " " - Northing " "
IALT	Altimeter (ft.)
IT5I	500 in phase Tridem (ppm)
IT5Q	500 Quadrature Tridem (ppm)
IT2I	2000 in phase Tridem (ppm)
IT2Q	2000 quadrature Tridem (ppm)
IT8I	8000 in phase Tridem (ppm)
IT8Q	8000 quadrature Tridem (ppm)

The printout of the tape has an external item (not on the tape) which is a serial number for data points on each line. Also, the area is printed as T or H.

A summary of line number, start and end fiducial and the number of records per line is given for each area in Tables III and IV.

TABLE III

AREA - TIMMINS FILE - 1

LINE	START FIDUCIAL	END FIDUCIAL	RECORDS
1	340	759	838
2	770	1209	878
3	1220	1689	934
103	201	466	530
4	1882	2309	854
104	10	179	338
5	2320	2779	918
6	2790	3209	838
7	3220	3687	934
8	3843	4282	878
108	810	922	224
9	4290	4729	878
10	4741	5142	802
11	180	631	902
12	640	1055	830
13	1061	1509	896
14	1780	2214	804
15	2230	2677	894
16	2690	3104	828
17	3112	3536	848
117	642	782	280
18	3720	4121	802
19	4130	4552	844
20	4560	4954	788
21	4960	5376	832
22	5510	5915	810
23	290	687	794
123	501	630	258
223	274	406	264
24	700	1142	884
25	1150	1553	806
26	1560	1987	854
27	2260	2674	824
28	2680	3107	854
29	3120	3526	812
30	3530	3969	878
31	4220	4594	748
32	4600	5041	882
33	5050	5451	802

TABLE IV

AREA - HAWKESBURY FILE - 2

LINE	START FIDUCIAL	END FIDUCIAL	RECORDS
1	3141	3372	463
2	2838	3075	476
3	2549	2781	464
4	2220	2457	475
5	1920	2148	456
6	1613	1843	460
7	1268	1519	503
8	636	879	487
108	318	541	448
208	967	1211	490
9	291	535	489
10	861	1101	481
11	1153	1389	473
12	1476	1716	481
13	1775	2012	472
14	2060	2294	469
15	2372	2611	479
16	262	503	483
17	483	699	434
18	1062	1290	457
19	1381	1624	488
20	1671	1897	452
21	1954	2205	503

A summary of missing records is given in Table V.

TABLE V

Area	Line	Start Fiducial	End Fiducial	Records	File
Timmins	3	1350	1351	4	1
Timmins	14	1887	1916	60	1
Timmins	14	2100	2101	4	1
Timmins	27	2510	2511	4	1
Hawkesbury	13	1840	1841	4	2

2. Spurious Spikes

Most spurious single record spikes of significant amplitude which only appear on the digital recording are removed by the computer automatically. Other spurious single or double record spikes which are not deleted by the computer have been removed manually from the computer generated analogue display. These spikes are approximately 75 ± 25 ppm in amplitude for the Tridem channels and slightly greater than about 10 feet for the altimeter channel. These spikes have not been removed from the digital magnetic tape and only those spikes which have been rejected by the computer have been deleted. A listing of the location of the manually removed spikes from the computer generated analogue display is given in Tables VI and VII.

TABLE VI
Timmins (Spurious Spikes)

Line Number	Fiducial Number	Channel	Line Number	Fiducial Number	Channel
2	255	2000 IN	18	3741	2000 IN
2	1098	2000 IN	18	3750	2000 IN
2	1194	500 IN	18	3855	2000 QUAD
2	840	2000 QUAD	19	4480	500 IN
2	884	2000 QUAD	21	5200	500 IN
3	1640	500 IN	21	5170	500 QUAD
3	1420	8000 QUAD	22	5720	500 IN
5	2580	2000 IN	22	5840	500 QUAD
6	2870	500 IN	23	642	500 IN
6	2878	500 IN	23	629	500 IN
6	3065	500 IN	23	492	8000 QUAD
6	2940	500 QUAD	23	334	2000 QUAD
7	3568	500 IN	23	347	500 QUAD
8	4272	500 IN	24	864	8000 IN
9	4368	8000 IN	24	841	500 IN
10	4811	500 IN	24	912	500 IN
10	4760	500 QUAD	24	970	500 QUAD
11	320	500 QUAD	24	724	500 QUAD
11	330	500 QUAD	24	953	500 QUAD
12	689	2000 IN	25	1352	8000 IN
13	1211	500 IN	25	1190	2000 QUAD
13	1098	2000 IN	26	1830	8000 IN
13	1293	2000 QUAD	26	1798	2000 QUAD
14	2058	500 IN	27	2287	2000 IN
14	2198	500 QUAD	29	3300	2000 QUAD
15	2467	8000 IN	31	4248	2000 IN
15	2416	2000 IN	32	4650	2000 IN
15	2548	8000 QUAD	32	4910	2000 IN
15	2482	2000 QUAD	32	5000	500 QUAD
16	2753	8000 IN	33	5133	500 IN
16	2941	2000 QUAD	33	5166	500 IN
16	3041	500 QUAD	33	5329	500 IN
17	3438	ALTIMETER	33	5110	500 QUAD
17	3172	8000 IN	103	265	2000 IN
17	3428	2000 IN	103	321	2000 IN
17	3360	500 IN	104	12	500 IN
17	3339	8000 QUAD	117	720	8000 QUAD
18	3864	2000 IN	117	678	8000 QUAD
			223	298	8000 IN

TABLE VII
Hawkesbury (Spurious Spikes)

Line Number	Fiducial Number	Channel	Line Number	Fiducial Number	Channel
1	3354	2000 QUAD	10	980	2000 QUAD
3	2577	ALTIMETER	10	999	500 QUAD
3	2676	500 QUAD	11	1300	500 IN
3	2596	500 IN	11	1325	500 IN
5	2093	8000 IN	16	469	2000 IN
5	2075	500 IN	16	476	2000 IN
8	647	500 IN	16	318	2000 IN
8	655	500 IN	17	630	2000 QUAD
9	513	500 IN	21	2125	2000 IN

FLIGHT LOG

FLIGHT NO. 1

307

SHEET 1 OF 1

JOB NO. OTTAWA TESTS

DATE 3 NOVEMBER 74

AREA HAWKSBURY

WEATHER FAIR

TIME : RETURN

PILOT JOE

TAKE OFF

NAVIGATOR ERIC

FLYING TIME hrs.

OPERATOR JEAN & SANDY

FLIGHT ABORTED DUE TO:

EQUIPMENT

FULL SCALE SENSITIVITY

E.M. TRIDEM

I.P. 1000 10,000

O.P. 1000 10,000.

MAGNETOMETER GULF WITH D.VM.

SPECTROMETRE —

K — U — Th — T.C. —

LINE NO.	FIDUCIALS FROM	FIDUCIALS TO	LINE LENGTH	REMARKS
CAL	0	560		CALL
8 Cont	561	880		200'
9 North	881	1190.		150'
	1191			[illegible] LINE TO 1232

FLIGHT LOG

FLIGHT NO. 2

SHEET 1 OF

JOB NO. GSC OTTAWA

DATE Nov 4/74 308

AREA HAWKESBURY

WEATHER

TIME: RETURN

PILOT JOE BURCH

TAKE OFF 12:05

NAVIGATOR ERIC SARGOOD

FLYING TIME hrs.

OPERATOR KELLY & JEAN

FLIGHT ABORTED DUE TO:

EQUIPMENT

E.M. TRIDEM

MAGNETOMETER GULF MK II

SPECTROMETRE

FULL SCALE SENSITIVITY

I.P. 2000 – 500
10,000 – 842

O.P. 2000 – 500
10,000 – 842

K U Th T.C.

LINE NO.	FIDUCIALS FROM	FIDUCIALS TO	LINE LENGTH	REMARKS
2S	0	300		150'
2S	301	600		150'
CAL.	601	840		150'

FLIGHT LOG

FLIGHT NO. [illegible]

SHEET 1 OF

JOB NO. [illegible]

DATE [illegible]

AREA [illegible]

WEATHER [illegible]

TIME : RETURN 10 [illegible]

PILOT [illegible]

TAKE OFF 8 [illegible]

NAVIGATOR [illegible]

FLYING TIME [illegible] hrs.

OPERATOR [illegible]

TIME 2 4.

FLIGHT ABORTED DUE TO:

EQUIPMENT

E.M. [illegible]

MAGNETOMETER [illegible]

SPECTROMETRE [illegible]

FULL SCALE SENSITIVITY

I.P. [illegible] O.P. [illegible]

K [illegible] U [illegible] Th [illegible] T.C. [illegible]

LINE NO.	FIDUCIALS FROM	FIDUCIALS TO	LINE LENGTH	REMARKS
[illegible]	240	[illegible]		200'
[illegible]	540	[illegible]		175'
[illegible]	[illegible]	1236		150'
7 N	1240.	1552		
[illegible]	1570	1878		
5 S	1880.	2191		
4 N	2190	2500		
3 S	2500	2807		
2 N	[illegible]	3107		
1 [illegible]	3100	3396.		
		TAPE 024		

Ascale → 71000

FLIGHT LOG

FLIGHT NO. 4

SHEET 1 OF [illegible]

JOB NO. [illegible]

DATE 5 NOVEMBER

AREA [illegible]

WEATHER Good

TIME : RETURN

PILOT [illegible]

TAKE OFF

NAVIGATOR [illegible]

FLYING TIME hrs.

OPERATOR KELLY & SANDY

FLIGHT ABORTED DUE TO:

EQUIPMENT

FULL SCALE SENSITIVITY TAPE 24

E.M. [illegible]

I.P. [illegible] 10 000

O.P. 100 [illegible]

MAGNETOMETER [illegible]

SPECTROMETRE

K U Th T.C.

LINE NO.	FIDUCIALS FROM	FIDUCIALS TO	LINE LENGTH	REMARKS
9 S	250	568		
10 N	570	917		ARE
10 S	580	1182		[illegible] 2 [illegible]
11 N	1180	1433		" "
12	1440	1737		
13 S	1740	2010		
14 N	2010	2300		
15 S	2340	2[illegible]		
16 N	2[illegible]	—		RUN OUT OF [illegible]
7 S				
		TAPE 024		

FLIGHT LOG

FLIGHT NO. 5

SHEET 1 OF 1

JOB NO. OTTAWA

DATE 5 NOV / 94

AREA HAWKSBURY

WEATHER CLEAR

TIME: RETURN 15:02

PILOT JOE BURCH

TAKE OFF 14:59

NAVIGATOR ERIC SARSON

FLYING TIME 1 hrs.

OPERATOR KELLY & SANDY

FLIGHT ABORTED DUE TO:

EQUIPMENT

FULL SCALE SENSITIVITY

E.M. TRIDEM

I.P. O.P.

MAGNETOMETER GULF MK II

SPECTROMETRE K U Th T.C.

LINE NO.	FIDUCIALS FROM	FIDUCIALS TO	LINE LENGTH	REMARKS
16S	230	511		175'
17N	520	787		REDUCT
18S	790	1052		ABORT LINE
18N	1060	1316		
19S	1350	1641		CC/RE RESET
20N	1650	1922		
21S	1930	2217		
				TAPE 025

FLIGHT LOG

FLIGHT NO. 6

SHEET 1 OF 1

JOB NO. OTTAWA

DATE NOV 7/74

AREA HAWKSBURY

WEATHER CLEAR

TIME : RETURN 16:12:20

PILOT JOE BURCH

TAKE OFF 15:42:51

NAVIGATOR ERIC SARSON

FLYING TIME _____ hrs.

OPERATOR KELLY & SANDY

FLIGHT ABORTED DUE TO: _____

EQUIPMENT

FULL SCALE SENSITIVITY TAPE 027

E.M. TRIDEM.

I.P. _____ O.P. _____

MAGNETOMETER GULF MK II

SPECTROMETRE _____ K _____ U _____ Th _____ T.C. _____

LINE NO.	FIDUCIALS FROM	FIDUCIALS TO	LINE LENGTH	REMARKS
17 N	470	727		175'

FLIGHT LOG

FLIGHT NO. 3-4

SHEET 1 OF 1

JOB NO. GSC#9630

DATE 5 Nov.

AREA HAWKESBURY

WEATHER Good

TIME : RETURN

PILOT Joe

TAKE OFF

NAVIGATOR ERIC

FLYING TIME hrs.

OPERATOR KELLY-SANDY

TAPE: 24

FLIGHT ABORTED DUE TO:

EQUIPMENT

FULL SCALE SENSITIVITY

E.M. TRIDEM

I.P. O.P.

MAGNETOMETER GULF

SPECTROMETRE K U Th T.C.

LINE NO.	FIDUCIALS FROM	FIDUCIALS TO	LINE LENGTH	REMARKS
9S	250	568		h = 175'
8S	280	589		h = 200'
8N	590	923		h = 175'
8S	930	1236		h = 150'
7N	1240	1562		h = 175'

APPENDIX 2

MERI's Report Number 1

IREM·MERI

COMPUTER PROGRAMS FOR INTERPRETATION OF FREQUENCY DOMAIN AIRBORNE ELECTROMAGNETIC DATA

Report N° 1

Noise Reduction and Altitude Correction

Prepared for The Geological Survey of Canada
under DSS Contract N° OEQ4-0805

By Alex Becker, Ph.D., B. Eng.

MINERAL EXPLORATION RESEARCH
INSTITUTE (IREM-MERI)

Montreal, March 24, 1975

1. SUMMARY

This preliminary report on work done to date relating to the interpretation of three-frequency TRIDEM airborne electromagnetic data summarily describes the computer programs needed for data processing prior to interpretation. The first of these - PROGRAM FILTRE - is used to reduce the noise inherent to the high frequency components of the data and, in particular, the altimeter trace. It must be used prior to the altitude correction program if "false" anomalies caused by altimeter "bounce" are to be avoided.

The second program, presented here in the form of a sub-routine (CORREC) is designed for correcting the in-phase and quadrature components of field data for altitude variations.

The noise reduction program was tested on actual field data and was found to perform in a satisfactory fashion. The elevation correction program was tested on theoretical data and yielded errors lower than 7% for corrections of height up to 40 feet.

It must be noted that both programs can only be used directly in conjunction with data obtained with the Scintrex TRIDEM system when flown under Geological Survey of Canada's specifications. They can also be applied to frequency domain data obtained under other specifications if appropriate changes are made to the fixed constants used in both programs.

2. NOISE REDUCTION PROGRAM

2.1 General Description

The Noise Reduction program is based on a conventional time domain 65 coefficient low pass filter. It cuts off all signal whose

frequency exceeds 0.1 cycles/data interval, conversely it passes all data whose "period" is more than ten data intervals. The filtering is accomplished by straight forward multiplication of data and filter coefficients.

Thus we have

$$A_N = \sum_{i = N - 32,\ j = -32}^{i = N + 32,\ j = 32} W_j \ A_i$$

Where $A_N \equiv$ filtered output at N^{th} data point

$A_i \equiv$ input

$W_j \equiv$ filter coefficient.

The 65 filter coefficients are calculated from the relation

$$W_m = A(m,T)\ B\ (m)$$

Where $T \equiv$ cut-off period

$B(m) \equiv$ Parzen window factor

$A(m) \equiv$ "Infinite length" low pass filter coefficient.

More precisely

$$A(m) = \frac{2}{T} \ \frac{\mathrm{Sin}(2m\ \pi/T)}{2m\ \pi/T}$$

and $B(m) = 1 - 6x^2 + 6x^3$ for $x < 0.5$

$= 2\ (1 - x)^3$ for $0.5 < x < 1$

with $x = |m|/32$

The variation of A(m) is illustrated in Figure 1, while Figure 2 illustrates the behaviour of B(m).

The frequency response of the filter used is shown in Figure 3. Finally, Figures 4 and 5 allow an appreciation of the usefulness of the filter by contrasting filtered and raw data.

2.2 Particulars

The filtering program listing is presented in Appendix A. The coding embodies the principles discussed above. It is written to read the input data from cards and provides for the filtering of all the six TRIDEM outputs plus the altimeter. The program as presented in the listing provides for the processing of a data string of 200 entries. The sampling interval is set at 0.5 sec. and the cut-off period at 5 secs. The specific program features are established by setting the following variables:

NN	-	data string length
NPT	-	number of filter coefficients to be used
DT	-	sampling interval in secs.
TC	-	cut-off period in secs.

3. ALTITUDE CORRECTIONS

3.1 General features

3.1.1 Phase correction

The elevation correction sub-routine is derived on an heuristic basis from theoretical expressions for electromagnetic responses for a horizontally stratified earth. In particular, it appears that satisfactory phase angle corrections for all stratified earth models can be obtained by considering the "low frequency" expansion for the secondary field over a thin conducting sheet.

One then obtains,

$$\tan \phi\,(175) = \left\{ 1 + \frac{4\,h\,(175 - h)}{3364 + 4\,h^2} \right\} \tan \phi\,(h)$$

Where $\tan \phi\,(175)$ = desired value of phase angle at 175'

$\tan \phi\,(h)$ = measured value of phase angle at h'

h = flight elevation in feet a.g.l.

We illustrate the usefulness of this model in Table I by comparing the results for altitude corrections of phase angle over a homogenous ground with the exact phase angle at 175' elevation.

In the upper part of the table, we have applied a downward correction of 40 feet, in the lower half we applied an upward correction of 30 feet. In both cases the exercise was carried out for a large range of the induction parameter,

$$B = .035 \sqrt{\sigma f}$$

with σ = ground conductivity in mho/m

f = frequency in hz.

As shown in the last column of the table, the error in the correction was always inferior to 5%.

3.1.2 Amplitude corrections

The formulas used for correcting elevation effects in secondary field amplitudes are derived on a similar basis to those for the phase correction. The "in-phase" component is corrected on a purely "geometrical" image basis with the relation

$$P^2\,(175) = 1.9 \times 10^{-5} \theta^6\, P^2\,(h)$$

Where $\Theta = \left[1 - (h/29)^2\right]^{1/2}$.

$P(175)$ = Corrected value of in-phase component at 175'

$P(h)$ = Measured value of in-phase component at height "h".

On the other hand, the correction of the quadrature component is more complex and depends on whether the input data is typical of a thin conducting sheet or of a homogenous ground: the former is recognized by an inverse change of a factor of four in-phase angle tangent for a four-fold primary field frequency change. In the latter case, the secondary field phase angle tangents change but by a factor of two for the same frequency change.

Thus if we allow,

$$a = \frac{\tan \emptyset\ (h,\ 500\ hz)}{\tan \emptyset\ (h, 2000\ hz)}$$

the correction formulas for the quadrature component are,
for $a > 4$

$$Q_1^2\ (175) = \frac{1.8 \times 10^{-4}}{\left(1 - \frac{h}{29\ \Theta}\right)^2} \cdot Q^2\ (h)$$

for $a < 2$

$$Q_2^2\ (175) = \frac{6.8 \times 10^{-3}}{\left(\Theta - \frac{h}{29}\right)^2}\ ,\ Q^2\ (h)$$

Where $Q(h)$ = denotes the observed quadrature response, and,

$Q_i(175)$ = denotes the corrected value of the response.

For, $2<a<4$, one uses a weighted arithmetic mean of the two extreme cases thus

$$Q(175) = \frac{(a-2)}{2} Q_1 (175) + (1 - \frac{a-2}{2}) Q_2 (175)$$

Table II indicates the order of magnitude of the errors that can be expected when the actual model for which the elevation correction is computed does not correspond to either limiting case. Here we have computed, as a function of the induction parameter B, the altitude corrections for the case where we have about 3 feet of non-conductive overburden over a conductive half-space (K ≡ conductivity contrast ≡ 10). As in the case of the phase correction the comparison was made for both an upward and downward correction. The maximum error of 7% occurred for a downward correction of 40 feet.

3.2 Particulars

The altitude correction sub-routine listing is presented in Appendix B. The coding corresponds to the mathematical relations presented in the above section. It is written to obtain the input data from a main program and returns the corrected values to that program. To operate the sub-routine therefore one must provide a main program which would read data from an appropriate medium and output the corrected values in the described format. *Because the numerical constants used in the sub-routine relate only to the Scintrex TRIDEM system when flown to Geological Survey of Canada's specifications, it can only be used to process data obtained with that system.*

It is to be noted that the phase angle correction is done in one foot steps whereas the amplitude correction is applied in one global calculation.

Although the sub-routine as shown in Appendix B is coded in double precision, there is no need to maintain this feature for routine use.

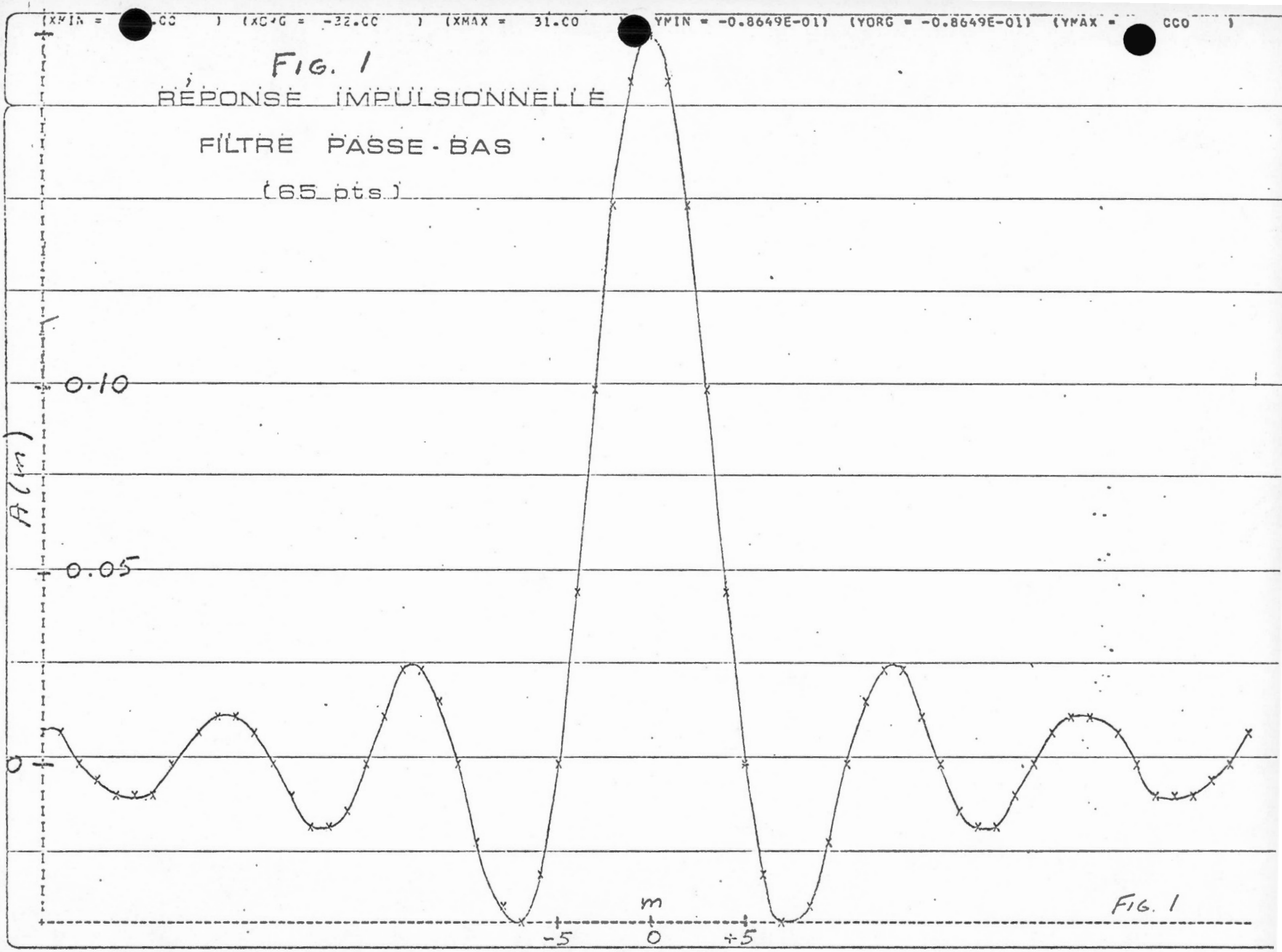
4. ACKNOWLEDGEMENTS

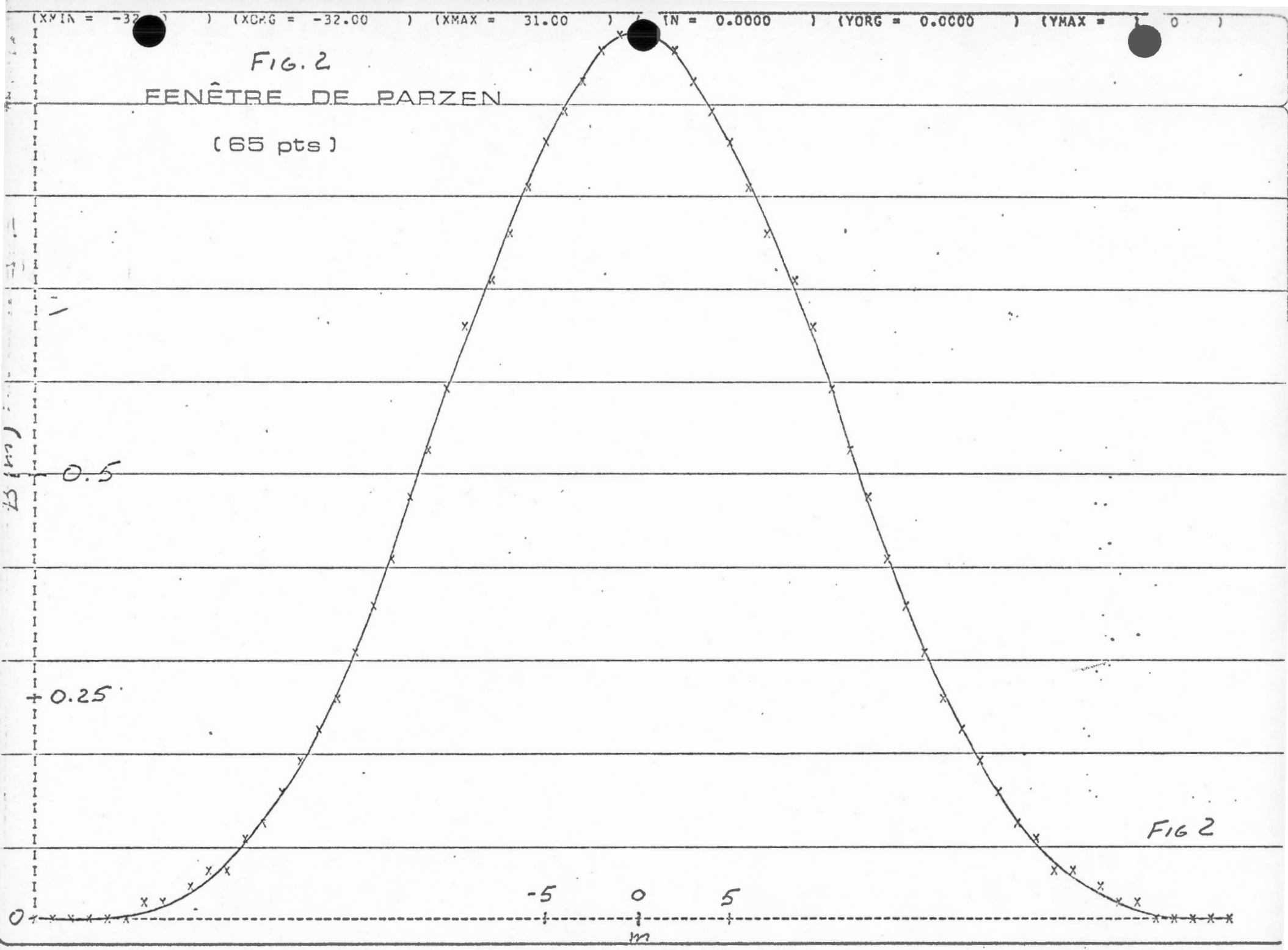
It is a pleasure to acknowledge the assistance of Dr. Pham Van Ngoc and Mr. Camil St-Hilaire in the preparation of these programs. Professor Pham provided much theoretical assistance with the filtering program. The coding of both programs and the theoretical work leading to the elevation correction program were done by Mr. St-Hilaire under the author's supervision.

A. Becker

Montreal, March 24, 1975

FIGURES


(XMIN = -.CC) (XORG = -32.CC) (XMAX = 31.CO) YMIN = -0.8649E-01) (YORG = -0.8649E-01) (YMAX = CCO)
FIG. 1
RÉPONSE IMPULSIONNELLE
FILTRE PASSE-BAS
(65 pts)
0.10
0.05
0
h(m)
m
-5
0
+5
FIG. 1


(XMIN = -32) (XORG = -32.00) (XMAX = 31.00) (YMIN = 0.0000) (YORG = 0.0000) (YMAX = 0)
FIG. 2
FENÊTRE DE PARZEN
(65 pts)
1
0.5
0.25
0
-5
0
5
m
FIG 2

(XMIN = 0.0000) (XORG = 0.0000) (XMAX = 63.00) (YMIN = 0.1004E-04) (YORG = 0.1004E-04) (YMAX = 0.0992)

FIG 3

FONCTION DE TRANSFERT

FILTRE + FENÊTRE DE PARZEN

(65 pts)

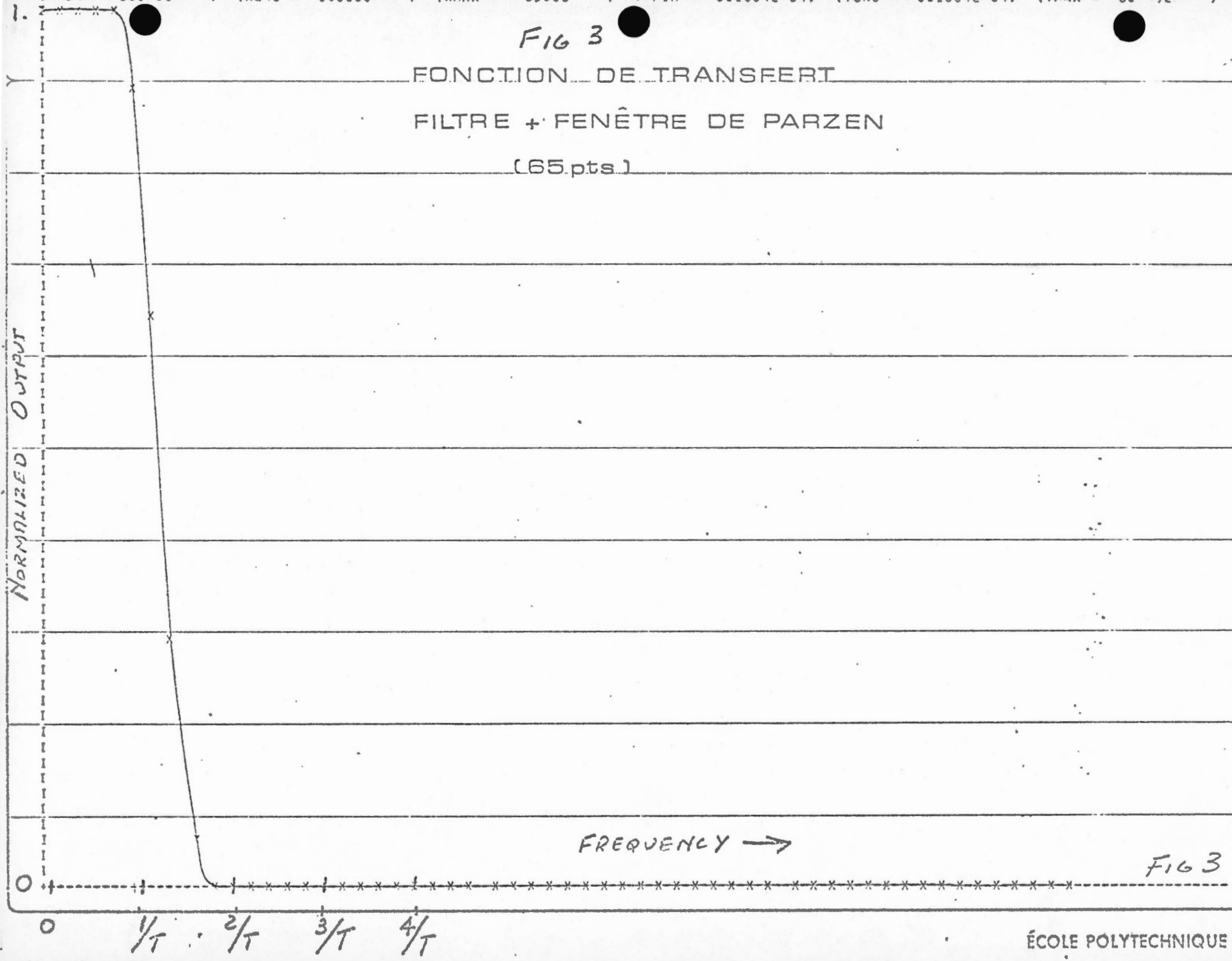


FIG 3

(XMIN = 1.000) (XORG = 1.000) (XMAX = 135.0) (YMIN = 551.0) (YORG = 551.0) (YMAX = 585.0)

FIGURE 4

SIGNAL NON FILTRÉ

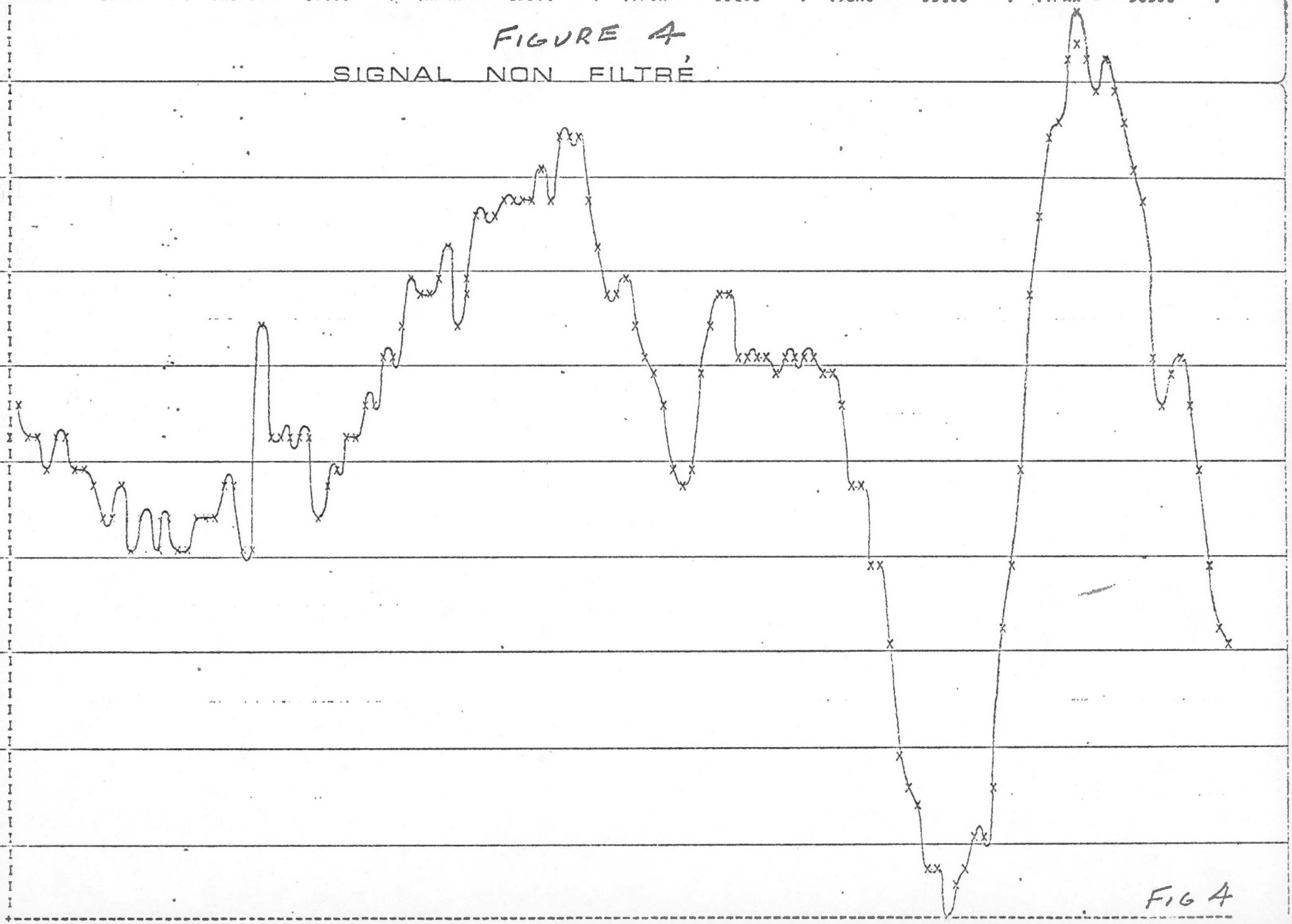


FIG 4

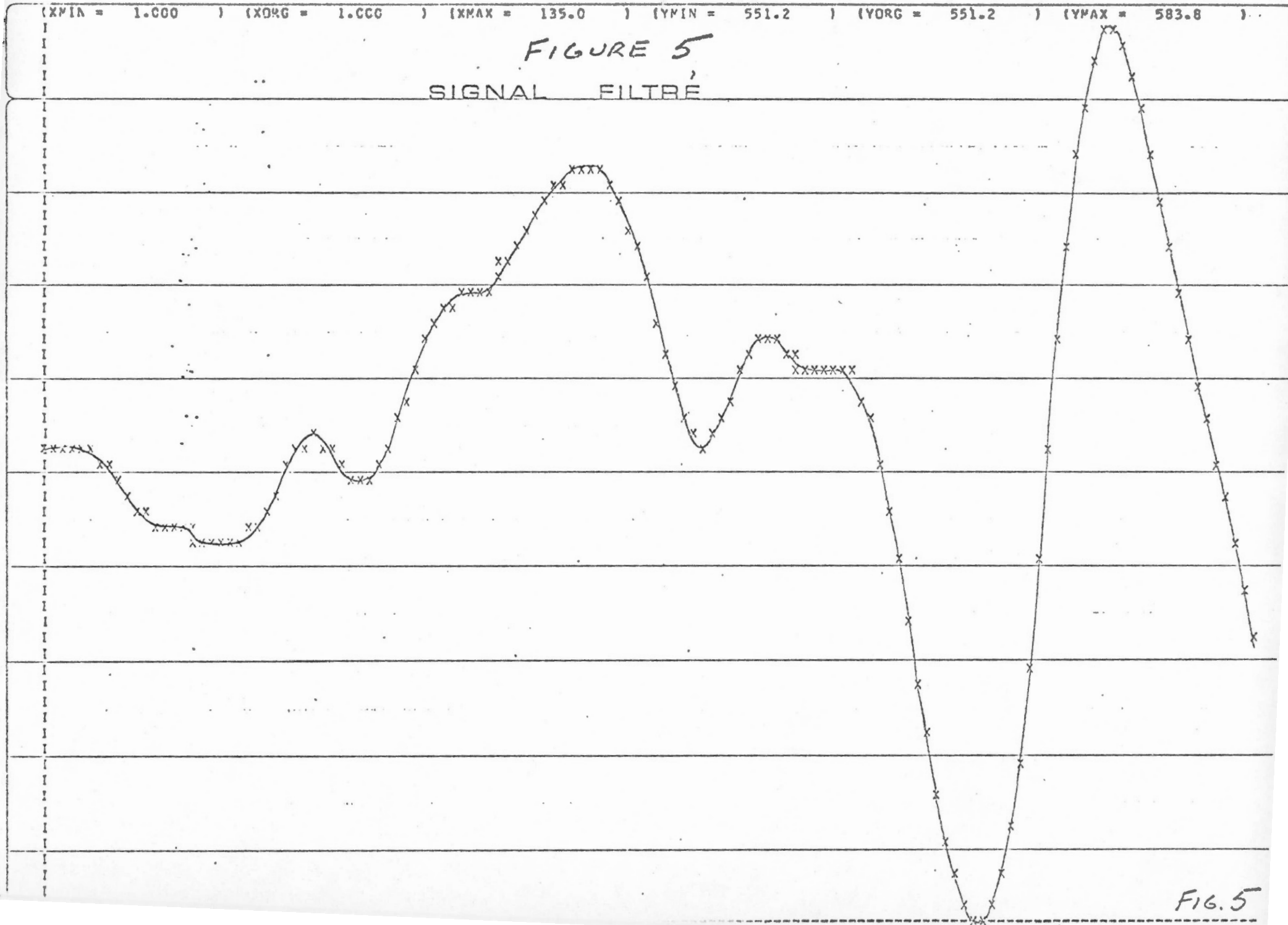

(XMIN = 1.000) (XORG = 1.000) (XMAX = 135.0) (YMIN = 551.2) (YORG = 551.2) (YMAX = 583.8)
FIGURE 5
SIGNAL FILTRÉ

FIG. 5

TABLES

TABLE I

K= 1.0 H INIT.=215.0 H STAN.=175.0

CORRECTION DE LA PHASE

B $0.035\sqrt{\sigma f}$	TANGT. INIT. $\tan\phi(215)$	TANGT. FIN. $\tan\phi(175)$ est	TANGT. STAN. $\tan\phi(175)$ exact	ERREUR %
0.040	4.6856	5.7026	5.6087	1.6741
0.080	2.7730	3.3749	3.2005	5.4477
0.160	1.5371	1.8707	1.7913	4.4310
0.320	0.9141	1.1125	1.0666	4.2989
0.640	0.5217	0.6349	0.6160	3.0671
1.280	0.2832	0.3447	0.3388	1.7237
2.560	0.1480	0.1801	0.1785	0.8881
5.120	0.0757	0.0922	0.0918	0.4478
10.240	0.0383	0.0466	0.0465	0.2137
20.480	0.0193	0.0235	0.0234	0.0908

K= 1.0 H INIT.=145.0 H STAN.=175.0

CORRECTION DE LA PHASE

B $0.035\sqrt{\sigma f}$	TANGT. INIT. $\tan\phi(145)$	TANGT. FIN. $\tan\phi(175)$ est	TANGT. STAN. $\tan\phi(175)$ exact	ERREUR %
0.040	6.5943	5.4664	5.6087	-2.5373
0.080	3.6606	3.0344	3.2005	-5.1895
0.160	2.0588	1.7066	1.7913	-4.7261
0.320	1.2244	1.0149	1.0666	-4.8467
0.640	0.7132	0.5912	0.6160	-4.0284
1.280	0.3970	0.3291	0.3388	-2.8856
2.560	0.2109	0.1748	0.1785	-2.0802
5.120	0.1089	0.0903	0.0918	-1.6469
10.240	0.0554	0.0459	0.0465	-1.4144
20.480	0.0279	0.0231	0.0234	-1.2909

TABLE II

K= 10.0 D/B= 0.1 H INIT.=145.0 H STAN.=175.0

CORRECTION DE L AMPLITUDE

B	AMPL. INIT. A(145)	AMPL. FIN. A(175) est.	AMPL. STAN. A(175) exact	ERREUR %
0.040	453.4467	359.9138	343.8017	4.6856
0.080	1189.8994	902.3459	859.7746	5.0096
0.160	2510.4889	1747.1245	1700.0234	2.7706
0.320	4106.2878	2604.0341	2615.1378	-0.4246
0.640	5411.1787	3237.2038	3305.2139	-2.0577
1.280	6231.8828	3644.3226	3721.8572	-2.0832
2.560	6692.5861	3887.1907	3951.7416	-1.6335
5.120	6947.7529	4028.1309	4078.0178	-1.2233
10.240	7114.6974	4123.2756	4160.2526	-0.8888
20.480	7296.4171	4228.1989	4249.3762	-0.4984

K= 10.0 D/B= 0.1 H INIT.=215.0 H STAN.=175.0

CORRECTION DE L AMPLITUDE

B	AMPL. INIT. A(215)	AMPL. FIN. A(175) est.	AMPL. STAN. A(175) exact	ERREUR %
0.040	251.6818	350.0396	343.8017	1.8144
0.080	589.2336	902.9266	859.7746	5.0190
0.160	1083.1563	1820.3843	1700.0234	7.0800
0.320	1563.5413	2774.4023	2615.1378	6.0901
0.640	1898.3235	3441.4538	3305.2139	4.1220
1.280	2093.1682	3819.7212	3721.8572	2.6294
2.560	2198.9973	4020.0475	3951.7416	1.7285
5.120	2256.6831	4127.4021	4078.0178	1.2110
10.240	2294.0868	4196.2354	4160.2526	0.8649
20.480	2334.4579	4270.1810	4249.3762	0.4896

APPENDICES

PROGRAM - "FILTRE"

```
C
C   FILTRAGE PAR FILTRE PASS BAS
C   FENETRE DE PARZEN
C   LONGUEUR DE LA FENETRE =NPT
C   LONGUEUR DES  DONNEES A FILTRER=NN
C   LN EST LA LONGUEUR DE LA FONCTION FILTREE
C
      REAL HR
      DIMENSION FIC(680),HR(680),ALT(680),P5(680),P8(680),P2(680),C5(680
     1),C2(680),C8(680)
      DIMENSION FIL(70),W(70),G1(630),G2(630),G3(630),G4(630),G5(630),G6
     1(630),G7(630)
      NPT=65
      NN=200
      LN=NN-NPT
      NP=NPT-1
      L=(NPT-1)/2
      LL=(3*(NPT-1))/4
      LI=L+1
      LF=LL+1
      DO 21 I=LI,LF
      P=I-LI
      Q=L
      U=ABS(P/Q)
   21 W(I)=1.-6.*U**2.+6.*U**3.
      LII=LL+2
      DO 22 I=LII,NPT
      P=I
      P=I-LI
      Q=L
      U=ABS(P/Q)
   22 W(I)=2.*(1.-U)**3.
      LIII=L+2
      DO 23 I=LIII,NPT
      J=NPT+1-I
   23 W(J)=W(I)
C
C   FILTRE PASS BAS IDEAL
C   DT=INTERVALLE DE TEMPS ENTRE LES DONNEES
C   WC=2*PI*(LA FREQUENCE DE COUPURE)
C   TC=PERIODE MAXIMALE DES FREQUENCES A ELIMINER
C
      PI=3.1415926535
      DT=0.5
      TC=5.0
      WC=2.*PI/TC
      DO 10 I=1,NPT
      AI=FLOAT(I-LI)
      IF(AI) 11,12,11
   12 FIL(I)=WC/PI
      GO TO 10
   11 FIL(I)=SIN(WC*AI*DT)/(AI*DT*PI)
   10 CONTINUE
C
C   FILTRE*PARZEN=FILTRE
      DO 13 I=1,NPT
   13 FIL(I)=FIL(I)*W(I)
      READ(5,14) (FIC(J),HR(J),ALT(J),P5(J),C5(J),P2(J),C2(J),P8(J),C8(J
     1),J=1,NN)
```

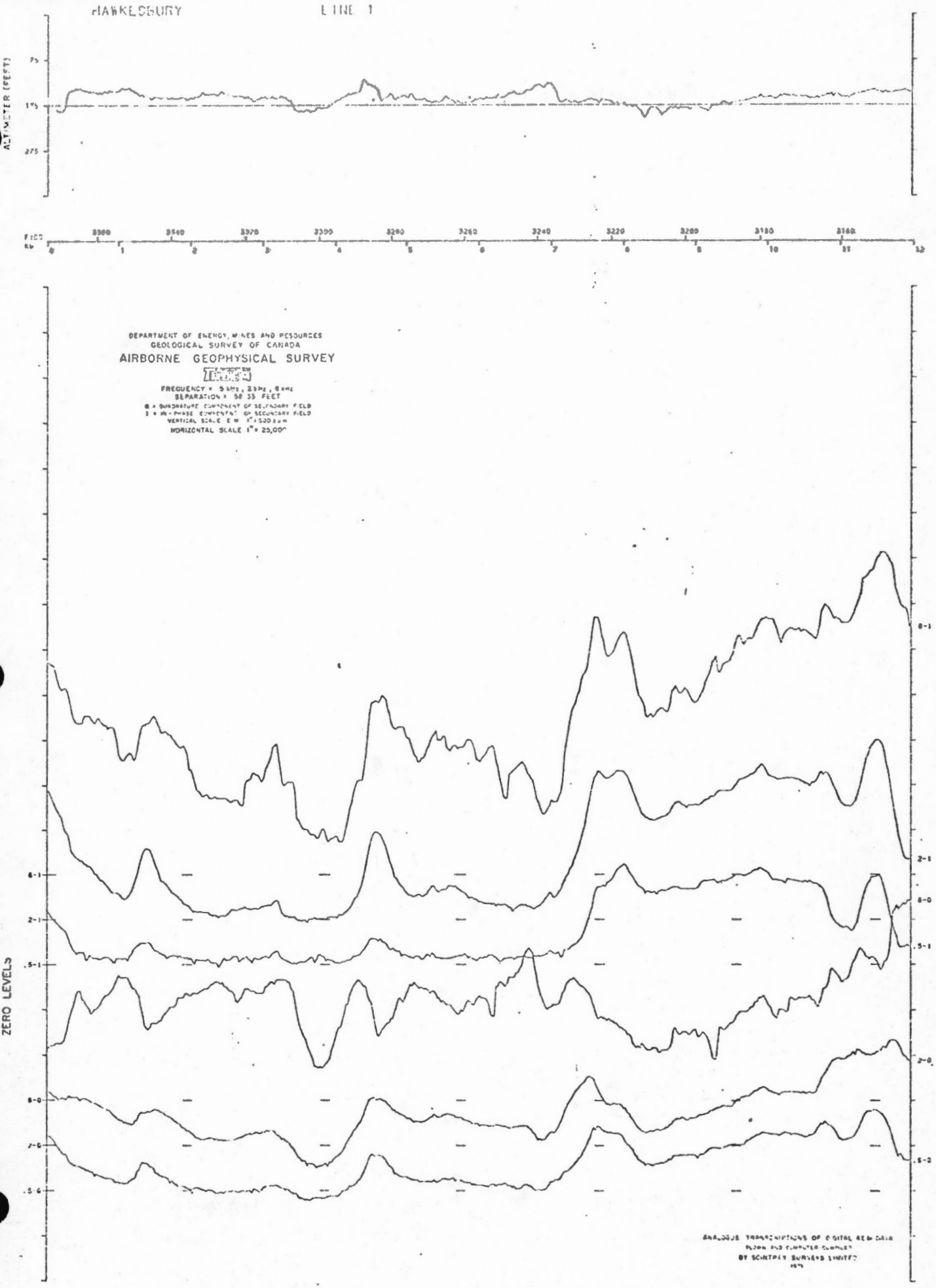
```
   14 FORMAT(F4.0,F6.0,6X,7F3.0,6X,F4.0,F6.0,6X,7F3.0)
C
      CALL FILPBI(D5,FIL,G1,LN,NPT,DT)
      CALL FILPBI(C5,FIL,G2,LN,NPT,DT)
      CALL FILPBI(D2,FIL,G3,LN,NPT,DT)
      CALL FILPBI(C2,FIL,G4,LN,NPT,DT)
      CALL FILPBI(D8,FIL,G5,LN,NPT,DT)
      CALL FILPBI(C8,FIL,G6,LN,NPT,DT)
      CALL FILPBI(ALT,FIL,G7,LN,NPT,DT)
C
      WRITE(6,15) (FID(J+32),HR(J+32),G7(J),G1(J),G2(J),G3(J),G4(J),G5(J
     1),G6(J),J=1,LN)
      WRITE(7,15) (FID(J+32),HR(J+32),G7(J),G1(J),G2(J),G3(J),G4(J),G5(J
     1),G6(J),J=1,LN)
   15 FORMAT(2X,F5.0,F7.0,7F6.2)
      STOP
      END

      SUBROUTINE FILPBI(D,FIL,G,LN,NPT,DT)
C
C
C-------------------------
C   D=DONNEES A FILTRER
C   G=DONNEES FILTREES
C   DT=INTERVALLE DE TEMPS ENTRE LES DONNEES
C   FIL=VALEURS DU FILTRE
C   LN=LONGUEUR DE LA FONCTION FILTREE
C   NPT=LONGUEUR DU FILTRE
C-------------------------
C
      DIMENSION FIL(70),D(660),G(630)
      DO 5 J=1,LN
      S=0.0
      DO 4 I=1,NPT
      IAK=I+J-1
    4 S=S+D(IAK)*FIL(I)
    5 G(J)=S*DT
      RETURN
      END
```

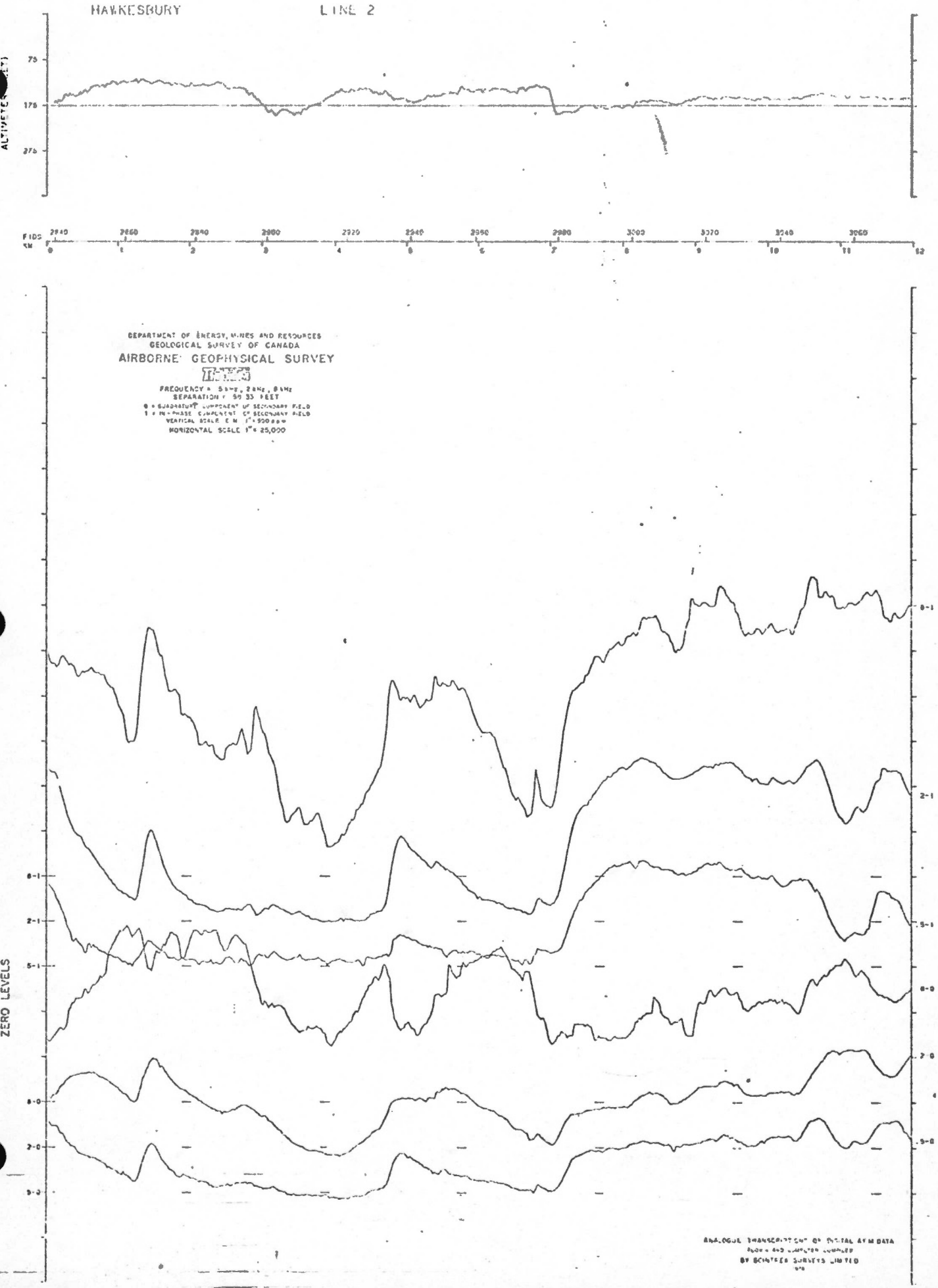
```
      SUBROUTINE CORREC(XI,YI,AMPI,TGI,H,AMPF,TGF)
C-----------------------------------------------------------------
C   SOUS-ROUTINE CALCULANT LA CORRECTION D ALTITUDE POUR LA PHASE ET
C   L AMPLITUDE
C   XI ET YI SONT LES COMPOSANTES EN PHASES ET EN QUADRATURES DU CHAMP
C   SECONDAIRE NORMALISE MESUREES A LA HAUTEUR DE VOL *H* EN PIEDS
C   AMPI ET TGI SONT LES AMPLITUDES ET LES TG(PHASE) CORRESPONDANTES
C   AMPF ET TGF SONT LES AMPLITUDES ET LES TG(PHASE) CORRIGEES
C   ON A SUPPOSE UNE HAUTEUR DE VOL STANDARD DE 175 PIEDS (D OU VIENNENT
C   LES VALEURS DE MC,HC,RC,HS)
C   LA DISTANCE EMETTEUR-RECEPTEUR EST DONNEE PAR *RO* EN PIEDS
C-----------------------------------------------------------------
      IMPLICIT REAL*8(A-Z)
      INTEGER HI,DEL,I,J
      DIMENSION XI(3),YI(3),AMPI(3),TGI(3),AMPF(3),TGF(3)
      HS=175.0
      MC=1.8101549D-04
      HC=6.7726151D-03
      RC=1.909253E-05
      RO=58.0
      H1=(1.+(2.*H/RO)**2.)
      H2=H1**3.
      H3=(DSQRT(H1)-2.*H/RO)**2.
      HI=H
      HA=DFLOAT(HI)
      IF((H-HS).GT.0.) GO TO 5
      S=1.
      HB=H-HA-1.
      DEL=(HS-(HA+1.))
      GO TO 6
    5 S=-1.
      HB=H-HA
      DEL=HA-HS
C---CALCUL DE NOTRE CORRECTION DE PHASE---
    6 DO 8 I=1,3
      TGF(I)=TGI(I)*(1.+4.*H*HB/(RO**2.+4.*H**2.))
      R=H-HB
      IF(DEL.EQ.0) GO TO 8
      DO 7 J=1,DEL
      R=R+S
    7 TGF(I)=TGF(I)*(1.-4.*(R-S)*S/(RO**2.+4.*(R-S)**2.))
    8 CONTINUE
C---CALCUL DE NOTRE CORRECTION D AMPLITUDE-
      TEST=TGI(1)/TGI(2)
      IF(TEST.GE.4.0) GO TO 12
      IF(TEST.LE.2.0) GO TO 14
      DO 11 I=1,3
      R=RC*H2*XI(I)**2.
      RAPPOR=(TEST-2.)/2.
      IIH=DSQRT((HC/H3)*YI(I)**2.)
      IIH=(1.-RAPPOR)*IIH
      IM=DSQRT((MC/H3)*HI*YI(I)**2.)
      IM=IM*RAPPOR
      INORME=(IM+IIH)**2.
   11 AMPF(I)=DSQRT(R+INORME)
      RETURN
   12 DO 13 I=1,3
      R=RC*H2*XI(I)**2.
      IM=(MC/H3)*HI*YI(I)**2.
   13 AMPF(I)=DSQRT(R+IM)
      RETURN
   14 DO 15 I=1,3
      R=RC*H2*XI(I)**2.
      IIH=(HC/H3)*YI(I)**2.
   15 AMPF(I)=DSQRT(R+IIH)
      RETURN
      END
```

APPENDIX 3

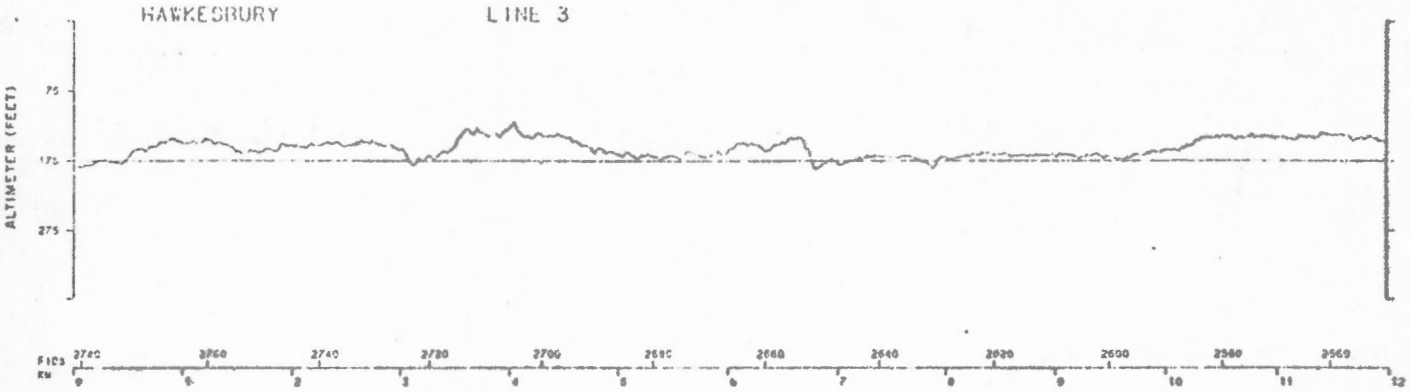
Original Data Set

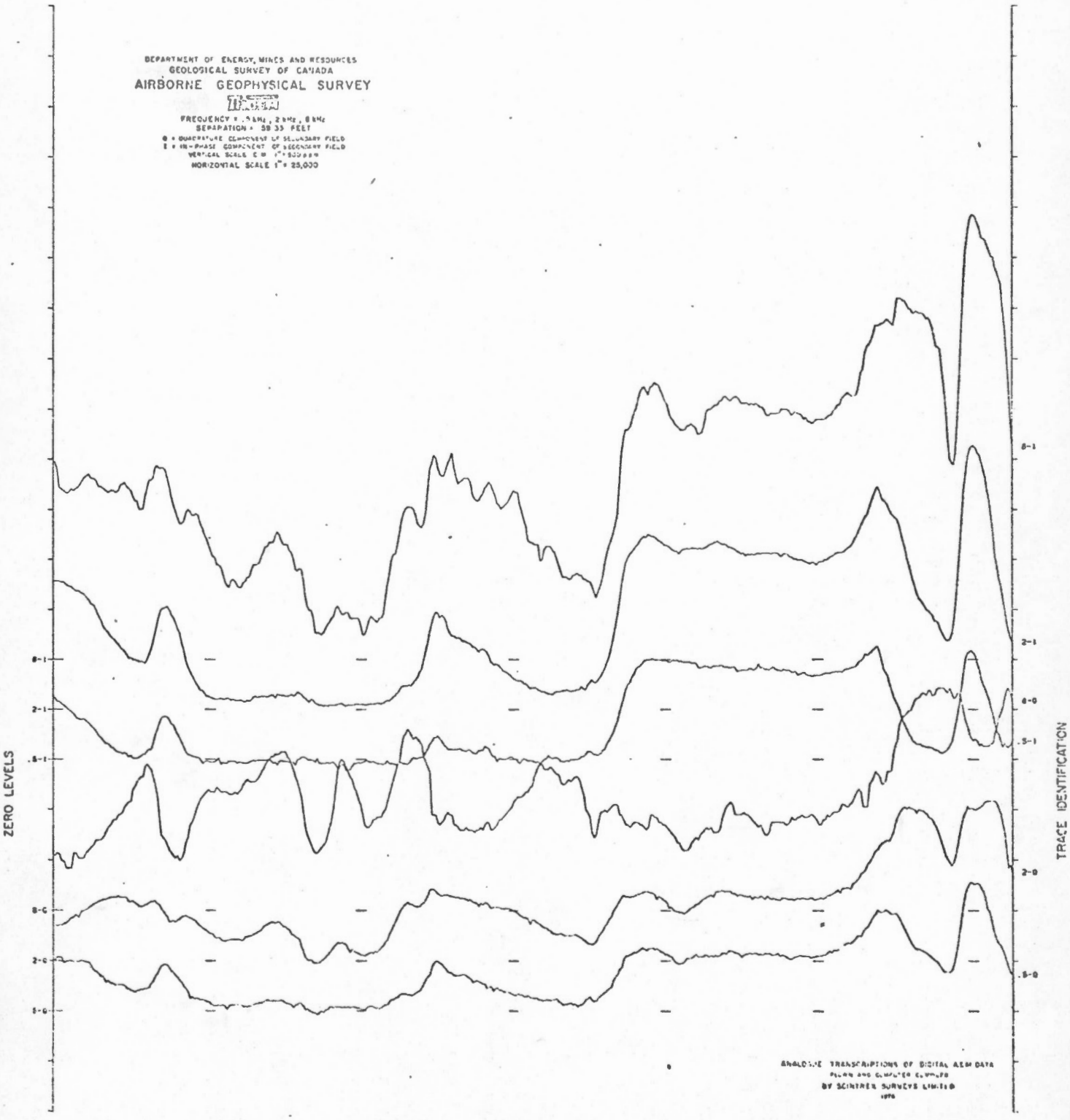

HAWKESBURY
LINE 1
ALTIMETER (FEET)
DEPARTMENT OF ENERGY, MINES AND RESOURCES
GEOLOGICAL SURVEY OF CANADA
AIRBORNE GEOPHYSICAL SURVEY
FREQUENCY = 5 kHz, 2.5 kHz, 0.5 kHz
SEPARATION = 58.33 FEET
Q = QUADRATURE COMPONENT OF SECONDARY FIELD
I = IN-PHASE COMPONENT OF SECONDARY FIELD
VERTICAL SCALE
HORIZONTAL SCALE 1" = 25,000'
ZERO LEVELS
TRACE IDENTIFICATION

HAWKESBURY LINE 2

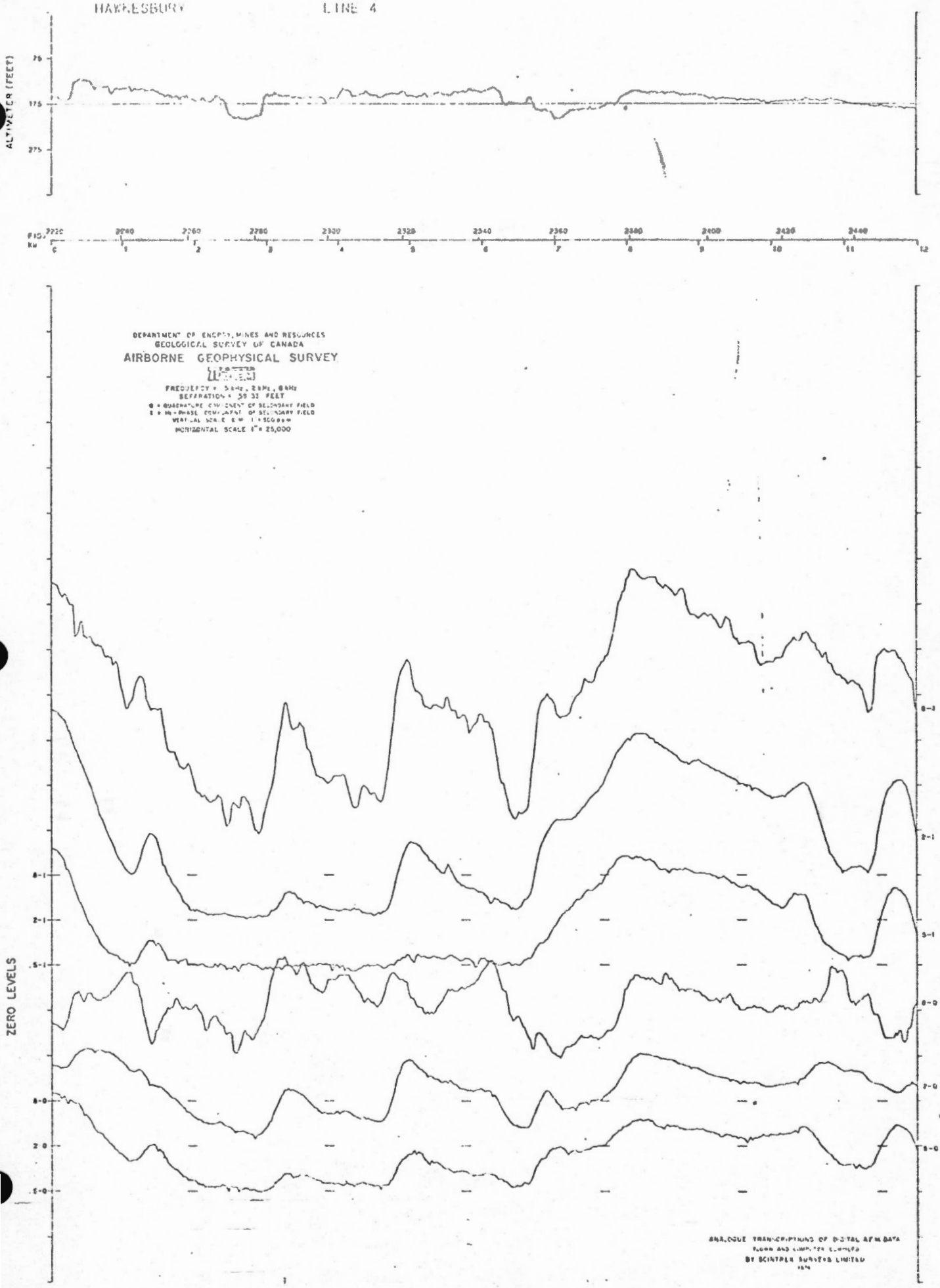


HAWKESBURY LINE 3

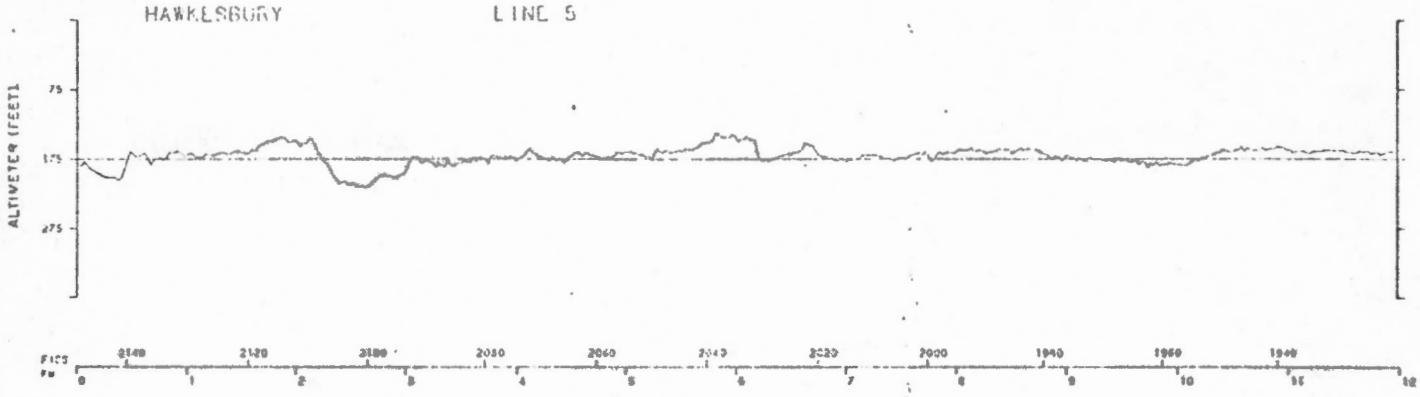




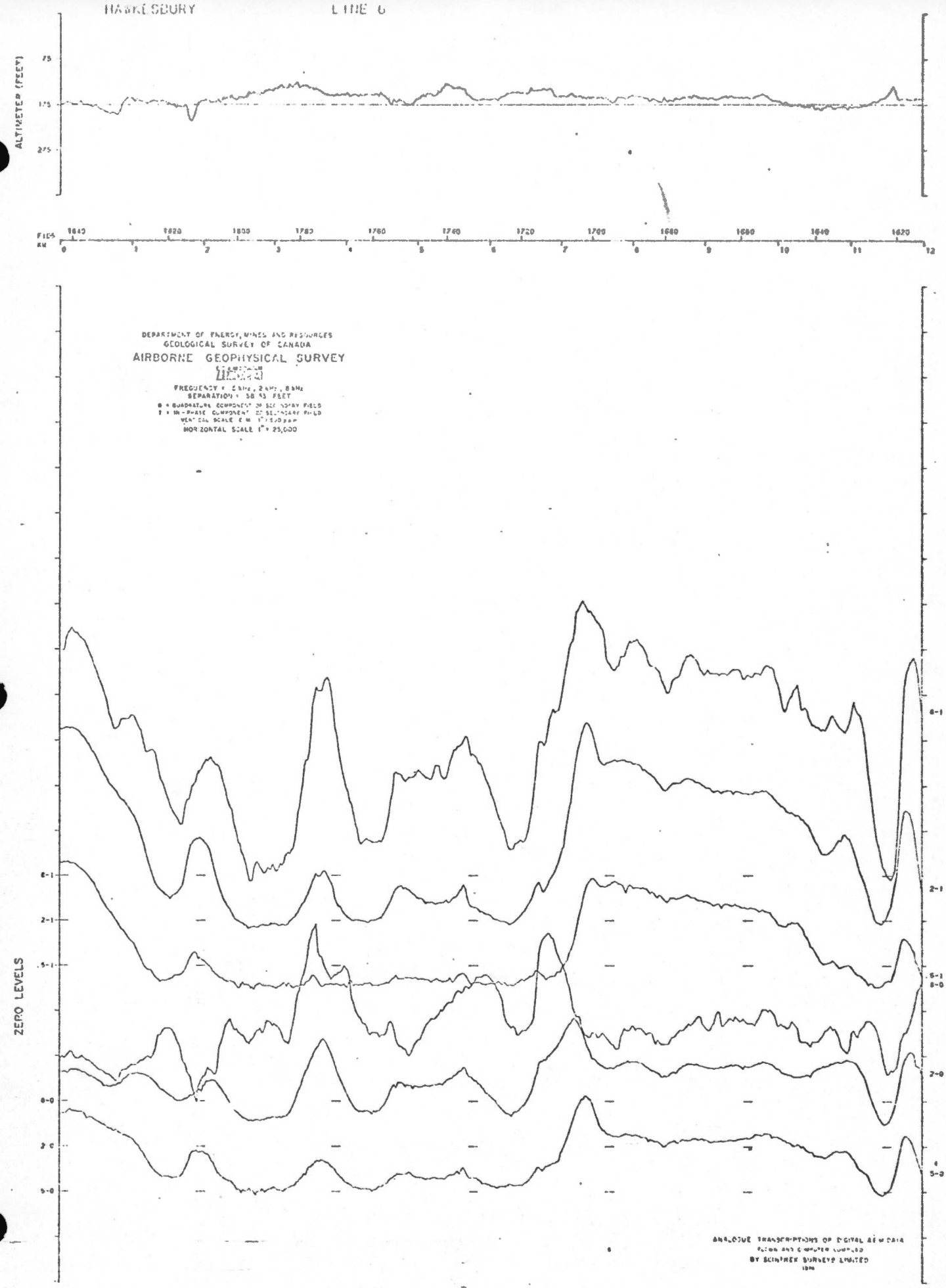
HAWKESBURY LINE 4

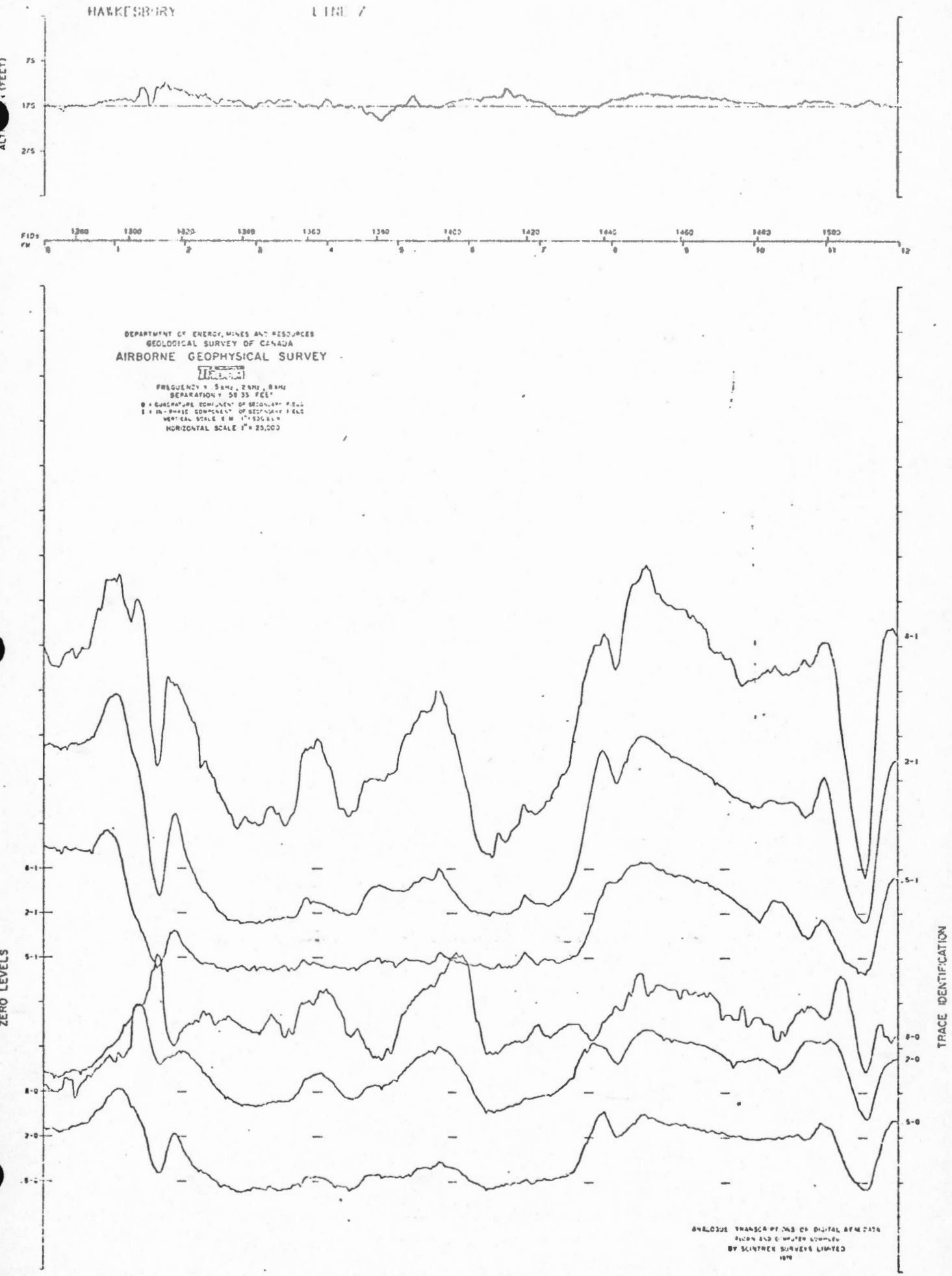


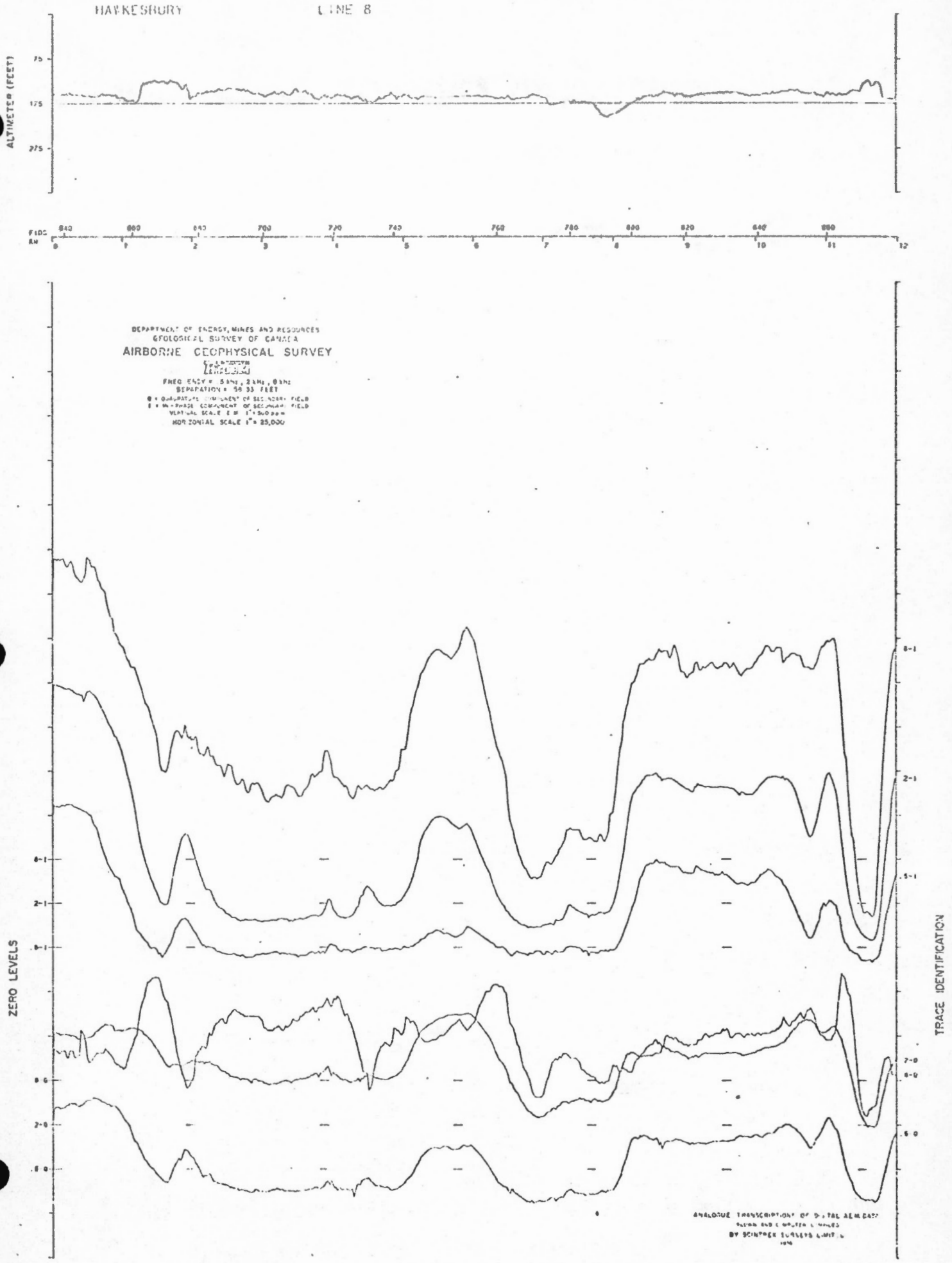
HAWKESBURY LINE 5



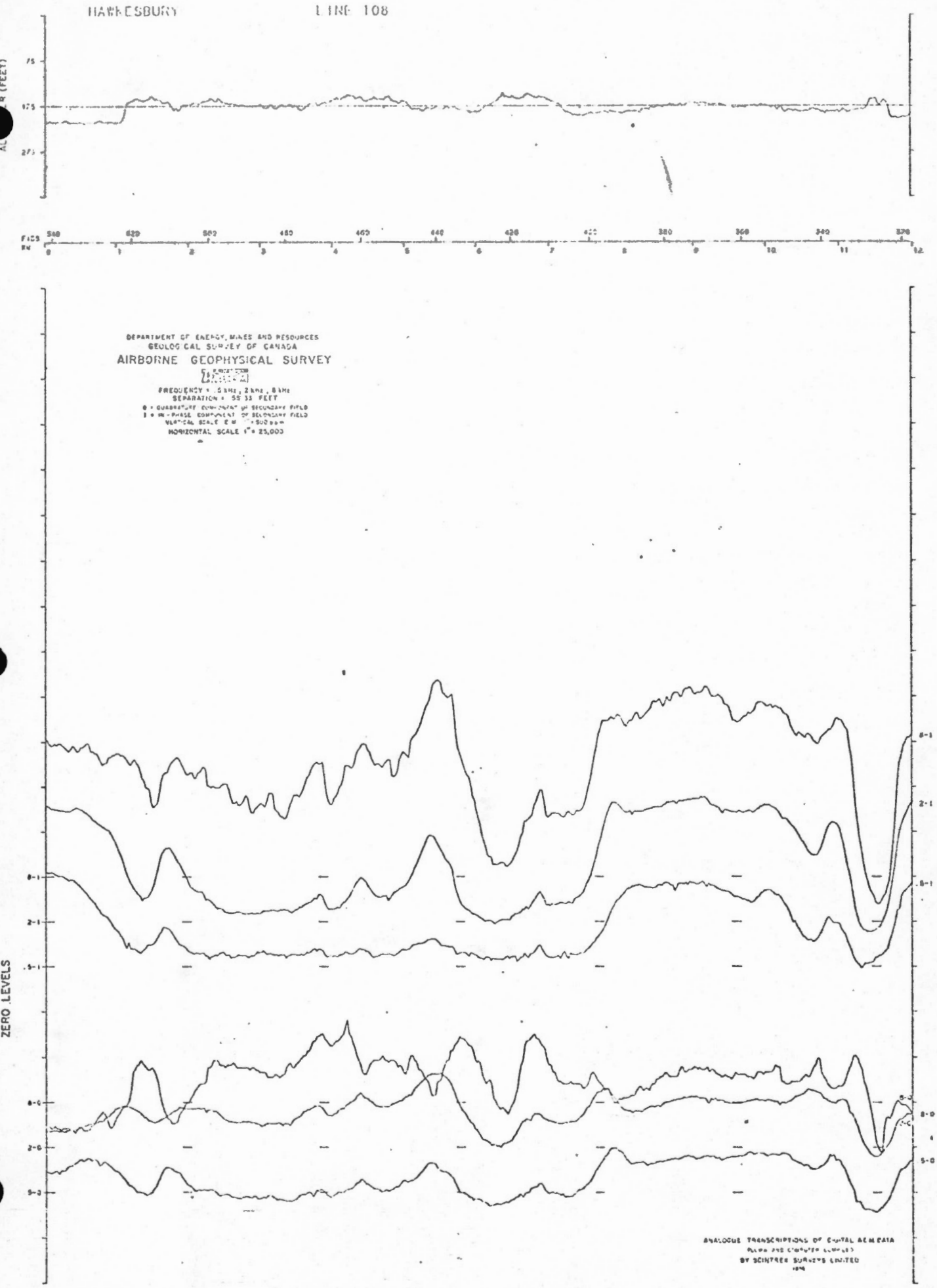
HAWKESBURY LINE 6



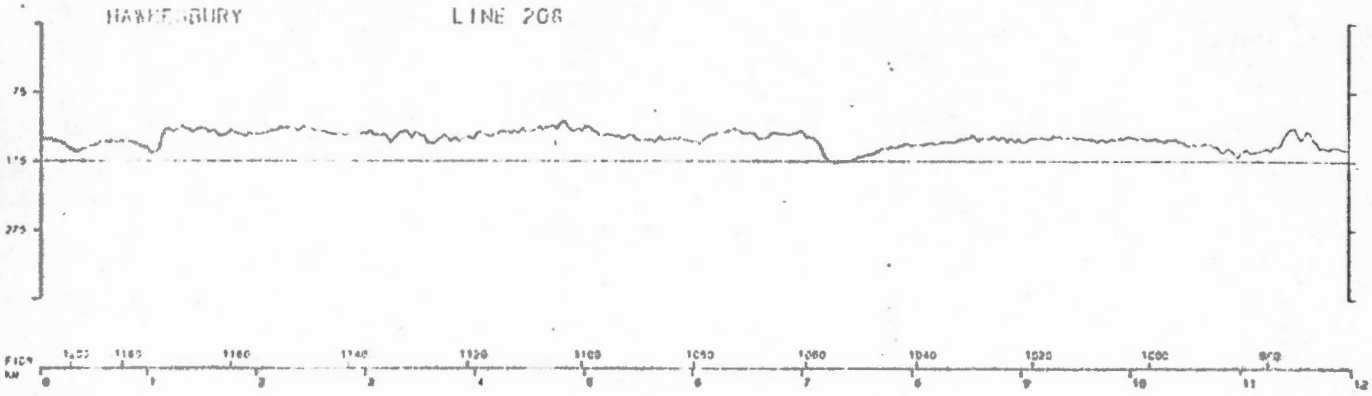

HAWKESBURY
LINE 7
ALT (FEET)
75
175
275
FIDS
KM
1300
1320
1340
1360
1380
1400
1420
1440
1460
1480
1500
0
1
2
3
4
5
6
7
8
9
10
11
12
DEPARTMENT OF ENERGY, MINES AND RESOURCES
GEOLOGICAL SURVEY OF CANADA
AIRBORNE GEOPHYSICAL SURVEY
FREQUENCY = 5 kHz, 2 kHz, 8 kHz
SEPARATION = 56.35 FEET
HORIZONTAL SCALE 1" = 25,000
ZERO LEVELS
8-1
2-1
5-1
8-0
2-0
5-0
TRACE IDENTIFICATION
BY SCINTREX SURVEYS LIMITED

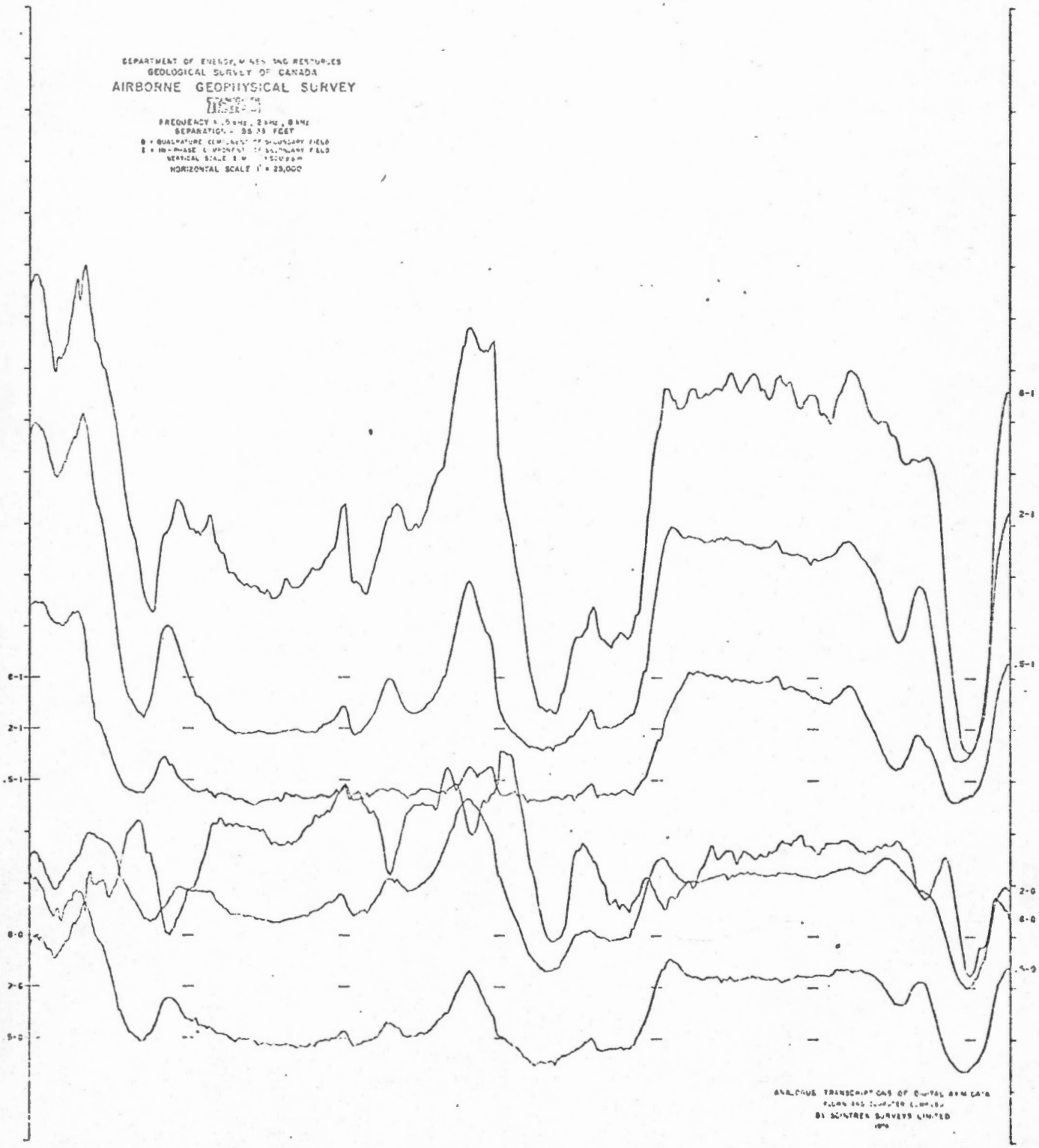

HAWKESBURY
LINE 8
ALTIMETER (FEET)
75
175
275
FIDS
KM
0
1
2
3
4
5
6
7
8
9
10
11
12
DEPARTMENT OF ENERGY, MINES AND RESOURCES
GEOLOGICAL SURVEY OF CANADA
AIRBORNE GEOPHYSICAL SURVEY
SEPARATION = 56.33 FEET
HORIZONTAL SCALE 1" = 25,000
ZERO LEVELS
TRACE IDENTIFICATION

HAWKESBURY LINE 108

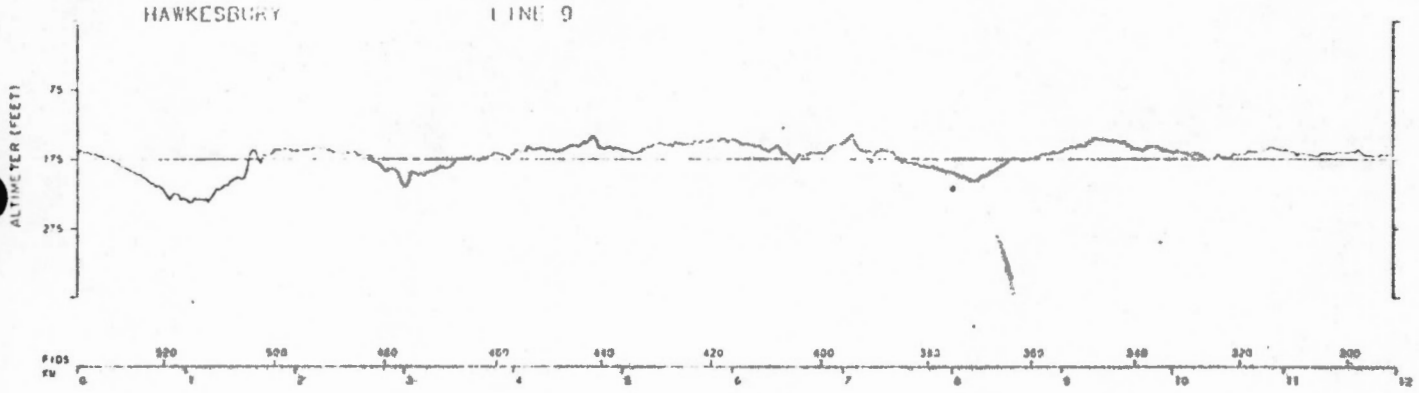


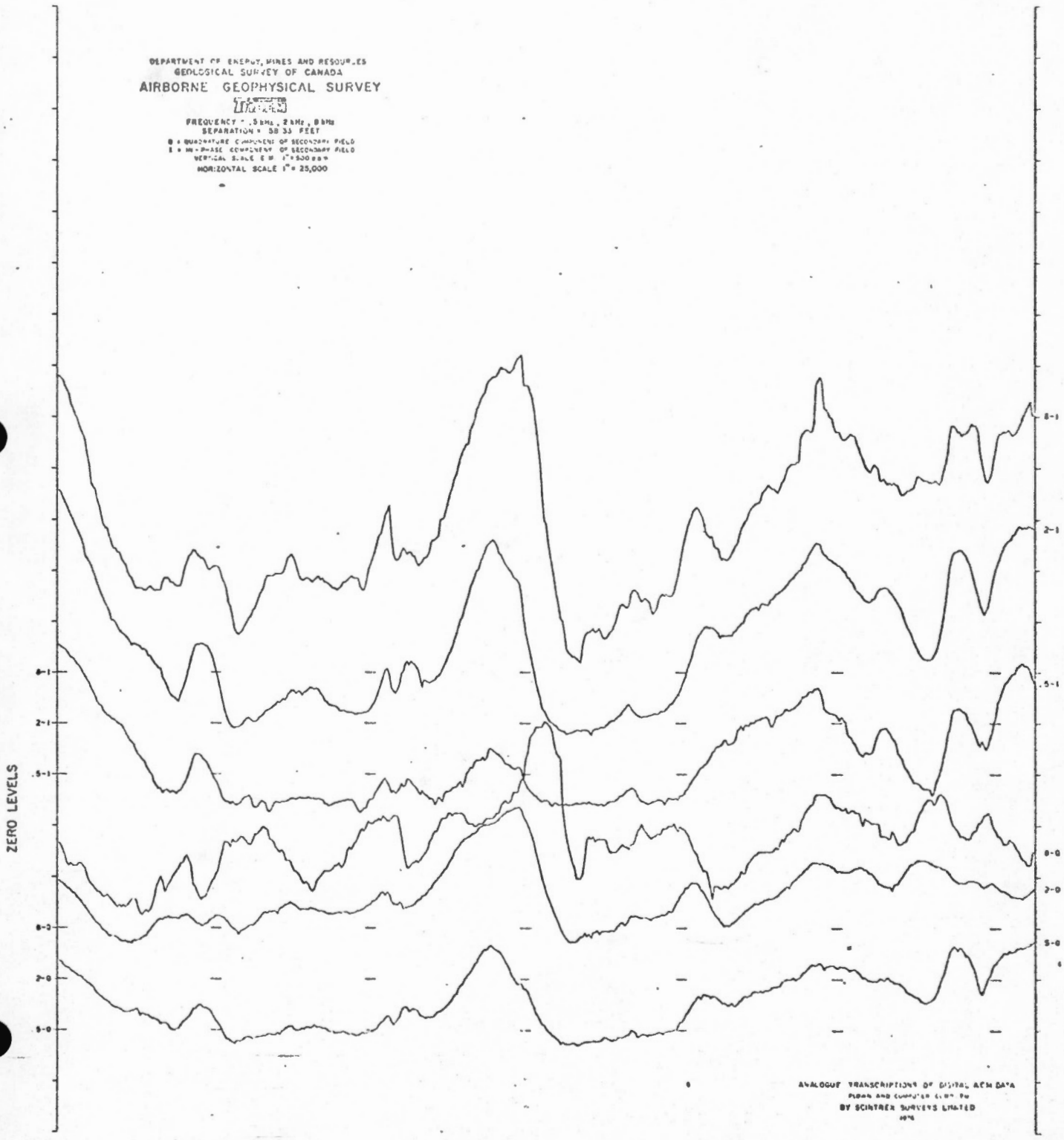
HAWKESBURY LINE 208



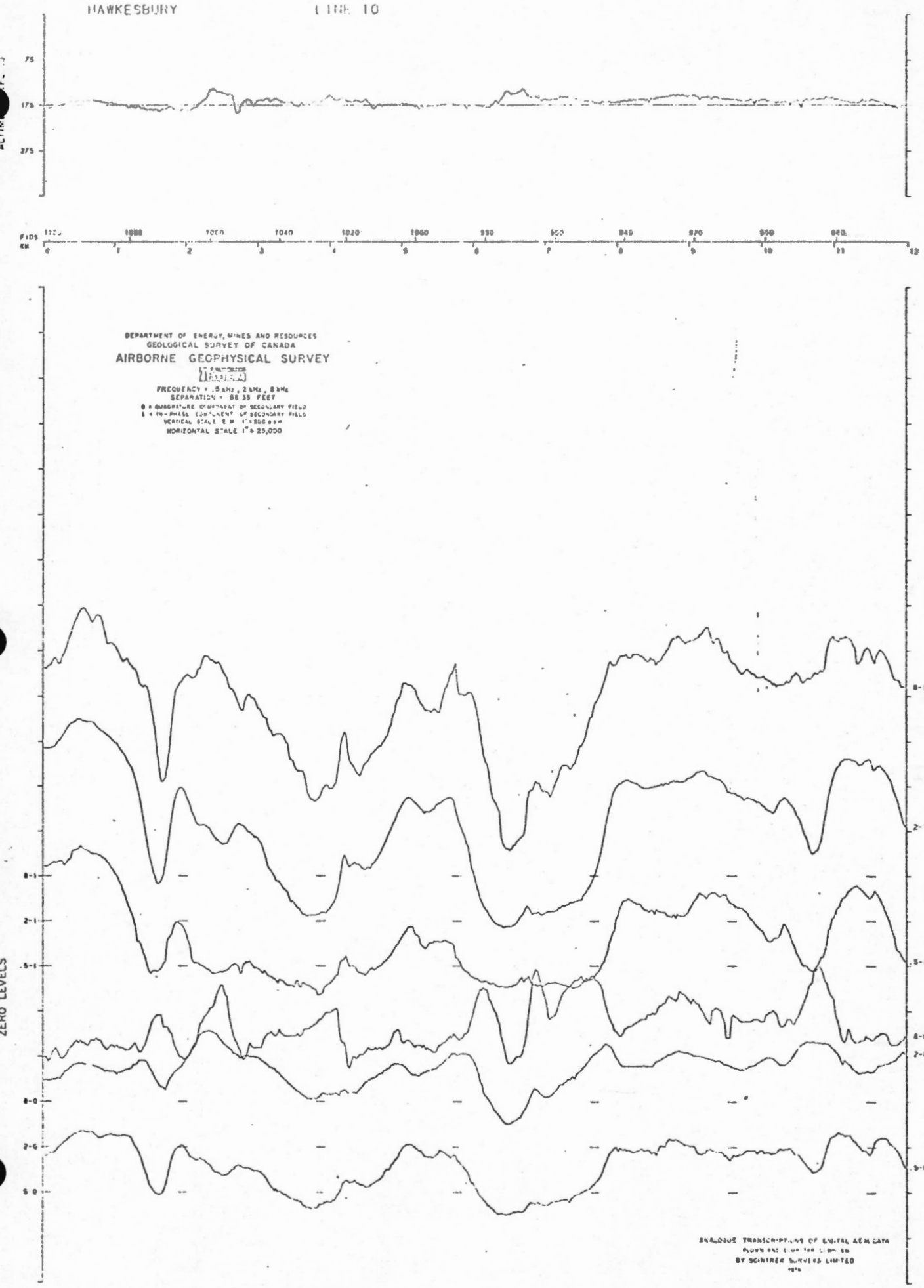


HAWKESBURY LINE 9

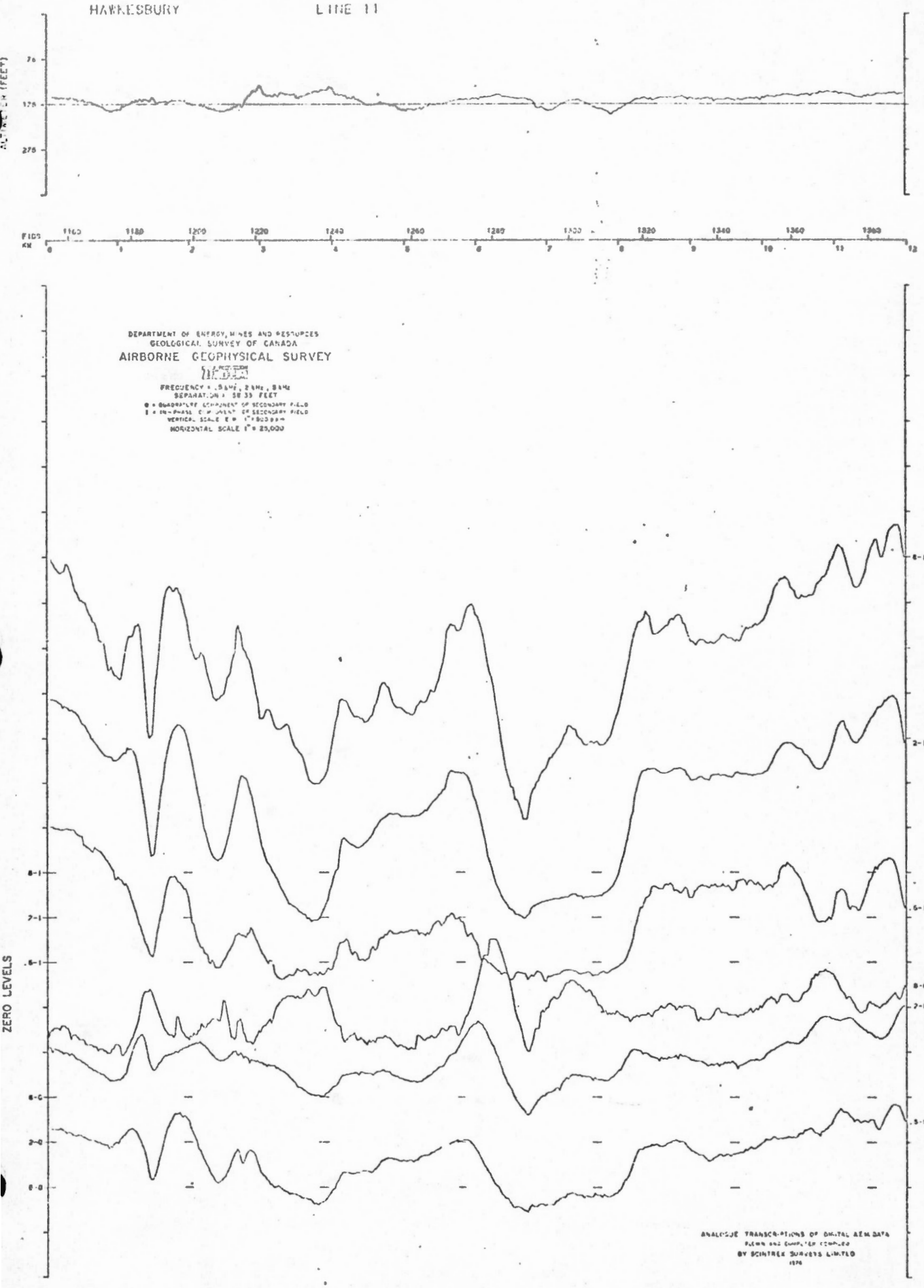




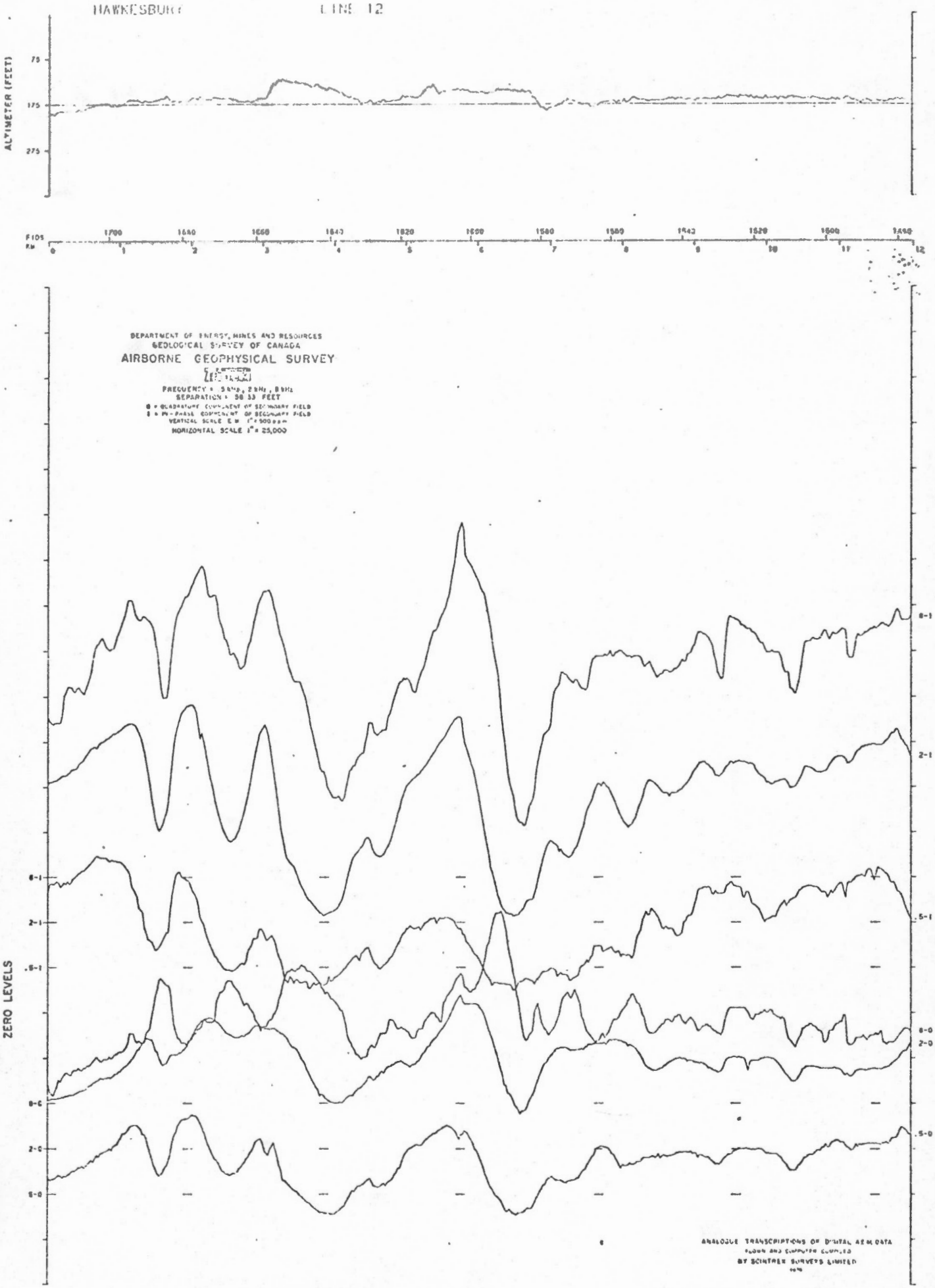
HAWKESBURY LINE 10



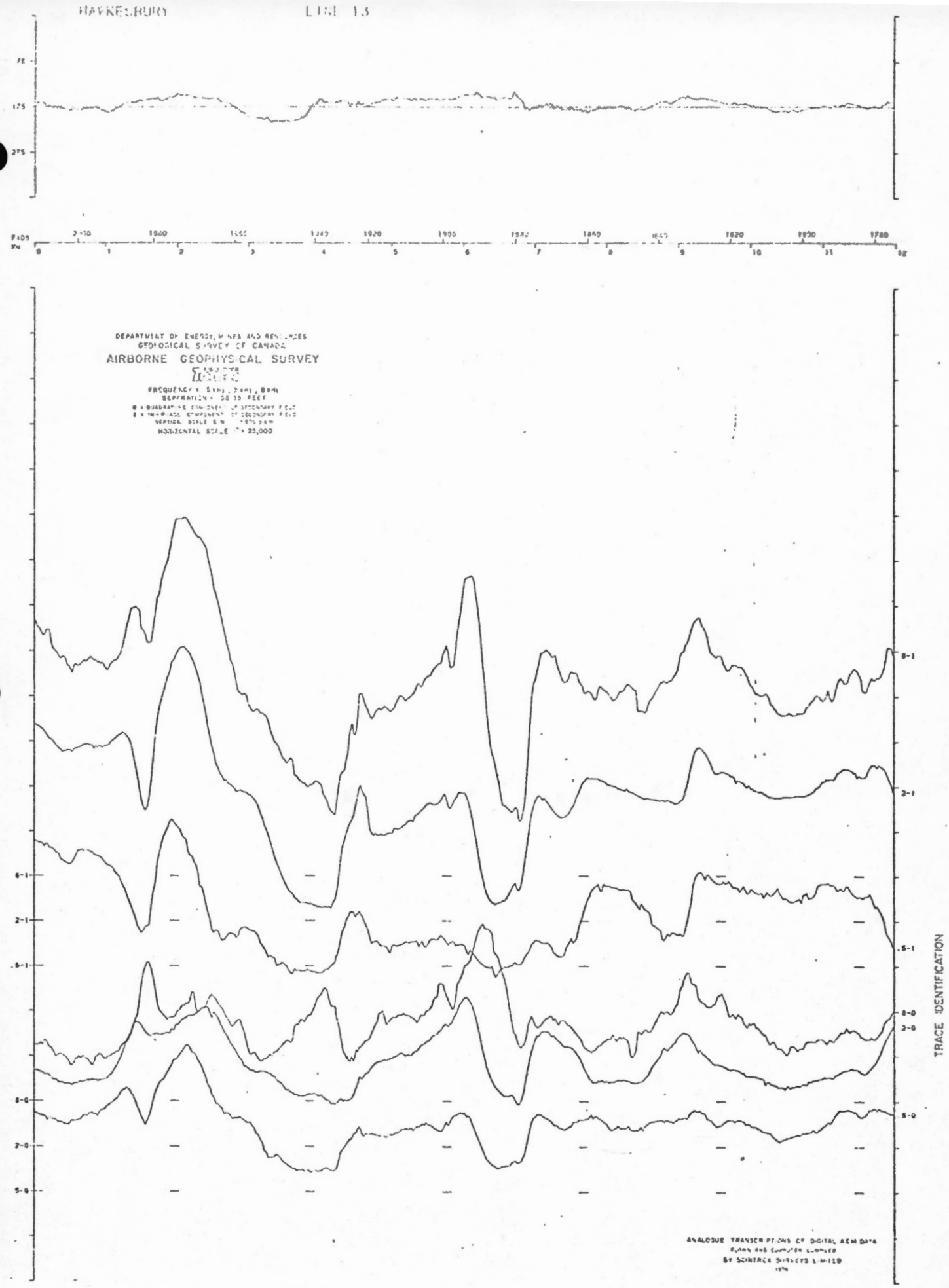
HAWKESBURY LINE 11



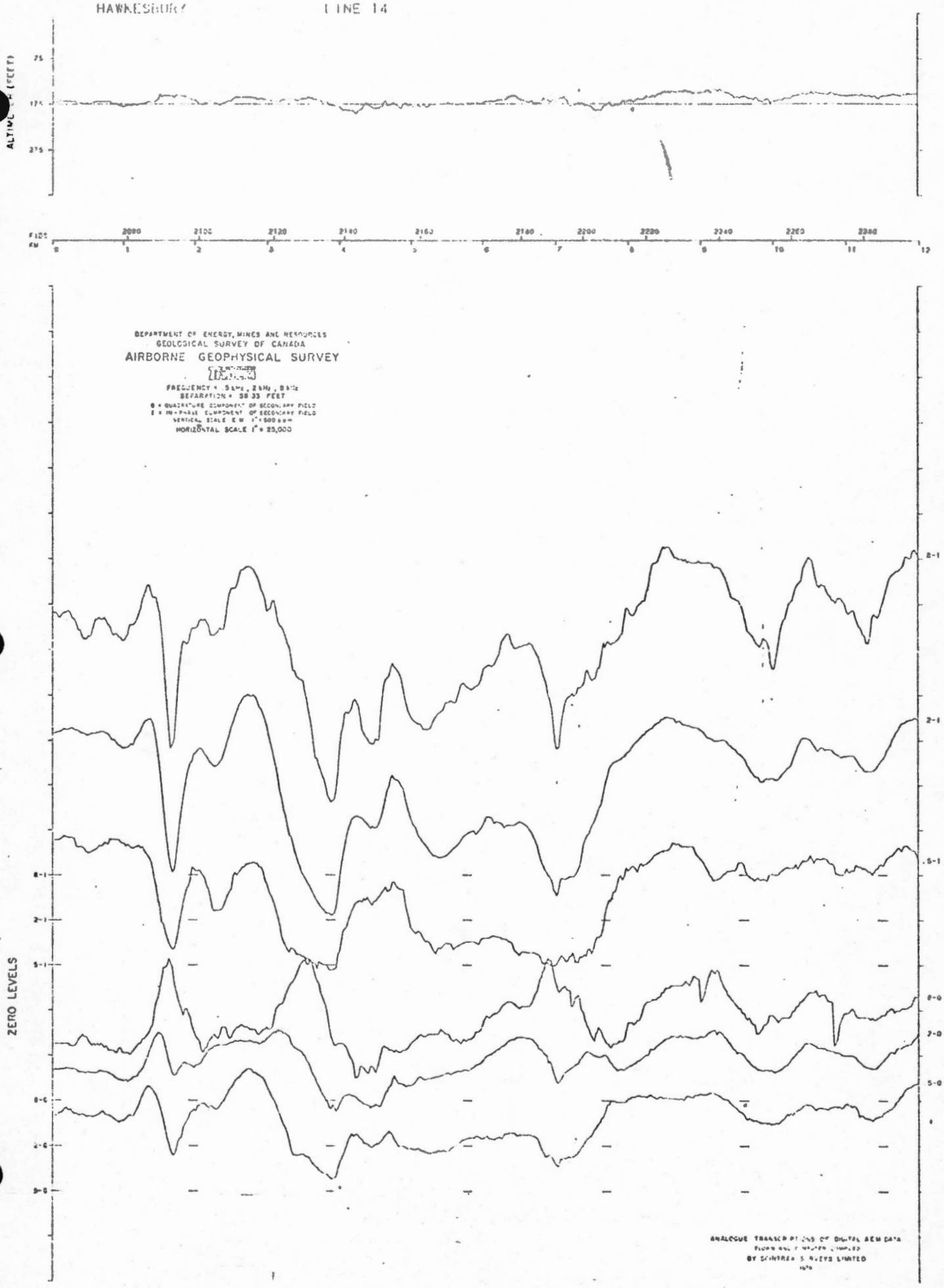
HAWKESBURY LINE 12



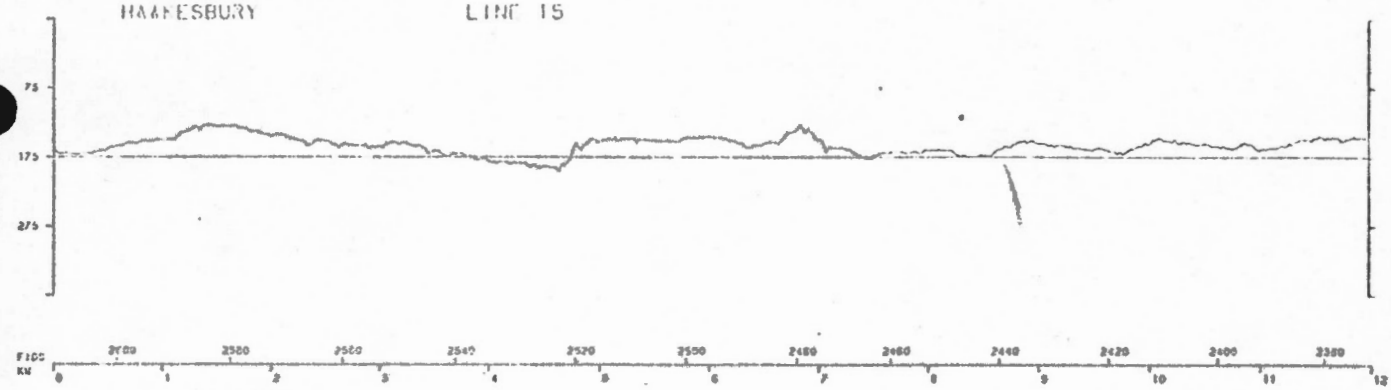
HAVKESBURY LINE 13

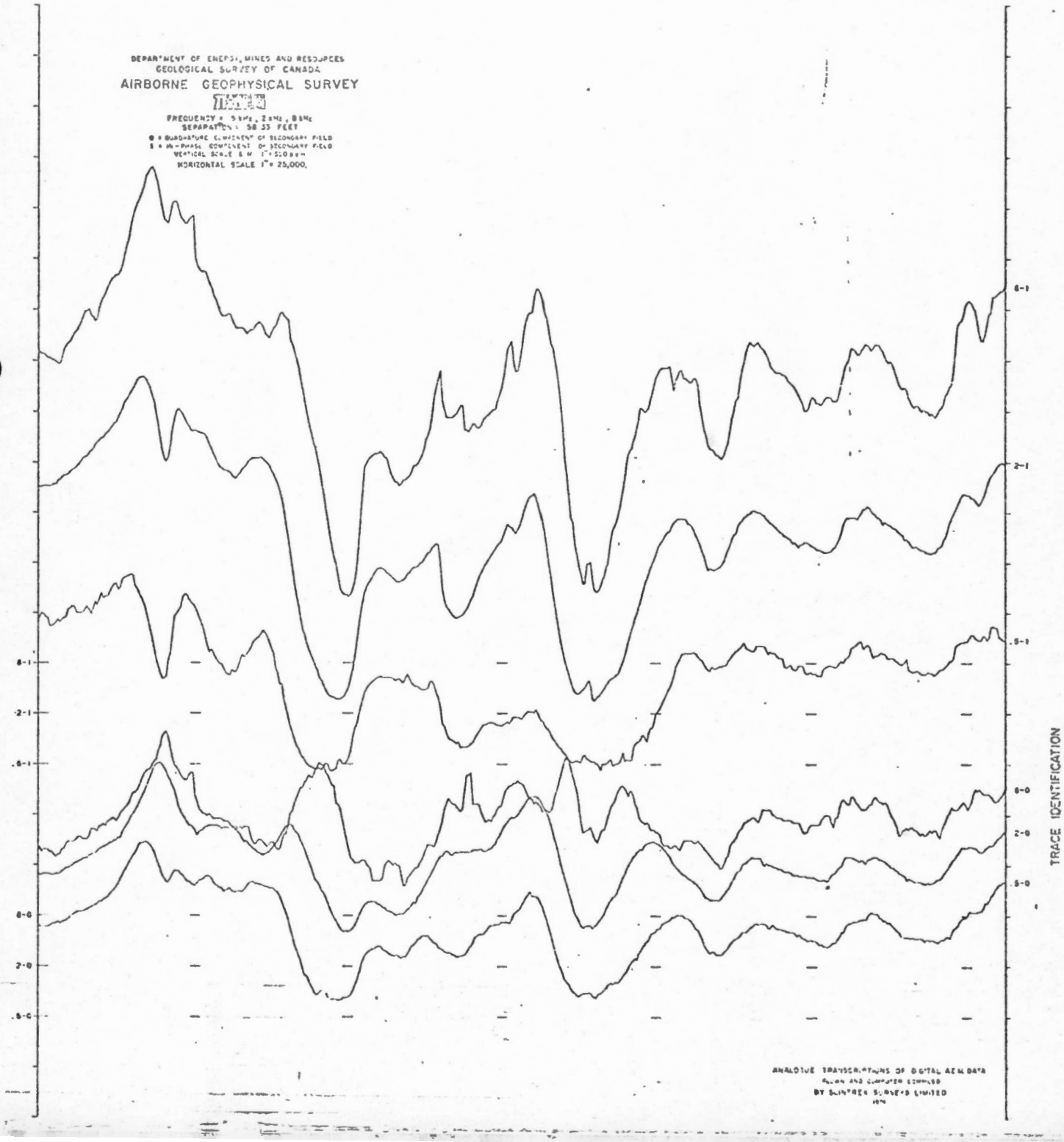


HAWKESBURY LINE 14

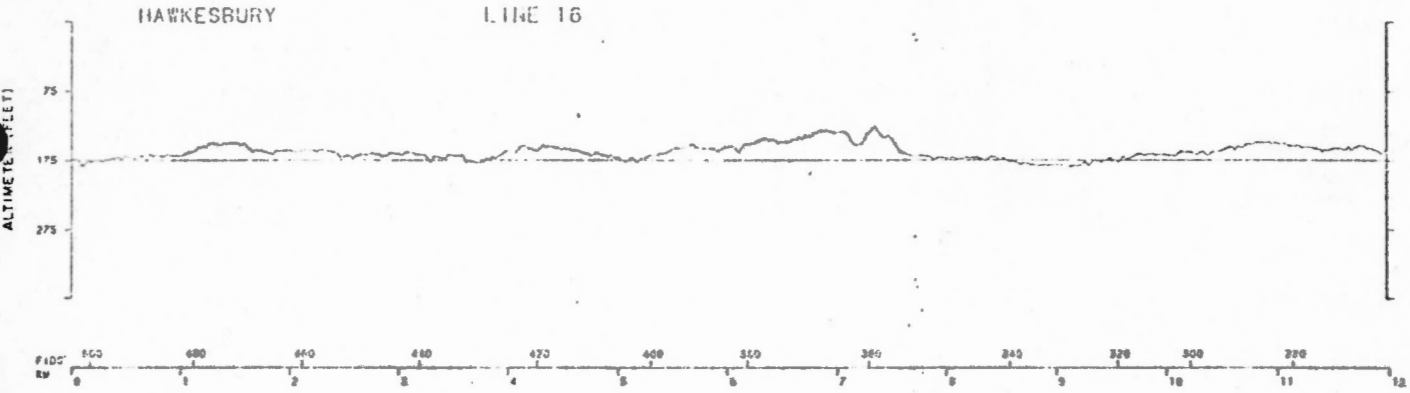


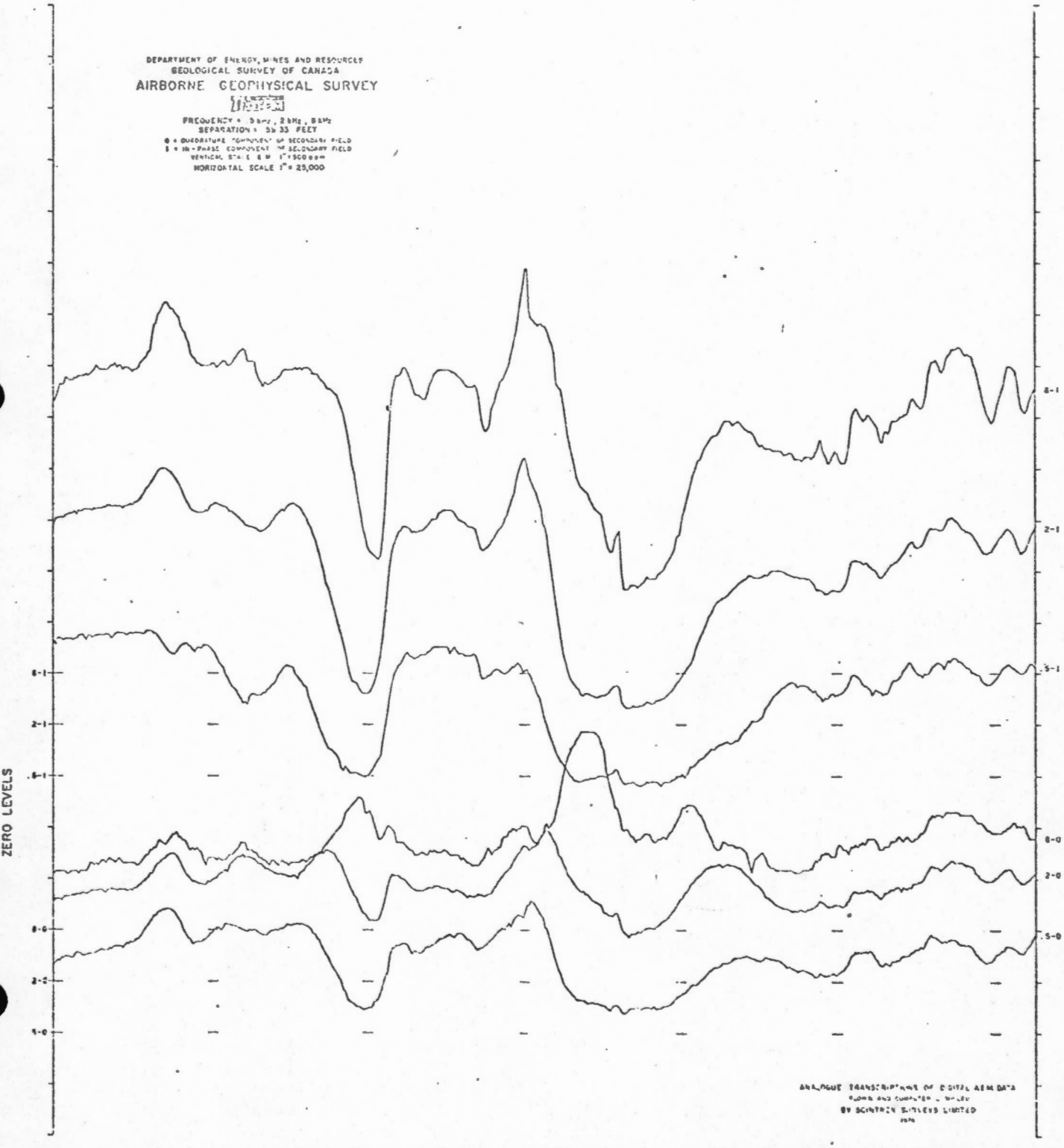
HAWKESBURY LINE 15



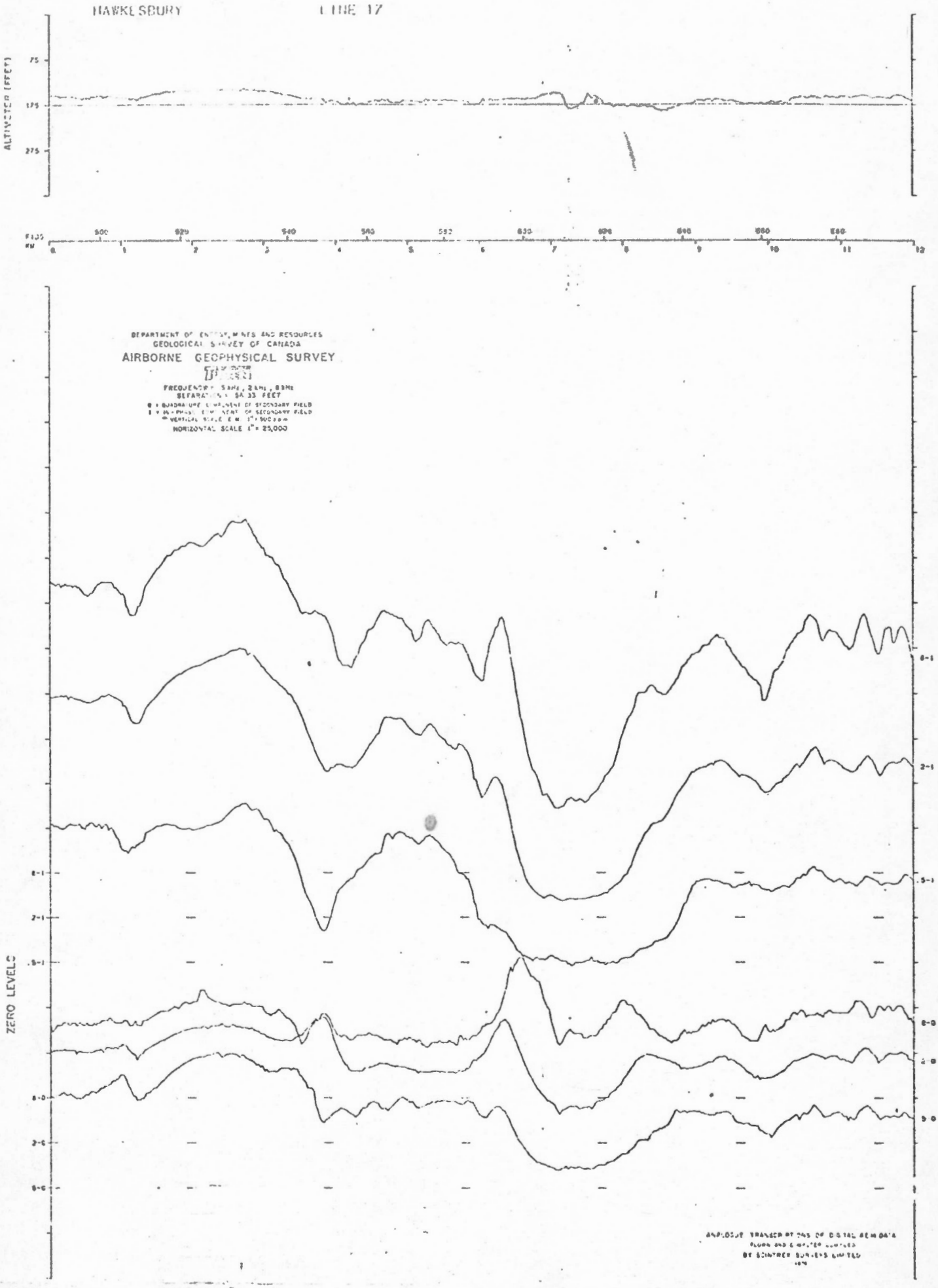


HAWKESBURY LINE 16

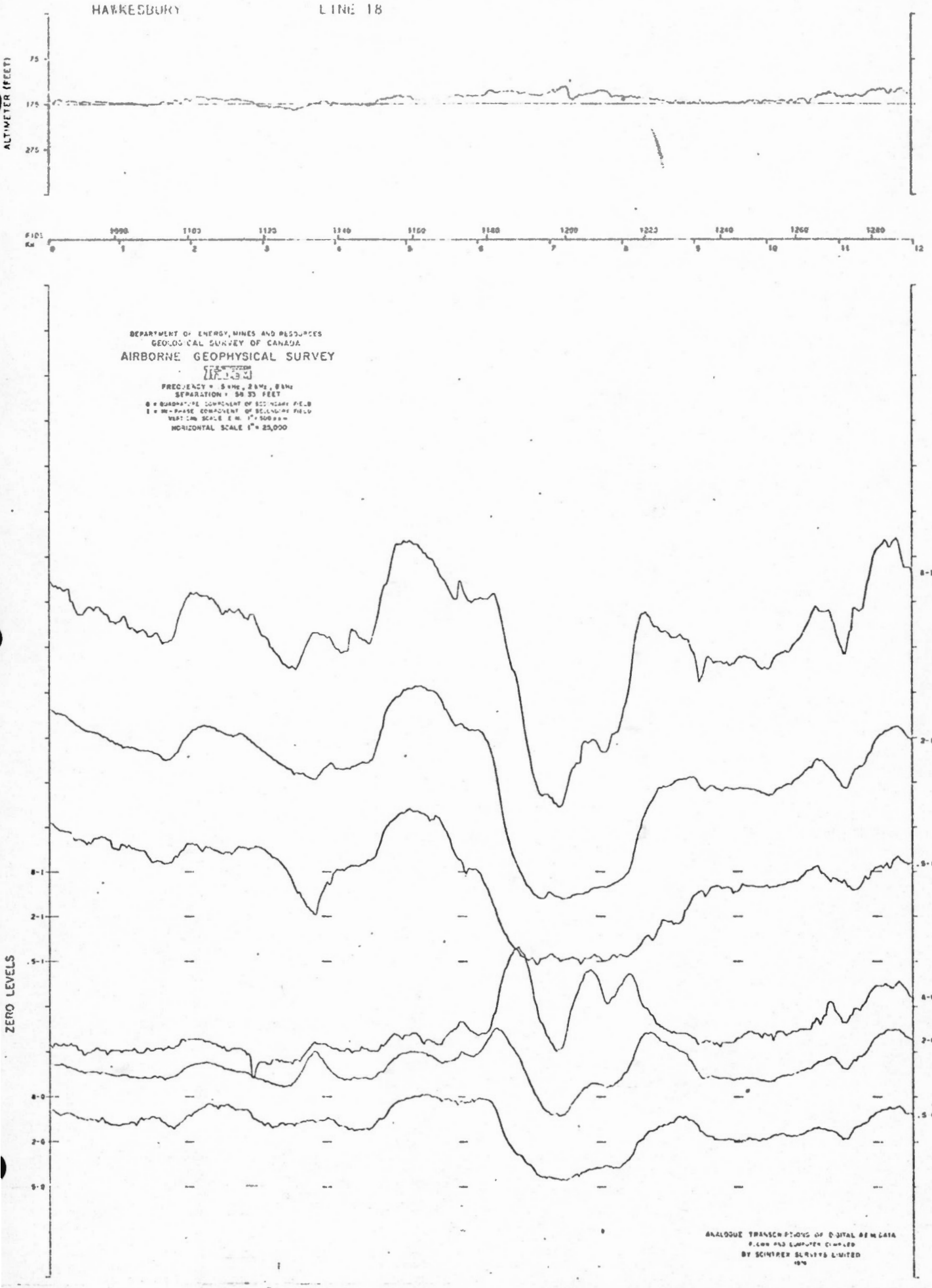




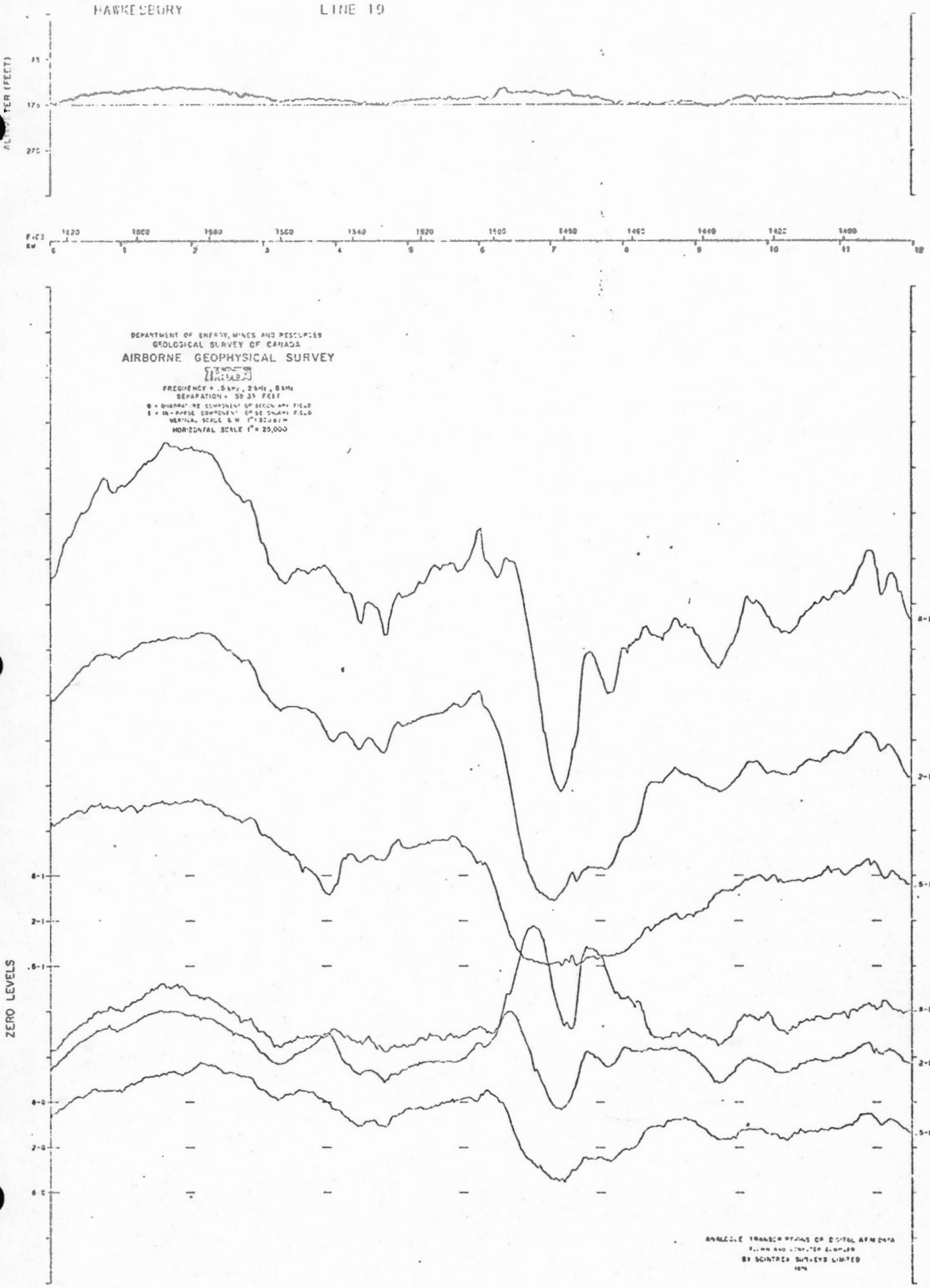
HAWKESBURY LINE 17

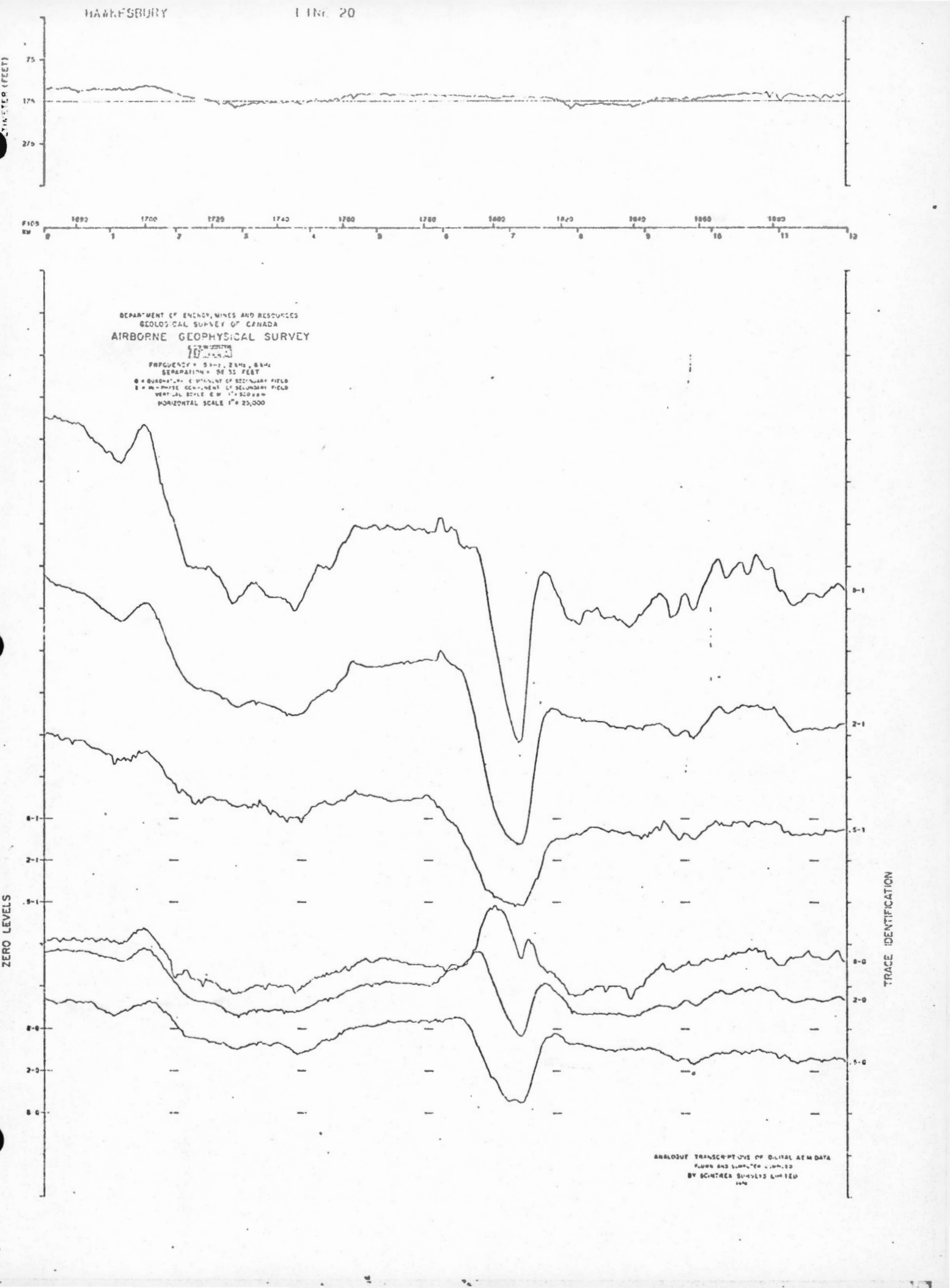


HAWKESBURY LINE 18

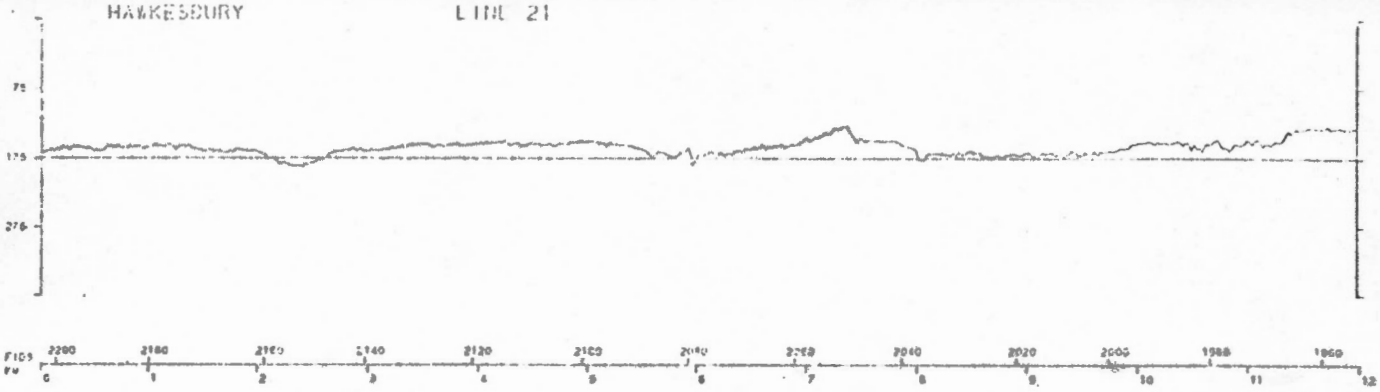


HAWKESBURY LINE 19




HAMLESBURY
LINE 20
DEPARTMENT OF ENERGY, MINES AND RESOURCES
GEOLOGICAL SURVEY OF CANADA
AIRBORNE GEOPHYSICAL SURVEY
HORIZONTAL SCALE 1" = 25,000
ZERO LEVELS
TRACE IDENTIFICATION

HAWKESBURY LINE 21



APPENDIX 4

Corrected Data Set

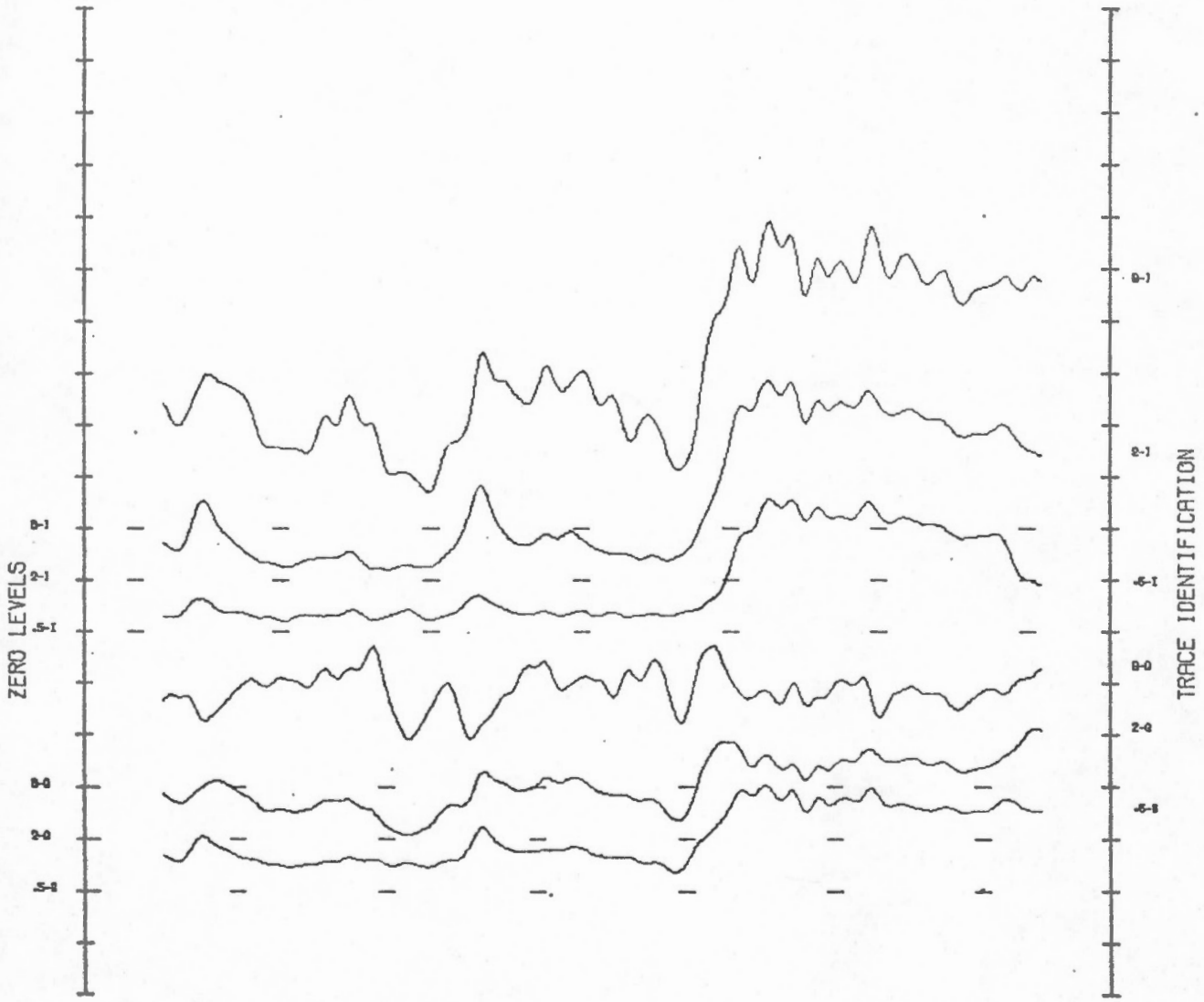
HAWKESBURY LINE 1

FIDS 3340 3320 3300 3280 3260 3240 3220 3200 3180 3160

KM 0 1 2 3 4 5 6 7 8 9 10 11 12

FILTERED AND ALTITUDE CORRECTED COMPONENTS OF THE SECONDARY FIELD

500 PPM



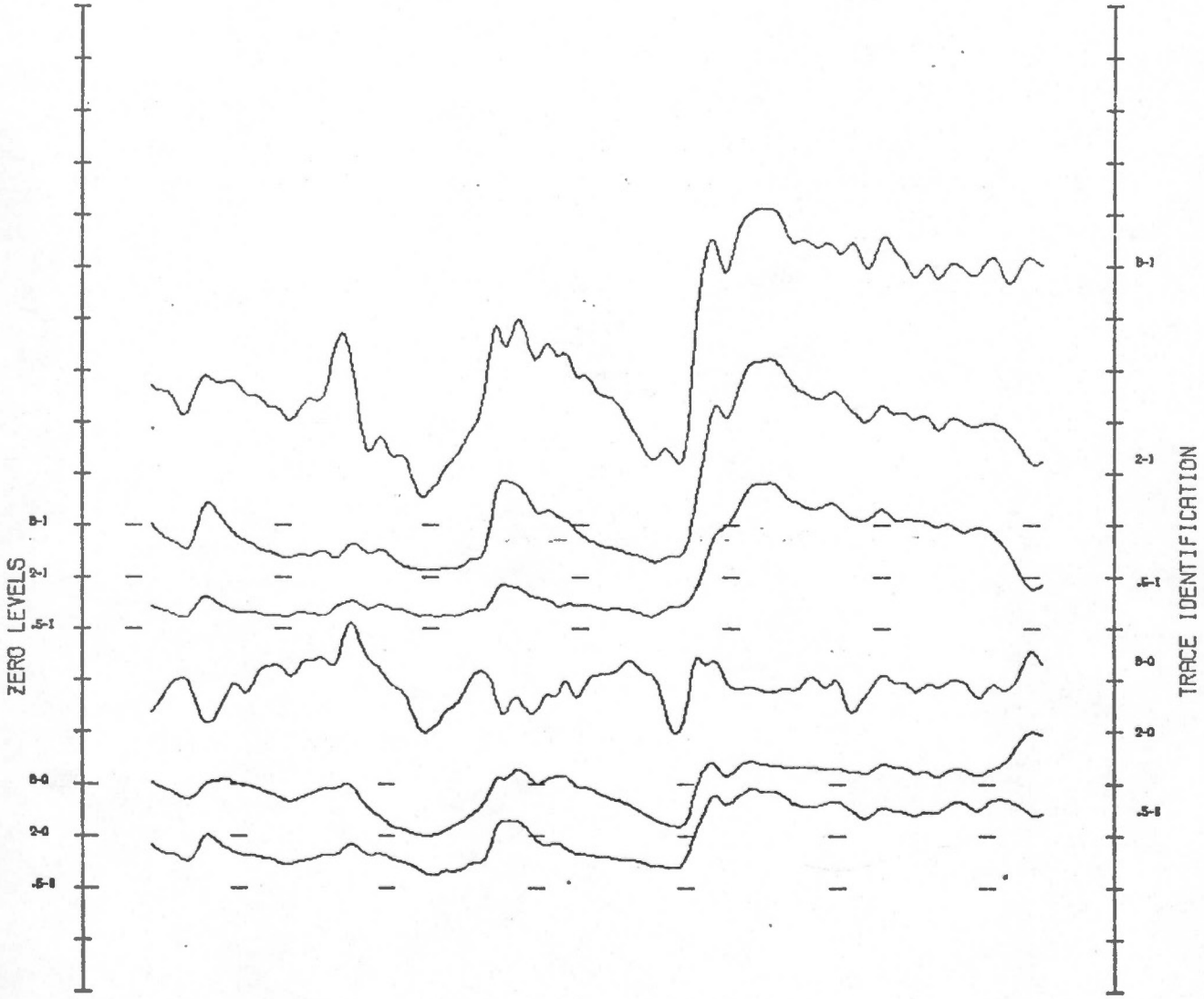
HAWKESBURY LINE 2

FIDS 2860 2880 2900 2920 2940 2960 2980 3000 3020 3040

KM 0 1 2 3 4 5 6 7 8 9 10 11 12

FILTERED AND ALTITUDE CORRECTED COMPONENTS OF THE SECONDARY FIELD

500 PPM



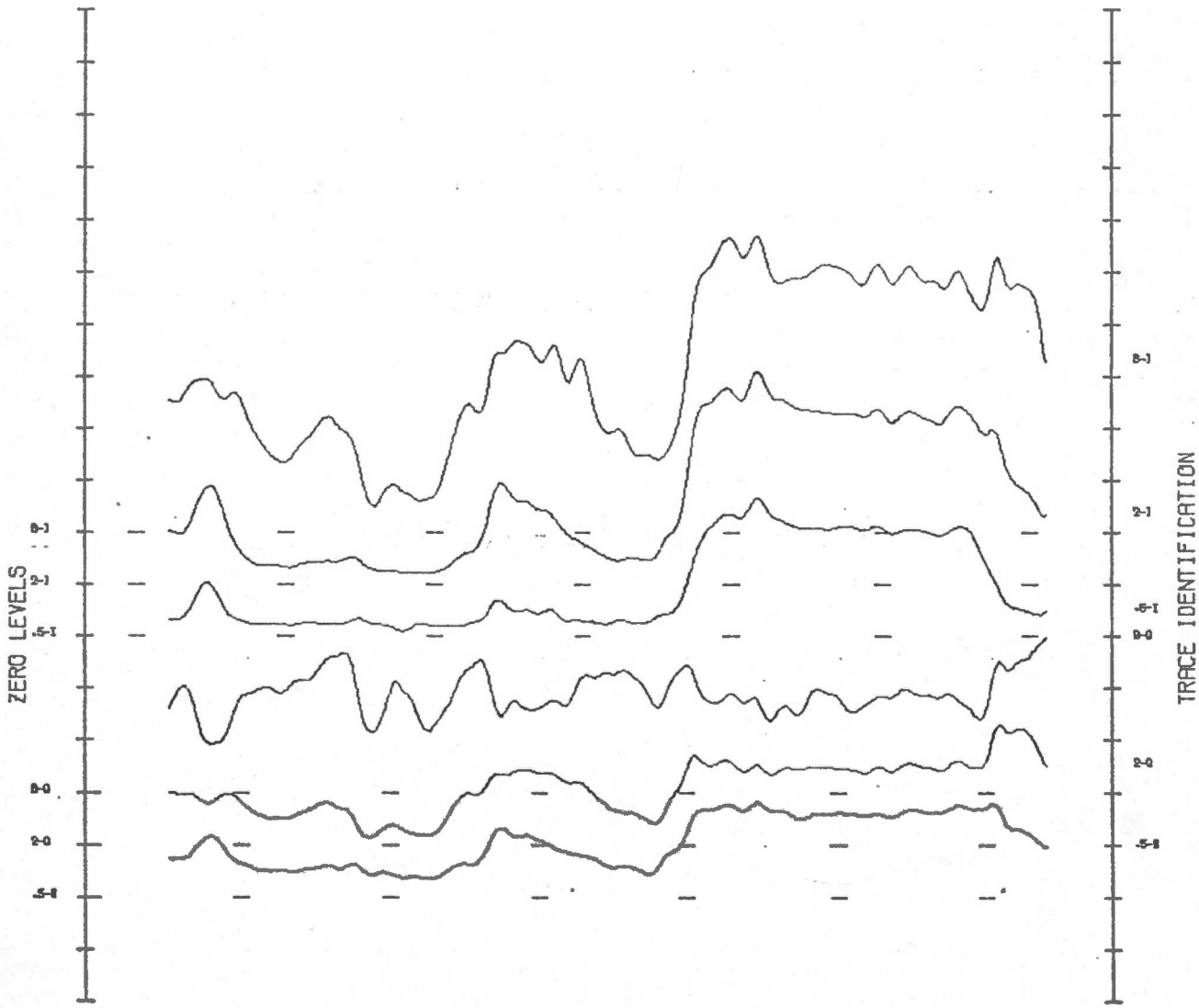
HAWKESBURY LINE 3

FIDS 2760 2740 2720 2700 2680 2660 2640 2620 2600 2580

KM 0 1 2 3 4 5 6 7 8 9 10 11 12

FILTERED AND ALTITUDE CORRECTED COMPONENTS OF THE SECONDARY FIELD

500 PPM



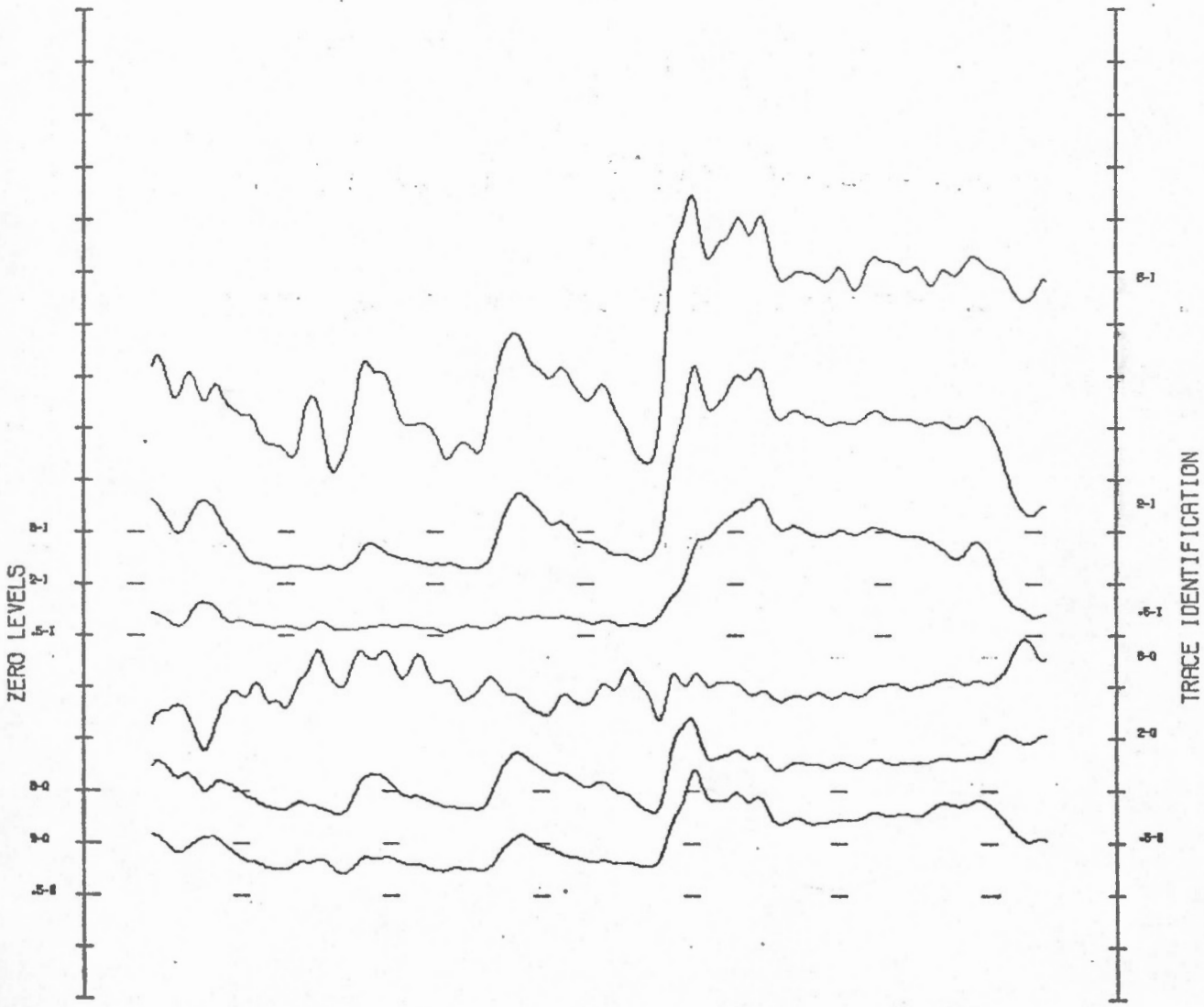
HAWKESBURY LINE 4

FIDS 2240 2260 2280 2300 2320 2340 2360 2380 2400 2420 2440

KM 0 1 2 3 4 5 6 7 8 9 10 11 12

FILTERED AND ALTITUDE CORRECTED COMPONENTS OF THE SECONDARY FIELD

500 PPM



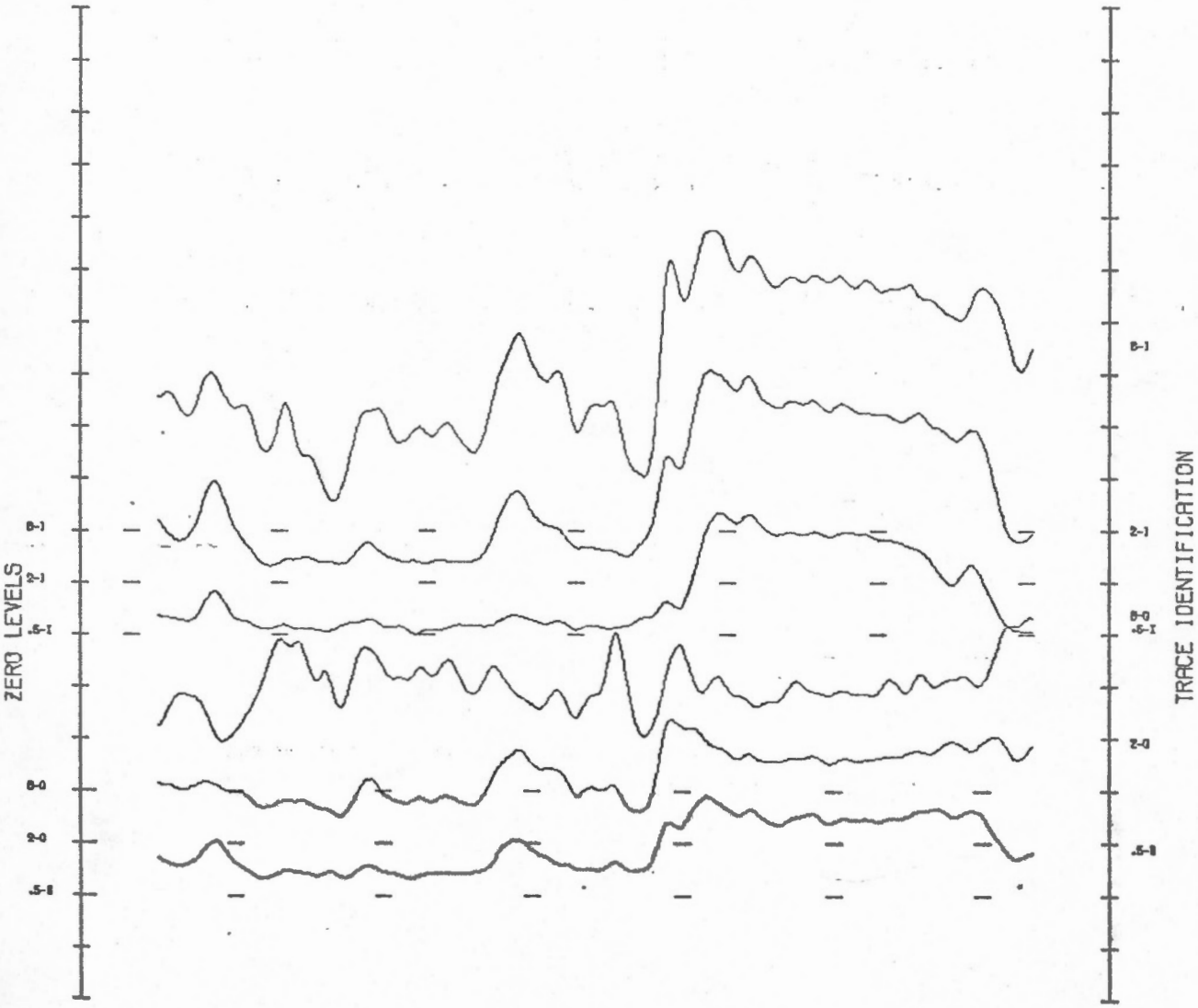
HAWKESBURY LINE 5

FIDS 2120 2100 2080 2060 2040 2020 2000 1980 1960 1940

KM 0 1 2 3 4 5 6 7 8 9 10 11 12

FILTERED AND ALTITUDE CORRECTED COMPONENTS OF THE SECONDARY FIELD

500 PPM



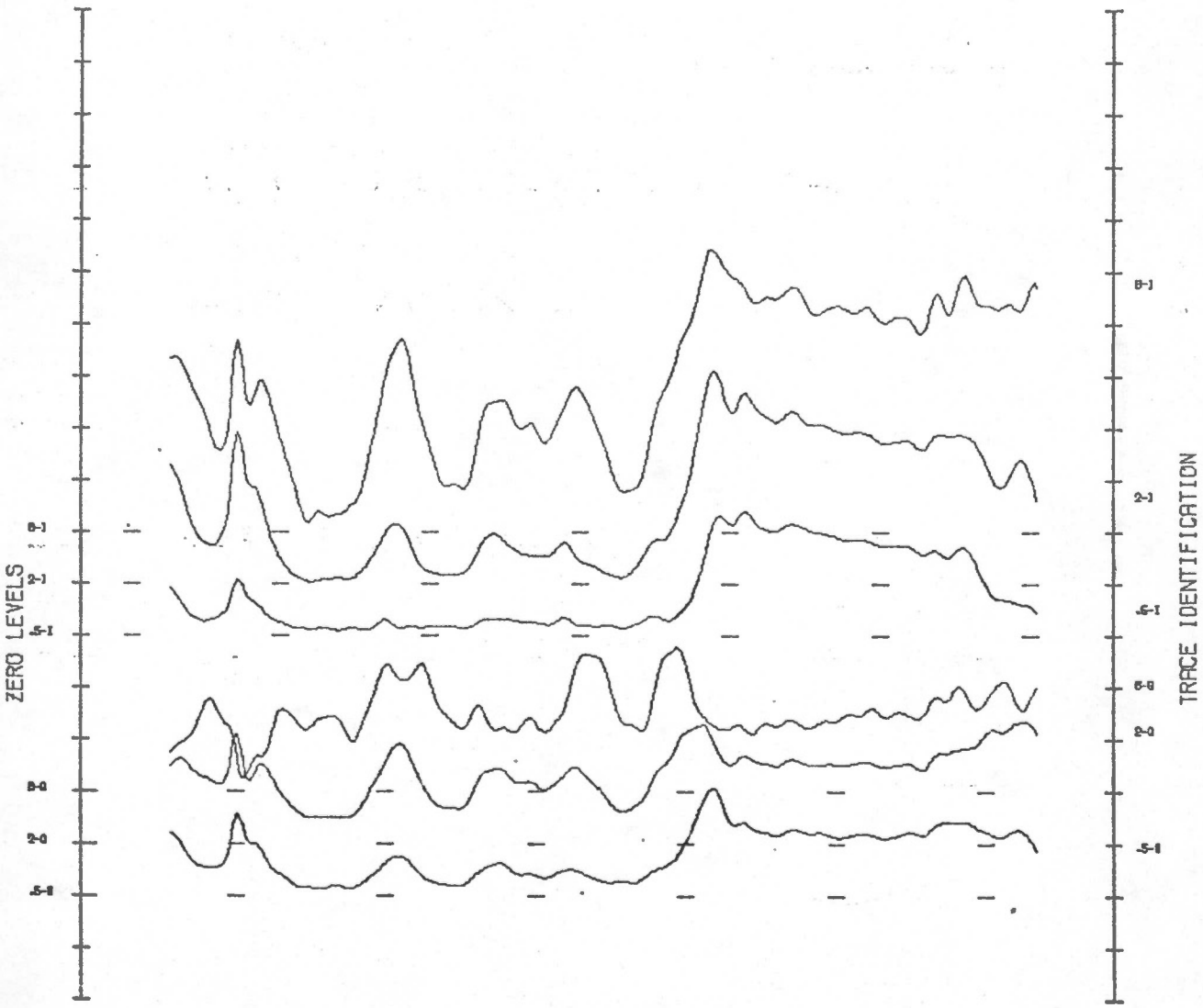
HAWKESBURY LINE 6

FIDS 1820 1800 1780 1760 1740 1720 1700 1680 1660 1640

KM 0 1 2 3 4 5 6 7 8 9 10 11 12

FILTERED AND ALTITUDE CORRECTED COMPONENTS OF THE SECONDARY FIELD

500 PPM



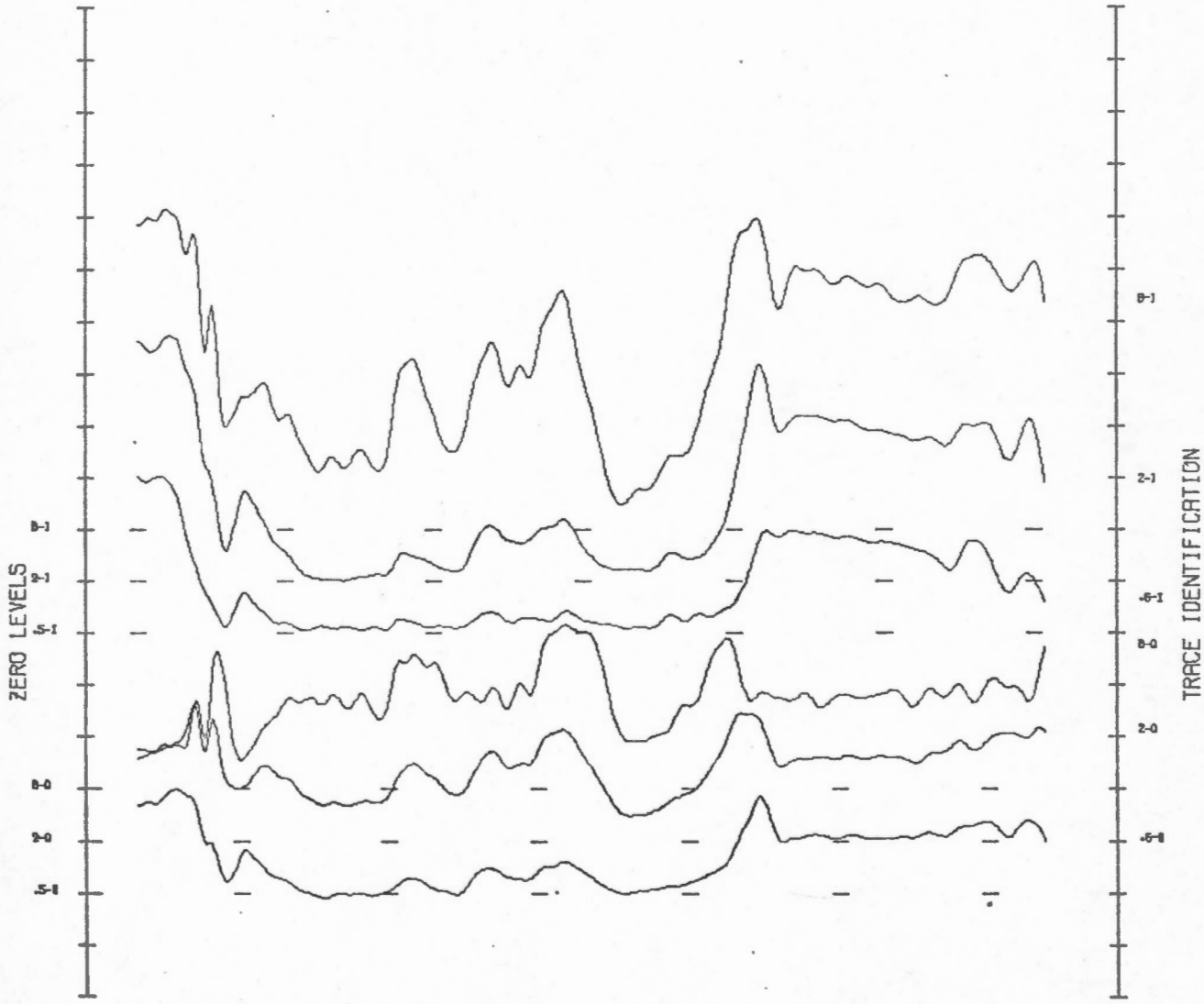
HAWKESBURY LINE 7

FIDS 1300 1320 1340 1360 1380 1400 1420 1440 1460 1480 1500

KM 0 1 2 3 4 5 6 7 8 9 10 11 12

FILTERED AND ALTITUDE CORRECTED COMPONENTS OF THE SECONDARY FIELD

600 PPM



h ~ 150'

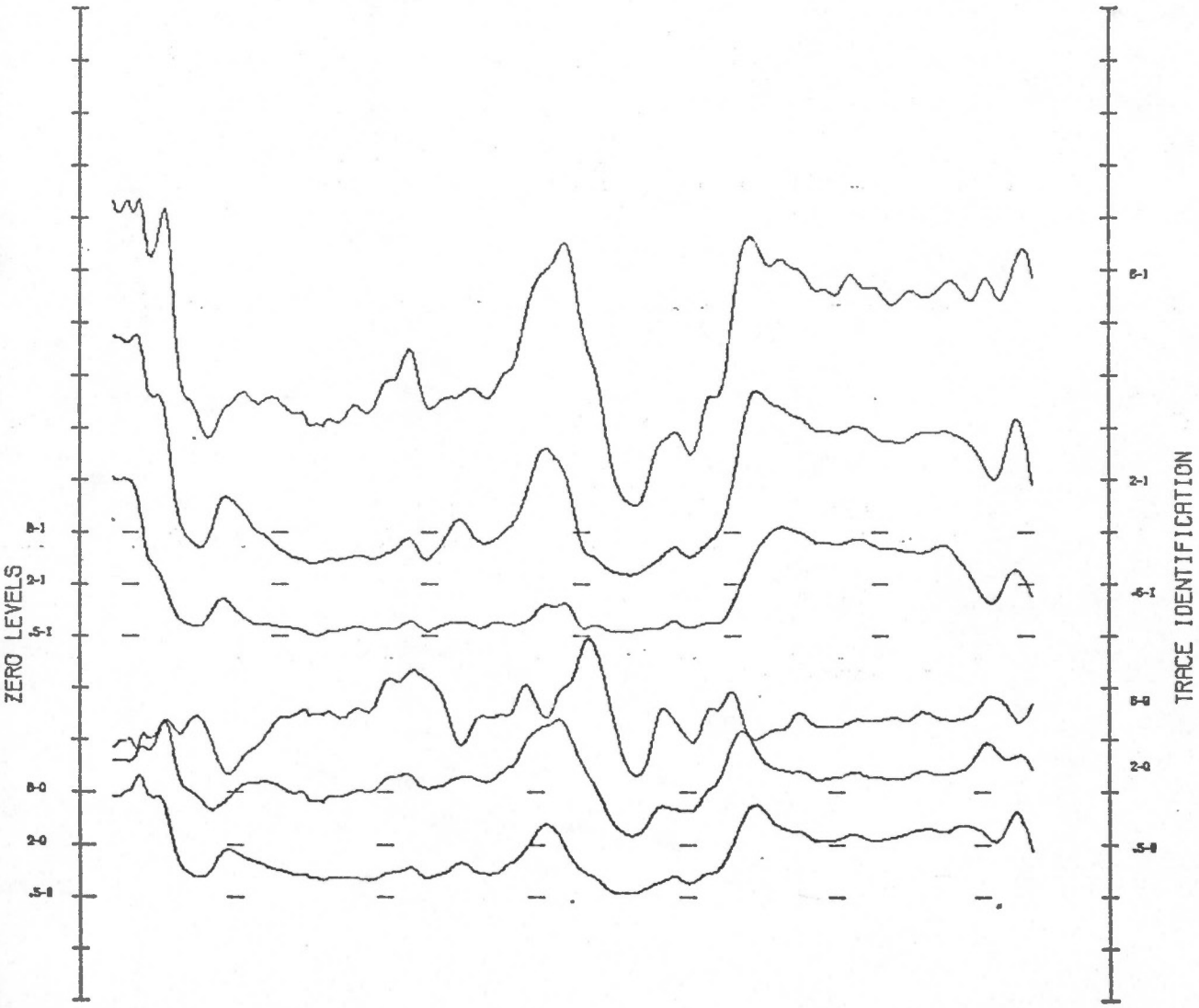
HAWKESBURY LINE 208

FIDS 1180 1160 1140 1120 1100 1080 1060 1040 1020 1000

KM 0 1 2 3 4 5 6 7 8 9 10 11 12

FILTERED AND ALTITUDE CORRECTED COMPONENTS OF THE SECONDARY FIELD

500 PPM



λ ~ 175'

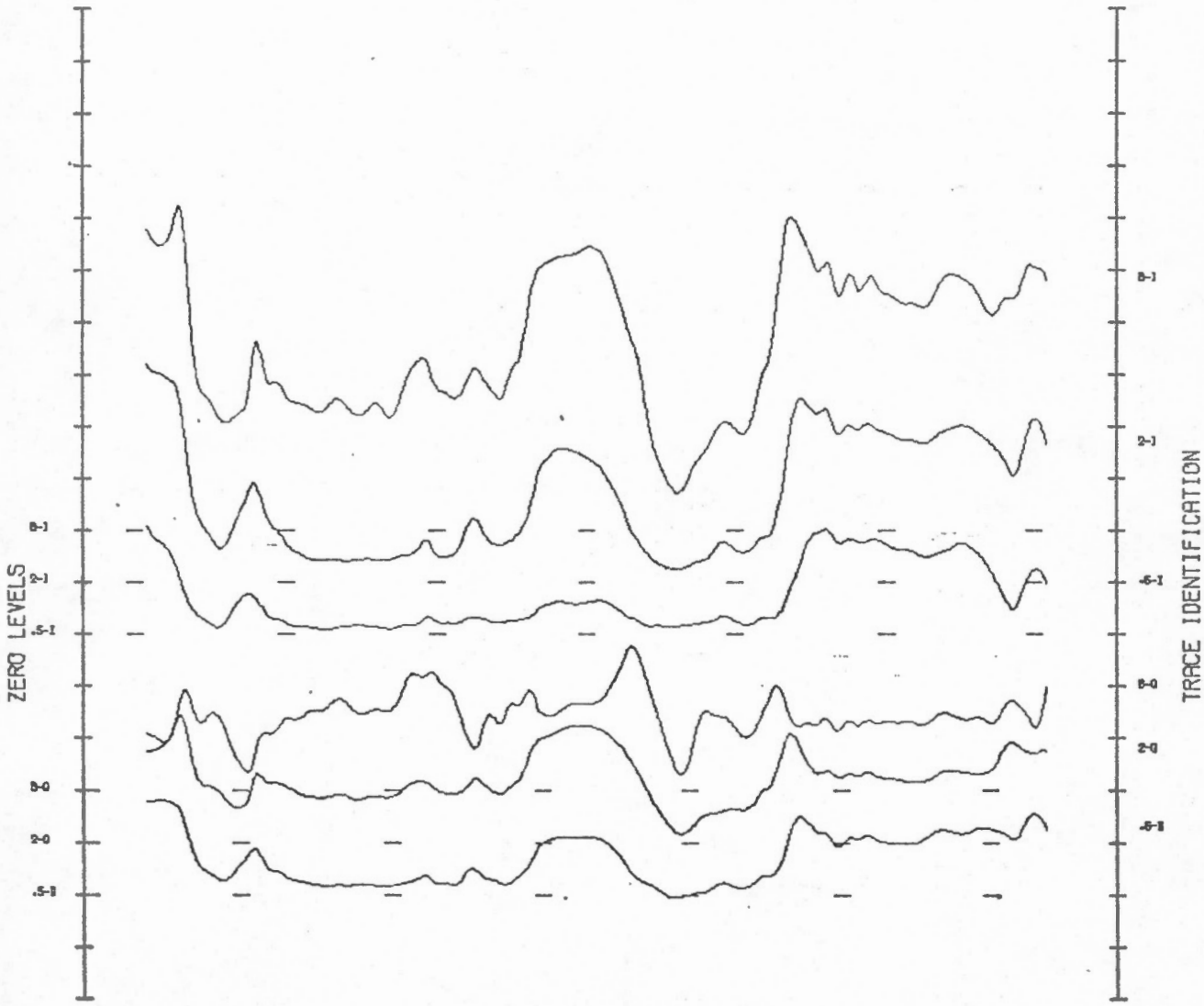
HAWKESBURY LINE 8

FIDS 660 680 700 720 740 760 780 800 820 840 860

KM 0 1 2 3 4 5 6 7 8 9 10 11 12

FILTERED AND ALTITUDE CORRECTED COMPONENTS OF THE SECONDARY FIELD

500 PPM



h ~ 300'

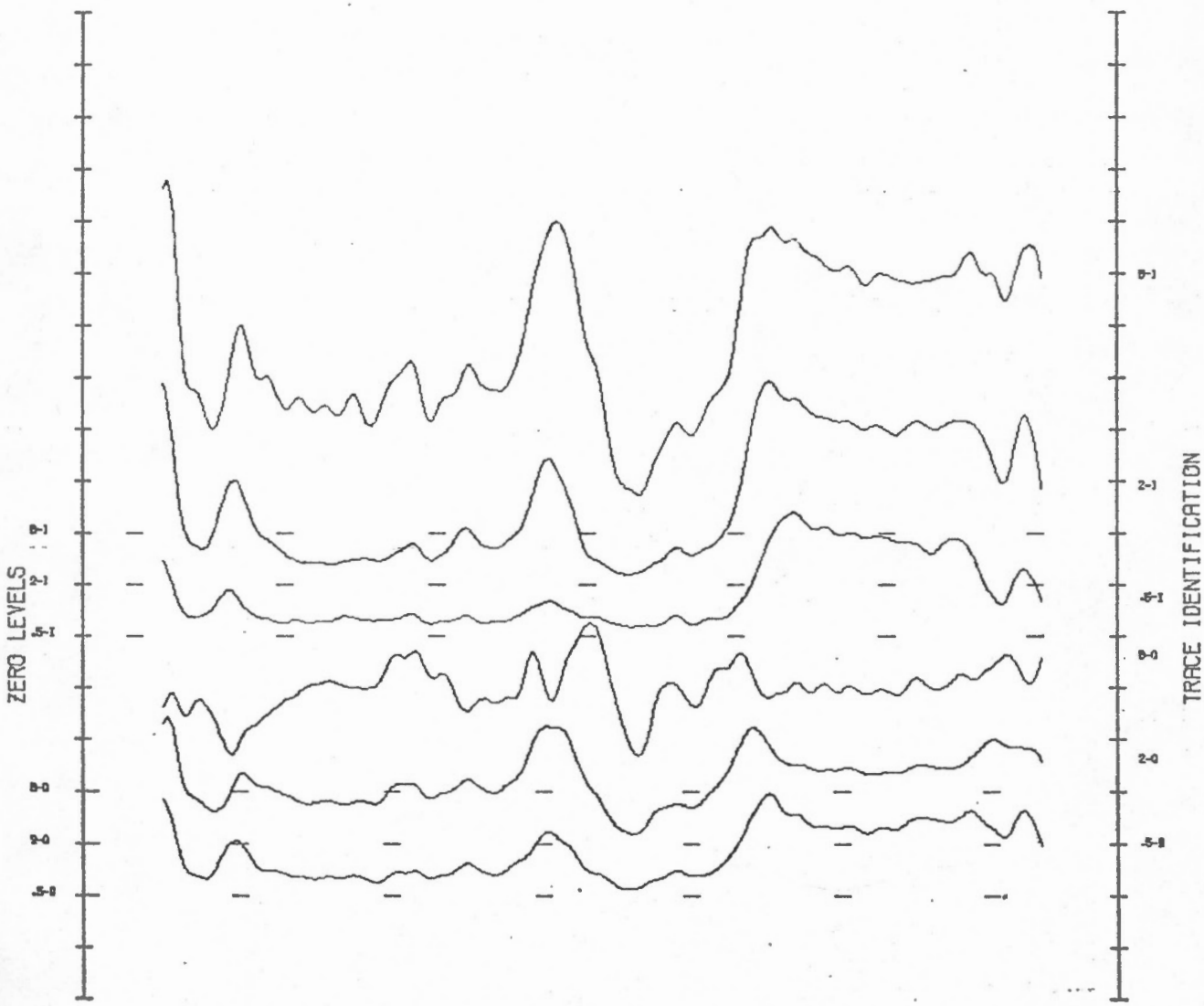
HAWKESBURY LINE 108

FIDS 520 500 480 460 440 420 400 380 360 340

KM 0 1 2 3 4 5 6 7 8 9 10 11 12

FILTERED AND ALTITUDE CORRECTED COMPONENTS OF THE SECONDARY FIELD

500 PPM



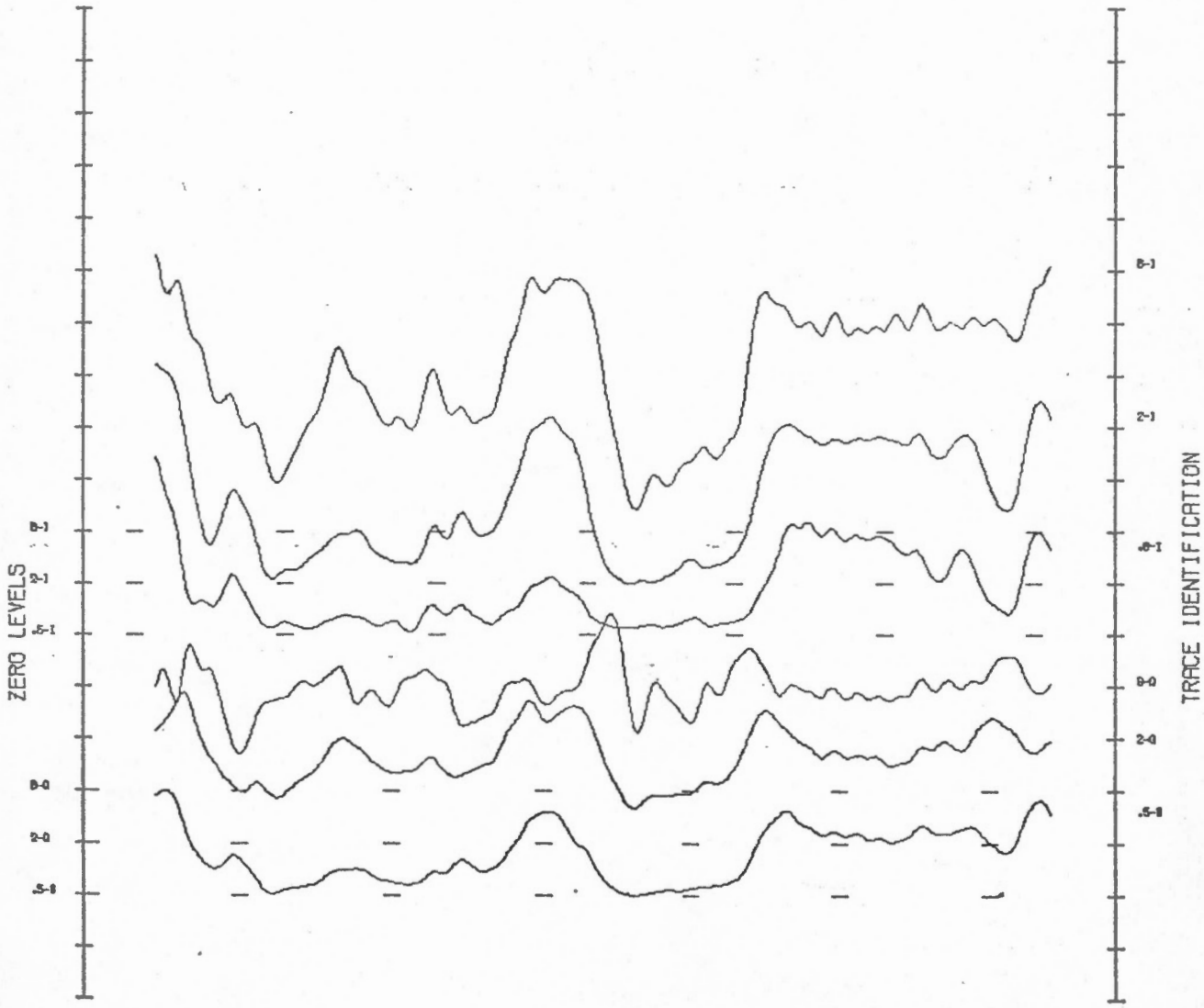
HAWKESBURY LINE 9

FIDS 500 480 460 440 420 400 380 360 340 320

KM 0 1 2 3 4 5 6 7 8 9 10 11 12

FILTERED AND ALTITUDE CORRECTED COMPONENTS OF THE SECONDARY FIELD

500 PPM



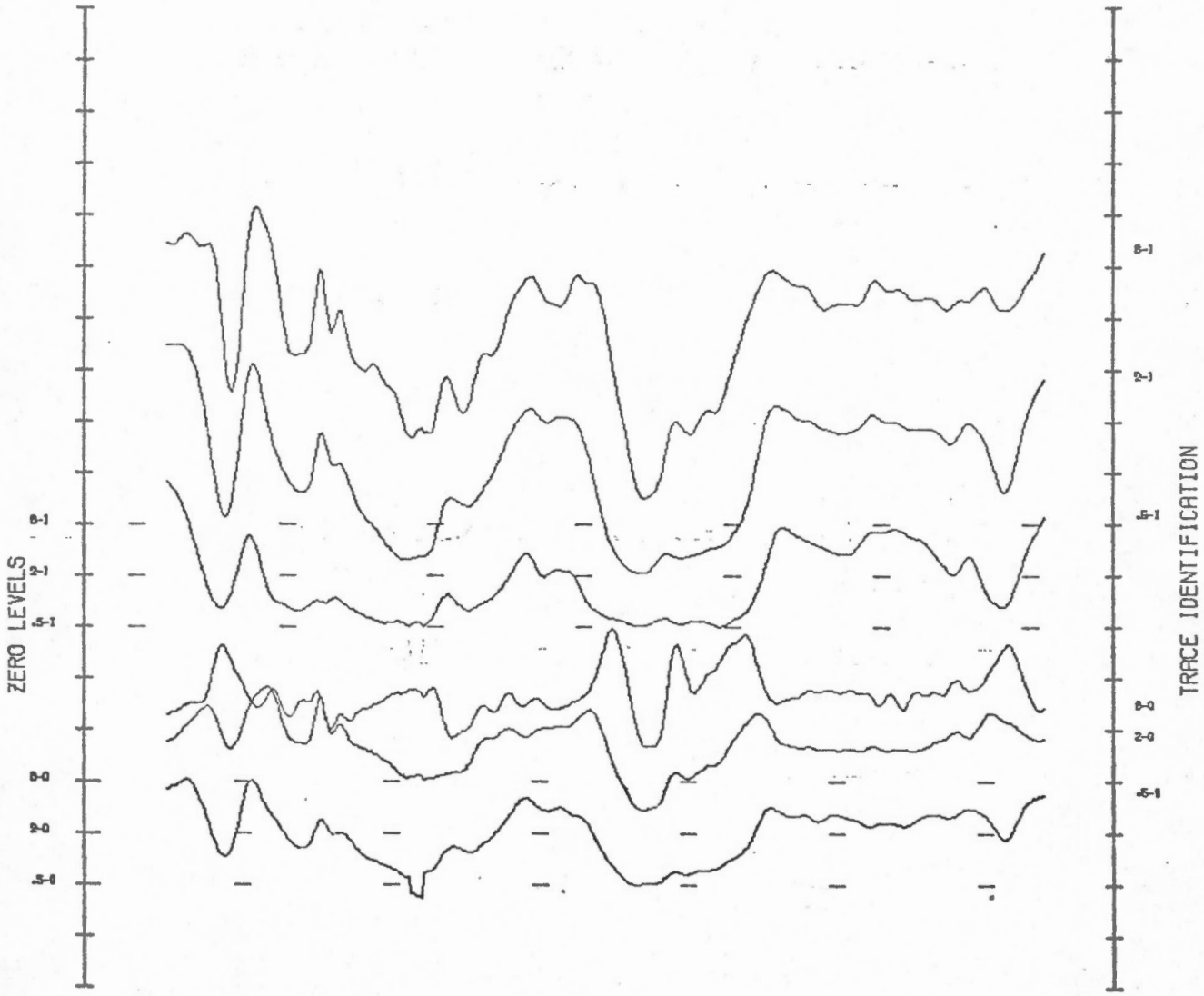
HAWKESBURY LINE 10

FIDS 1080 1060 1040 1020 1000 980 960 940 920 900 880

KM 0 1 2 3 4 5 6 7 8 9 10 11 12

FILTERED AND ALTITUDE CORRECTED COMPONENTS OF THE SECONDARY FIELD

500 PPM



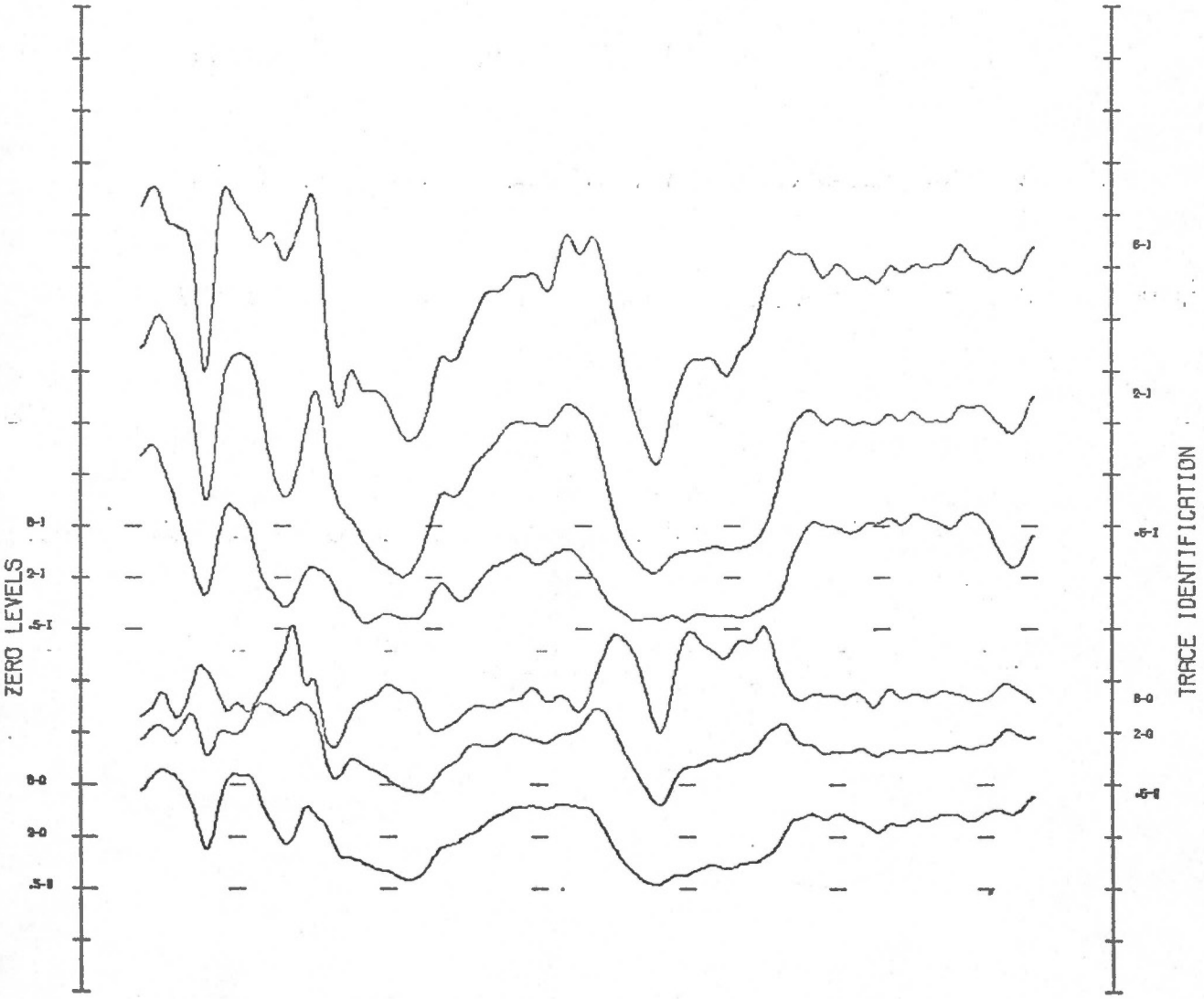
HAWKESBURY LINE 11

FIDS 1180 1200 1220 1240 1260 1280 1300 1320 1340 1360

KM 0 1 2 3 4 5 6 7 8 9 10 11 12

FILTERED AND ALTITUDE CORRECTED COMPONENTS OF THE SECONDARY FIELD

500 PPM



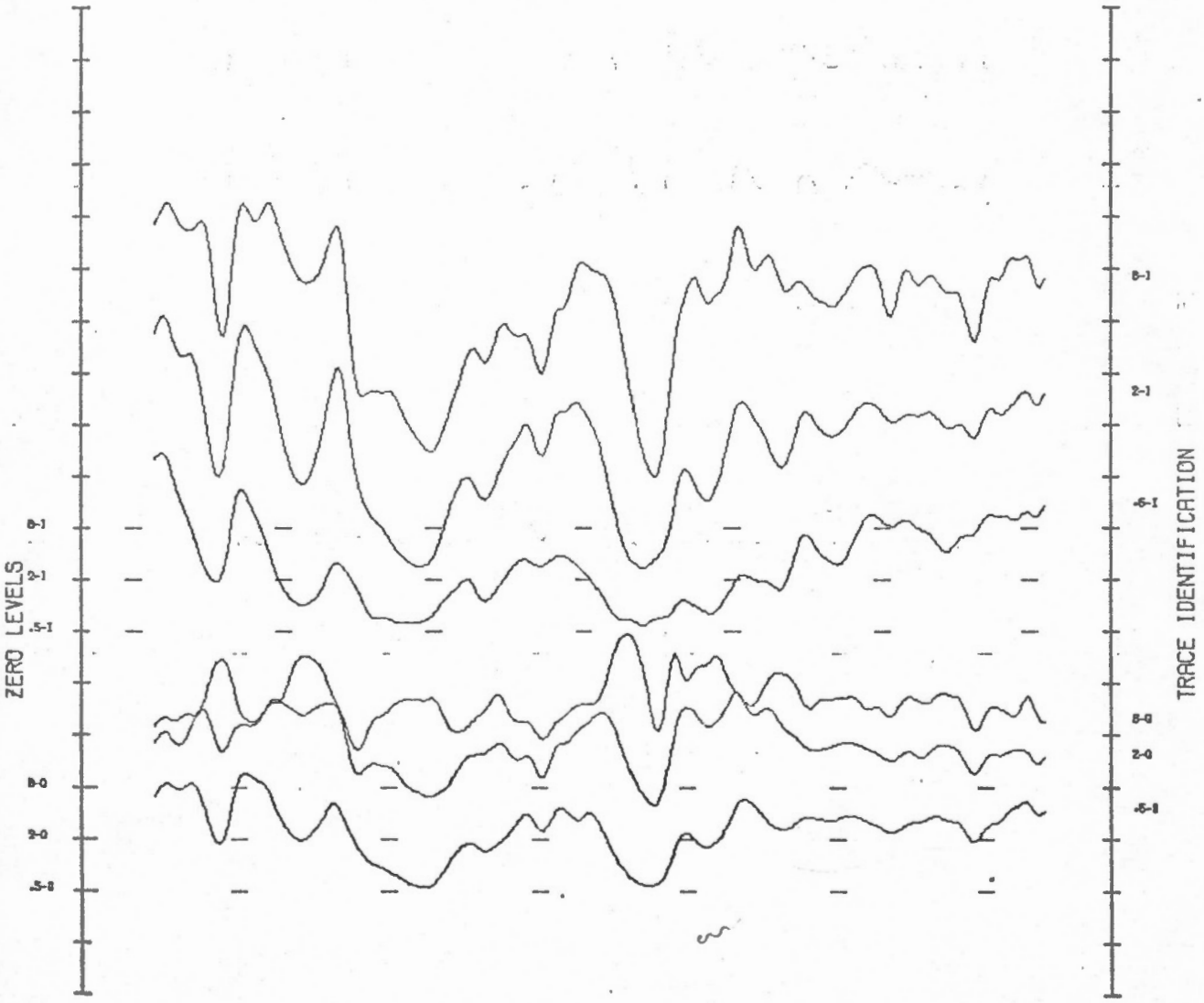
HAWKESBURY LINE 12

FIDS 1700 1680 1660 1640 1620 1600 1580 1560 1540 1520 1500

KM 0 1 2 3 4 5 6 7 8 9 10 11 12

FILTERED AND ALTITUDE CORRECTED COMPONENTS OF THE SECONDARY FIELD

500 PPM



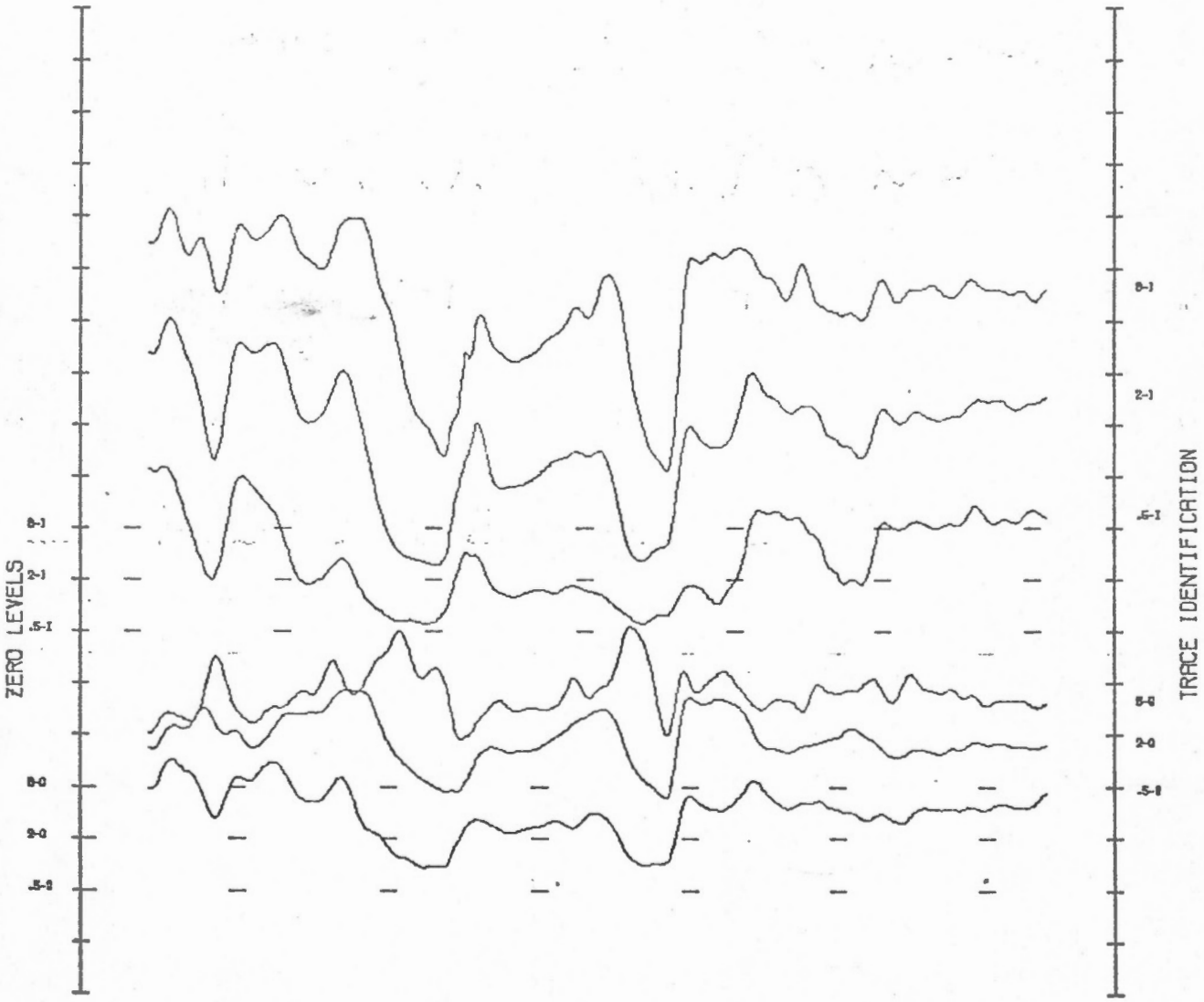
HAWKESBURY LINE 13

FIDS 1980 1960 1940 1920 1900 1880 1860 1820 1800

KM 0 1 2 3 4 5 6 7 8 9 10 11 12

FILTERED AND ALTITUDE CORRECTED COMPONENTS OF THE SECONDARY FIELD

500 PPM



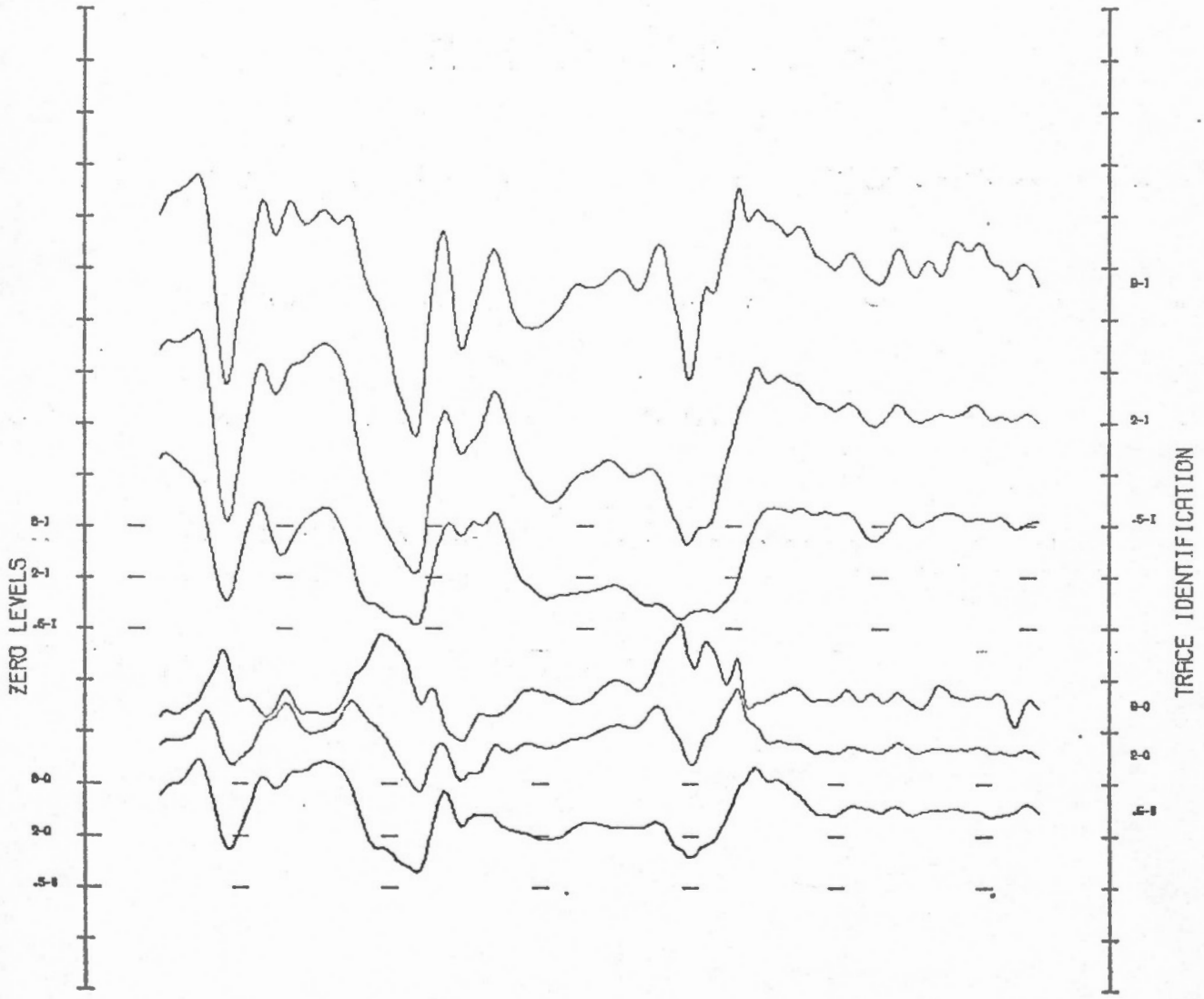
HAWKESBURY LINE 14

FIDS 2080 2100 2120 2140 2160 2180 2200 2220 2240 2260

KM 0 1 2 3 4 5 6 7 8 9 10 11 12

FILTERED AND ALTITUDE CORRECTED COMPONENTS OF THE SECONDARY FIELD

500 PPM



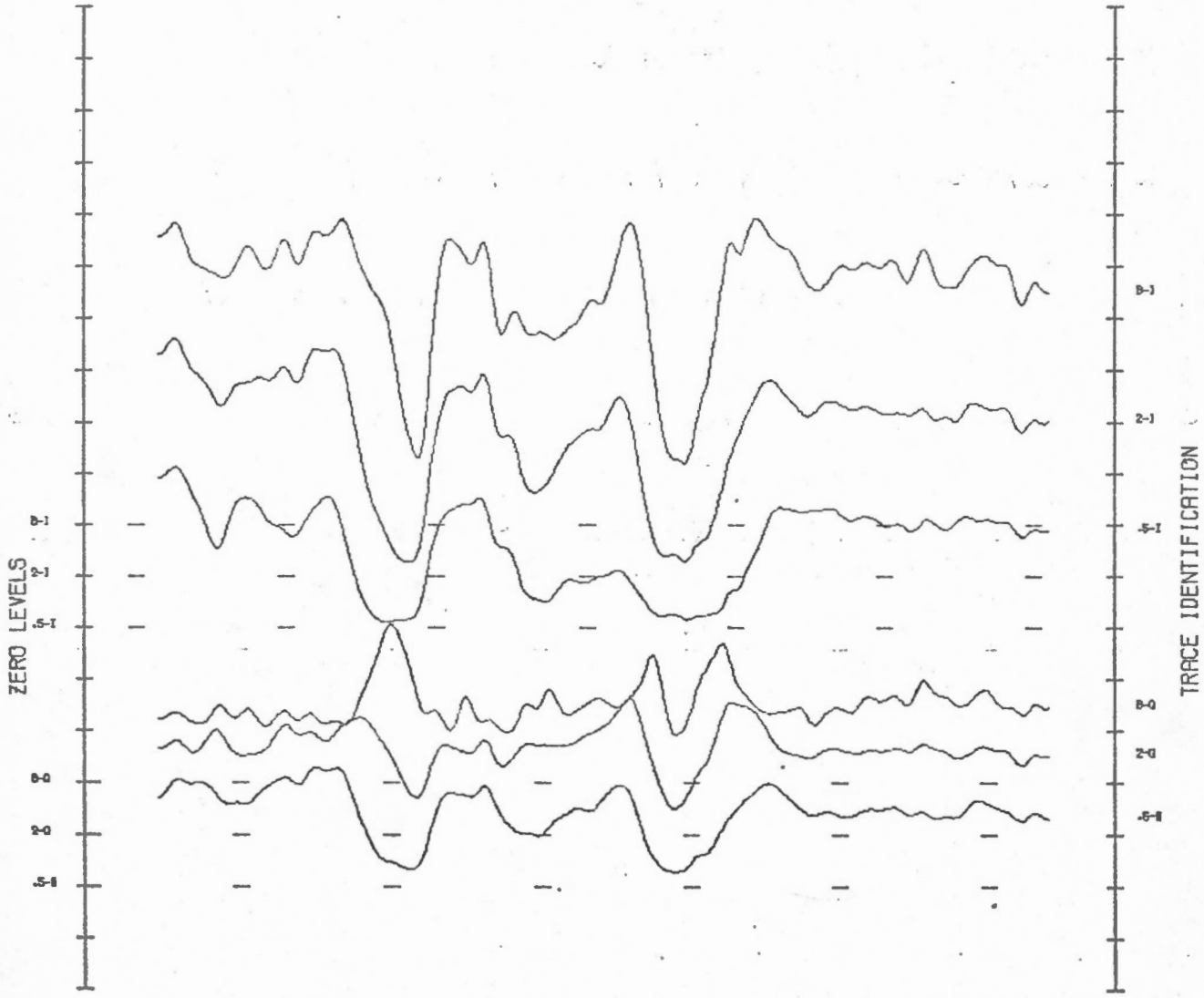
HAWKESBURY LINE 15

FIDS 2580 2560 2540 2520 2500 2480 2460 2440 2420 2400

KM 0 1 2 3 4 5 6 7 8 9 10 11 12

FILTERED AND ALTITUDE CORRECTED COMPONENTS OF THE SECONDARY FIELD

500 PPM



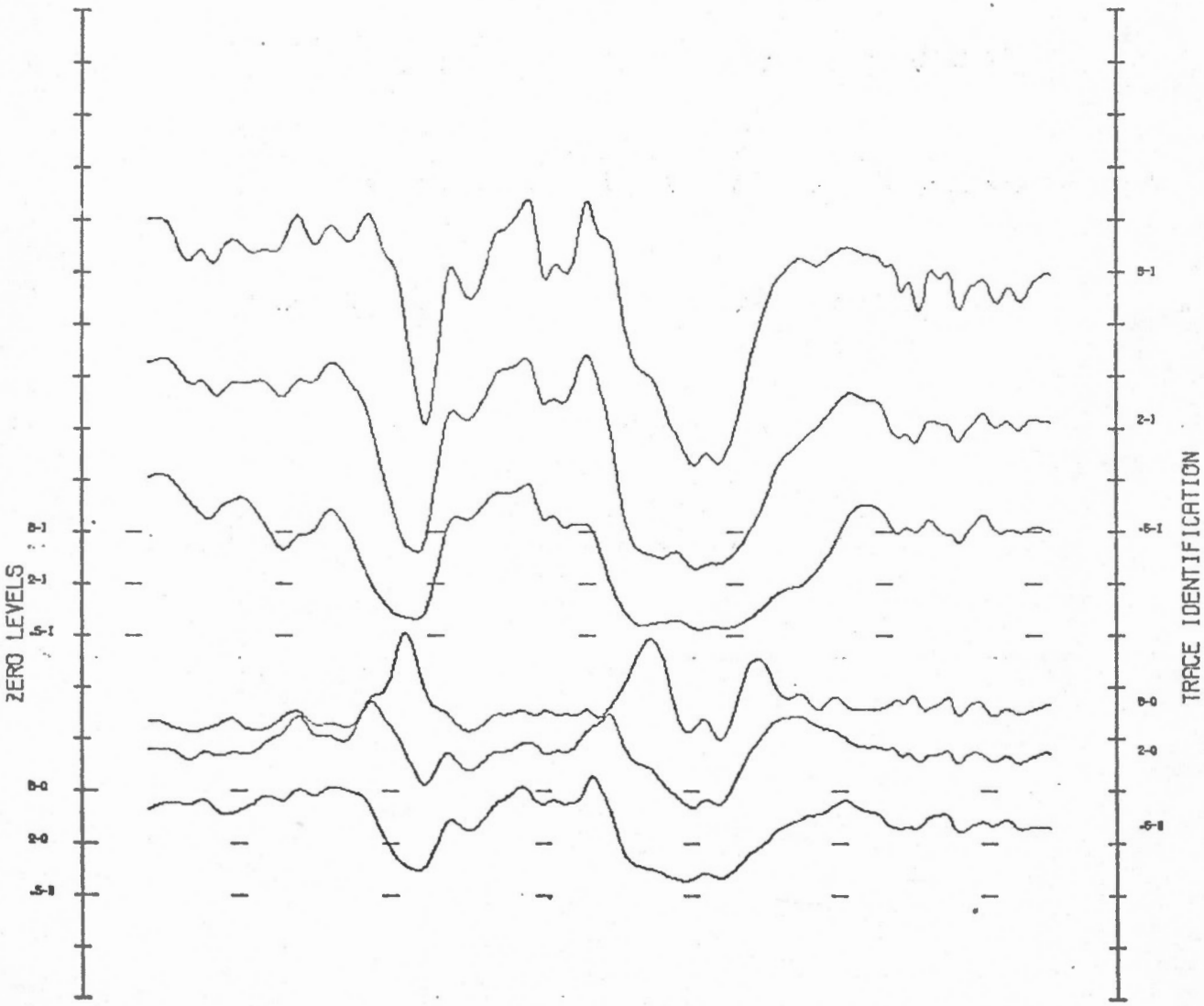
HAWKESBURY LINE 16

FIDS 480 460 440 420 400 380 360 340 320 300 280

KM 0 1 2 3 4 5 6 7 8 9 10 11 12

FILTERED AND ALTITUDE CORRECTED COMPONENTS OF THE SECONDARY FIELD

500 PPM



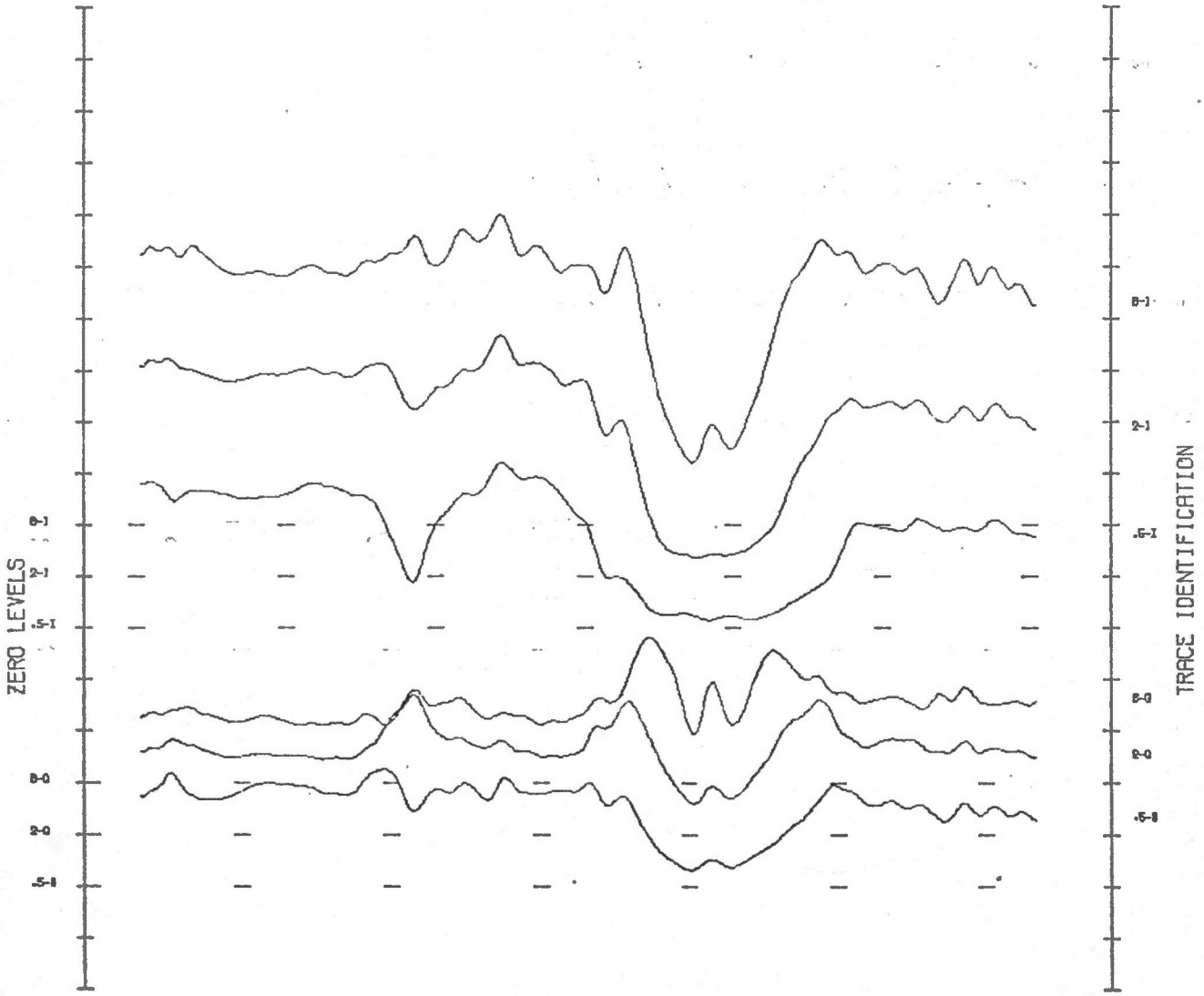
HAWKESBURY LINE 17

FIDS 500 520 540 560 580 600 620 640 660 680

KM 0 1 2 3 4 5 6 7 8 9 10 11 12

FILTERED AND ALTITUDE CORRECTED COMPONENTS OF THE SECONDARY FIELD

500 PPM



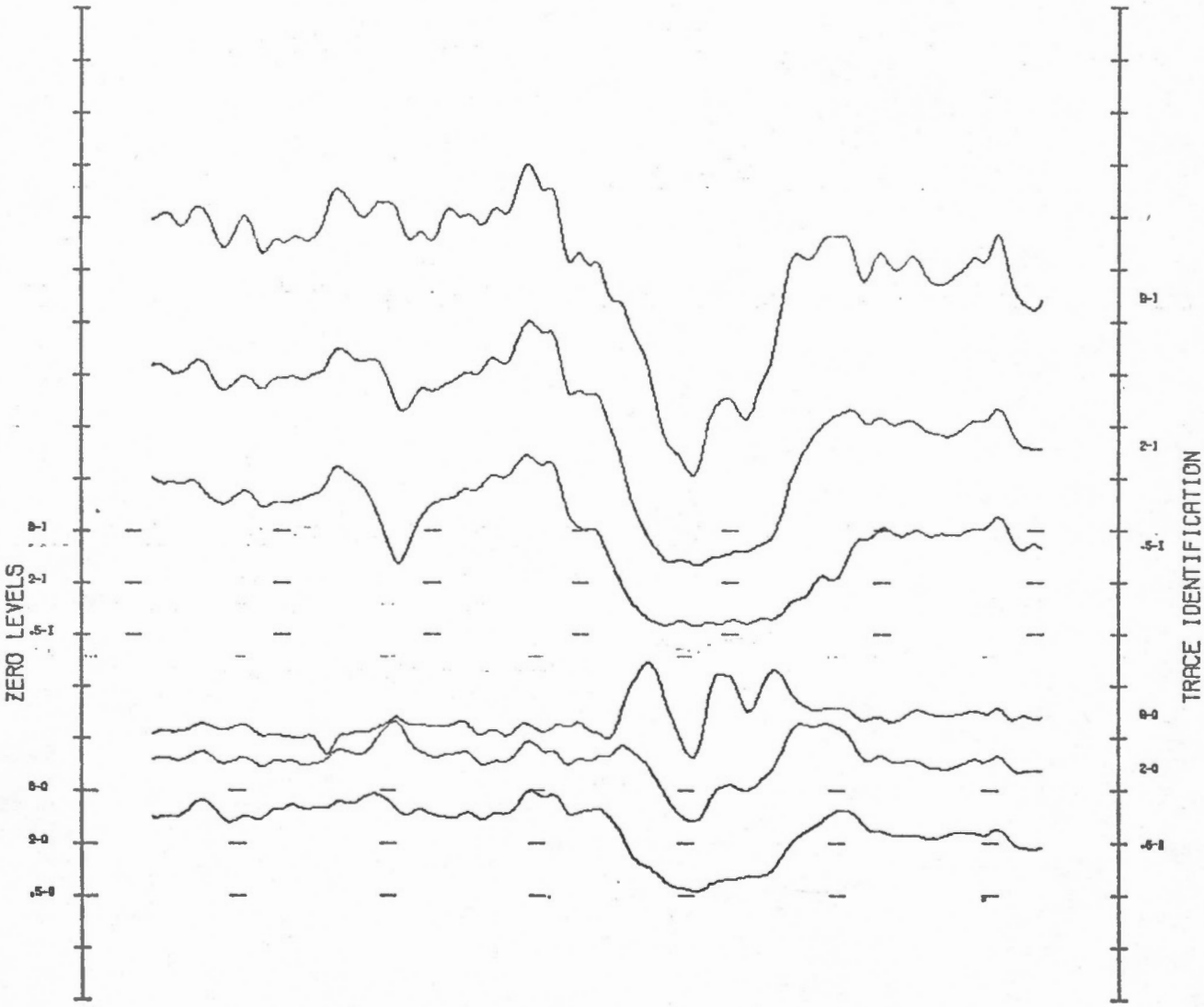
HAWKESBURY LINE 18

FIDS 1080 1100 1120 1140 1160 1180 1200 1220 1240 1260

KM 0 1 2 3 4 5 6 7 8 9 10 11 12

FILTERED AND ALTITUDE CORRECTED COMPONENTS OF THE SECONDARY FIELD

500 PPM



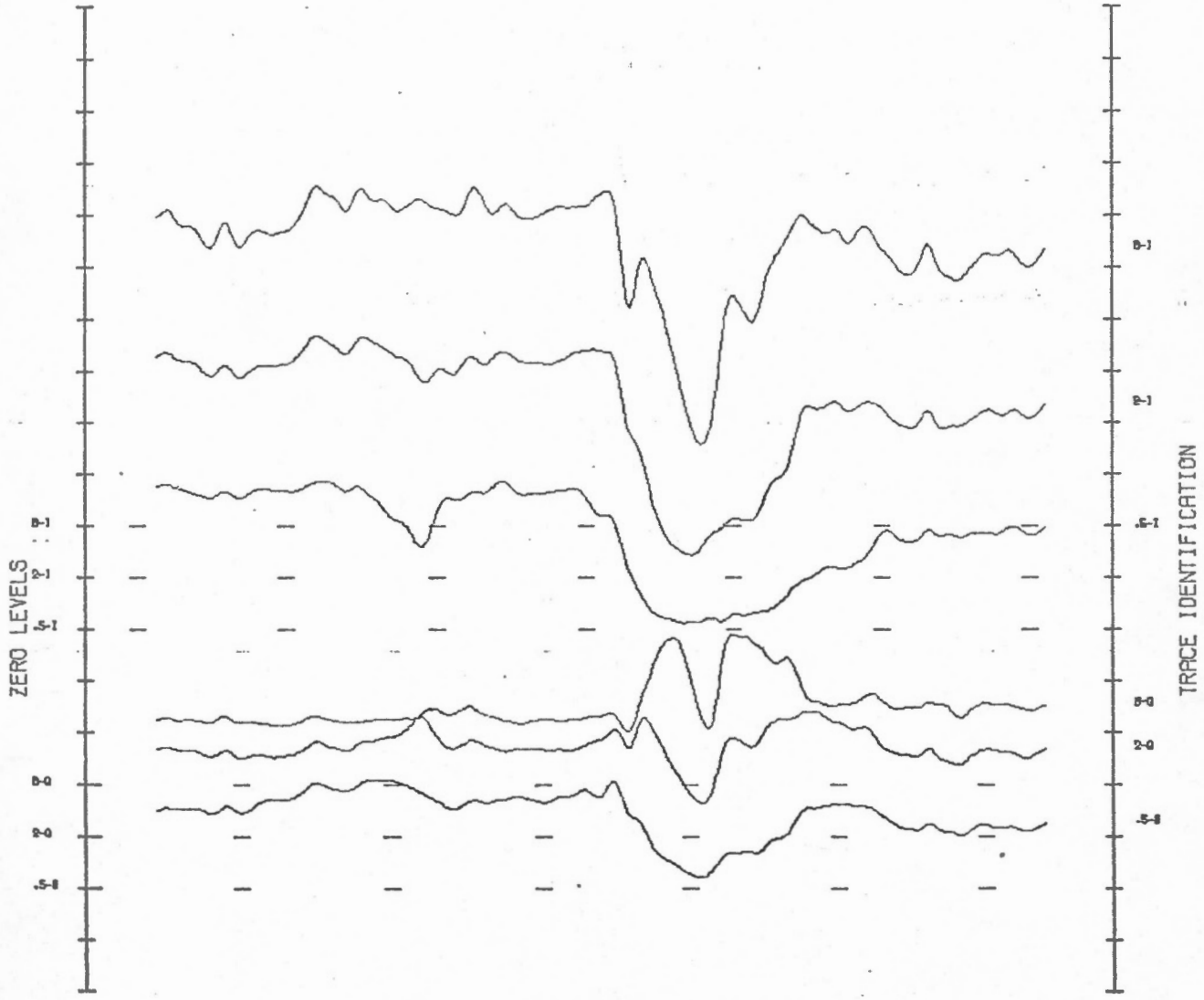
HAWKESBURY LINE 19

FIDS 1600 1580 1560 1540 1520 1500 1480 1460 1440 1420 1400

KM 0 1 2 3 4 5 6 7 8 9 10 11 12

FILTERED AND ALTITUDE CORRECTED COMPONENTS OF THE SECONDARY FIELD

500 PPM



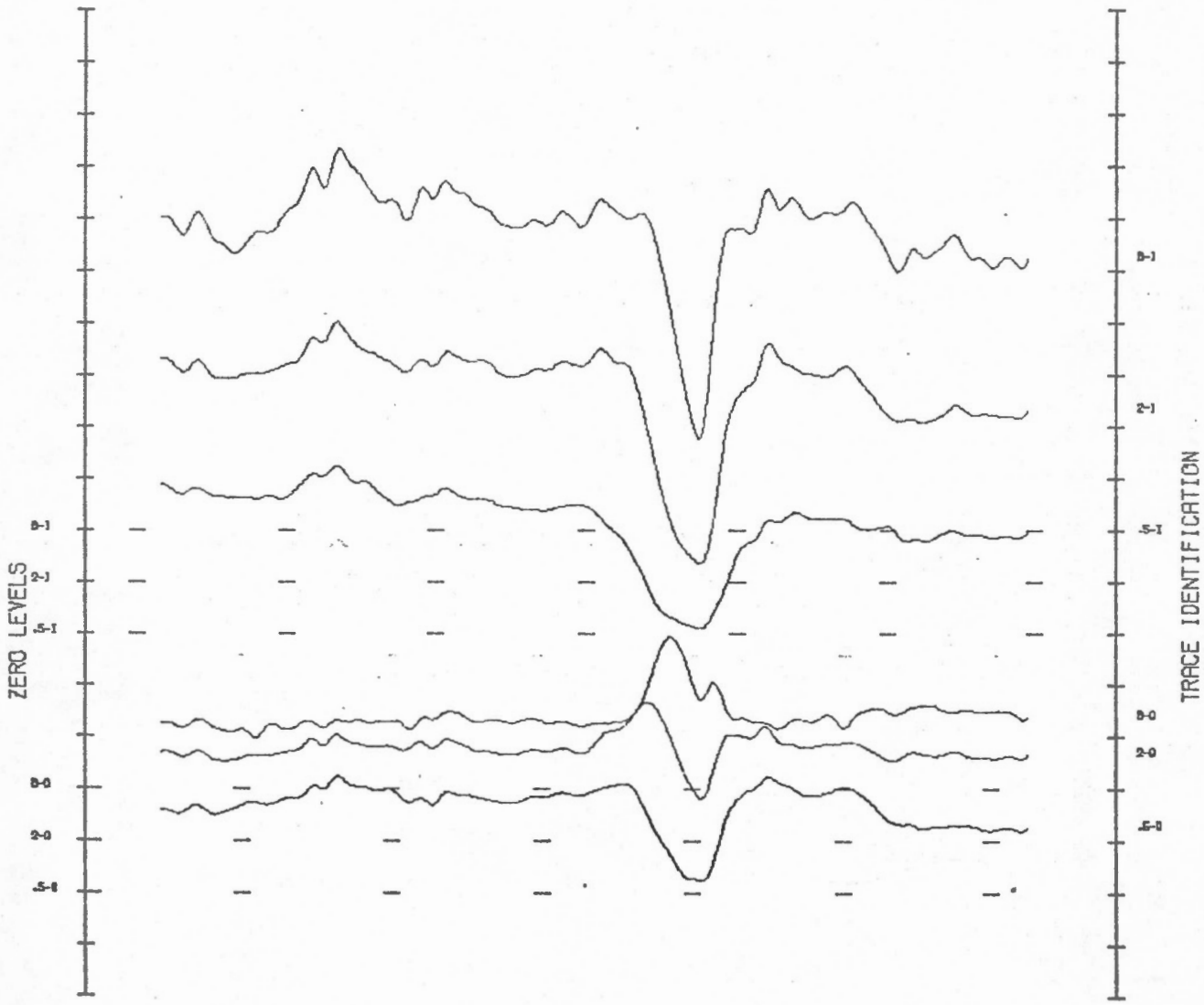
HAWKESBURY LINE 20

FIDS 1700 1720 1740 1760 1780 1800 1820 1840 1860 1880

KM 0 1 2 3 4 5 6 7 8 9 10 11 12

FILTERED AND ALTITUDE CORRECTED COMPONENTS OF THE SECONDARY FIELD

500 PPM



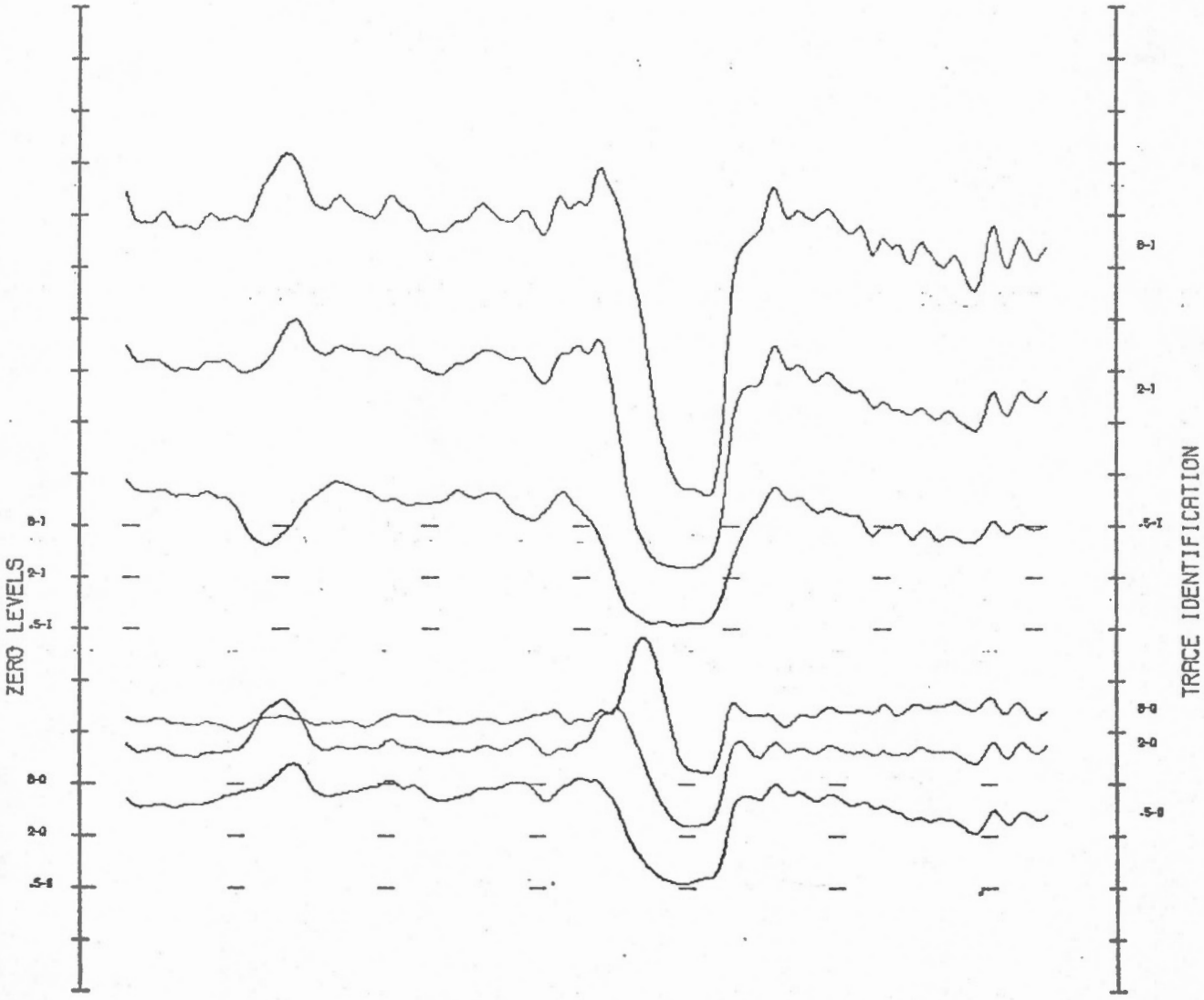
HAWKESBURY LINE 21

FIDS 2180 2160 2140 2120 2100 2080 2060 2040 2020 2000 1980

KM 0 1 2 3 4 5 6 7 8 9 10 11 12

FILTERED AND ALTITUDE CORRECTED COMPONENTS OF THE SECONDARY FIELD

500 PPM



APPENDIX 5

Amplitude-Phase Data Set

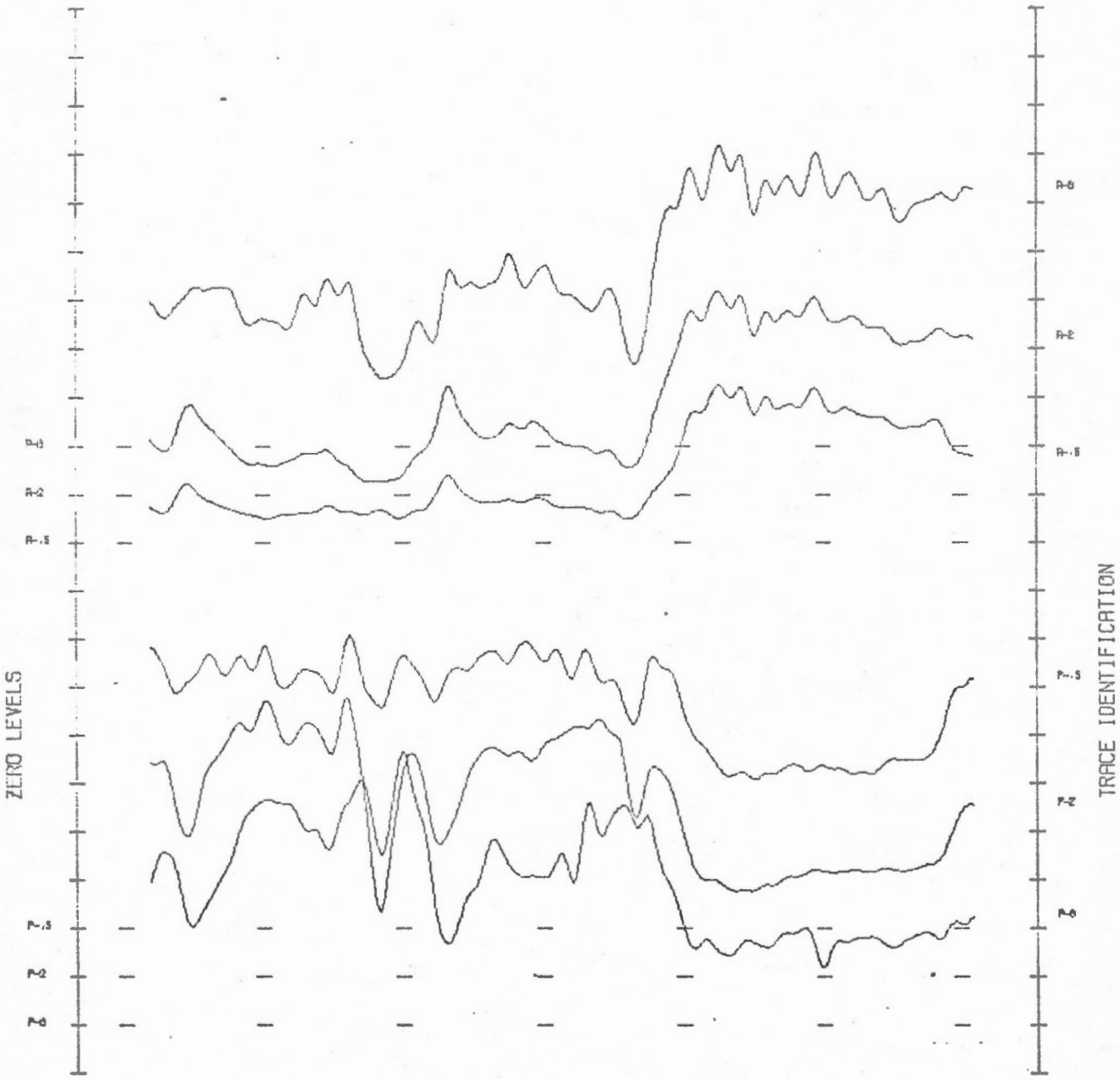
HAWKESBURY LINE 1

FIDS 3340 3320 3300 3280 3260 3240 3220 3200 3180 3160

KM 0 1 2 3 4 5 6 7 8 9 10 11 12

FILTERED AND ALTITUDE CORRECTED COMPONENTS OF THE SECONDARY FIELD

500 PPM..2 RAD.



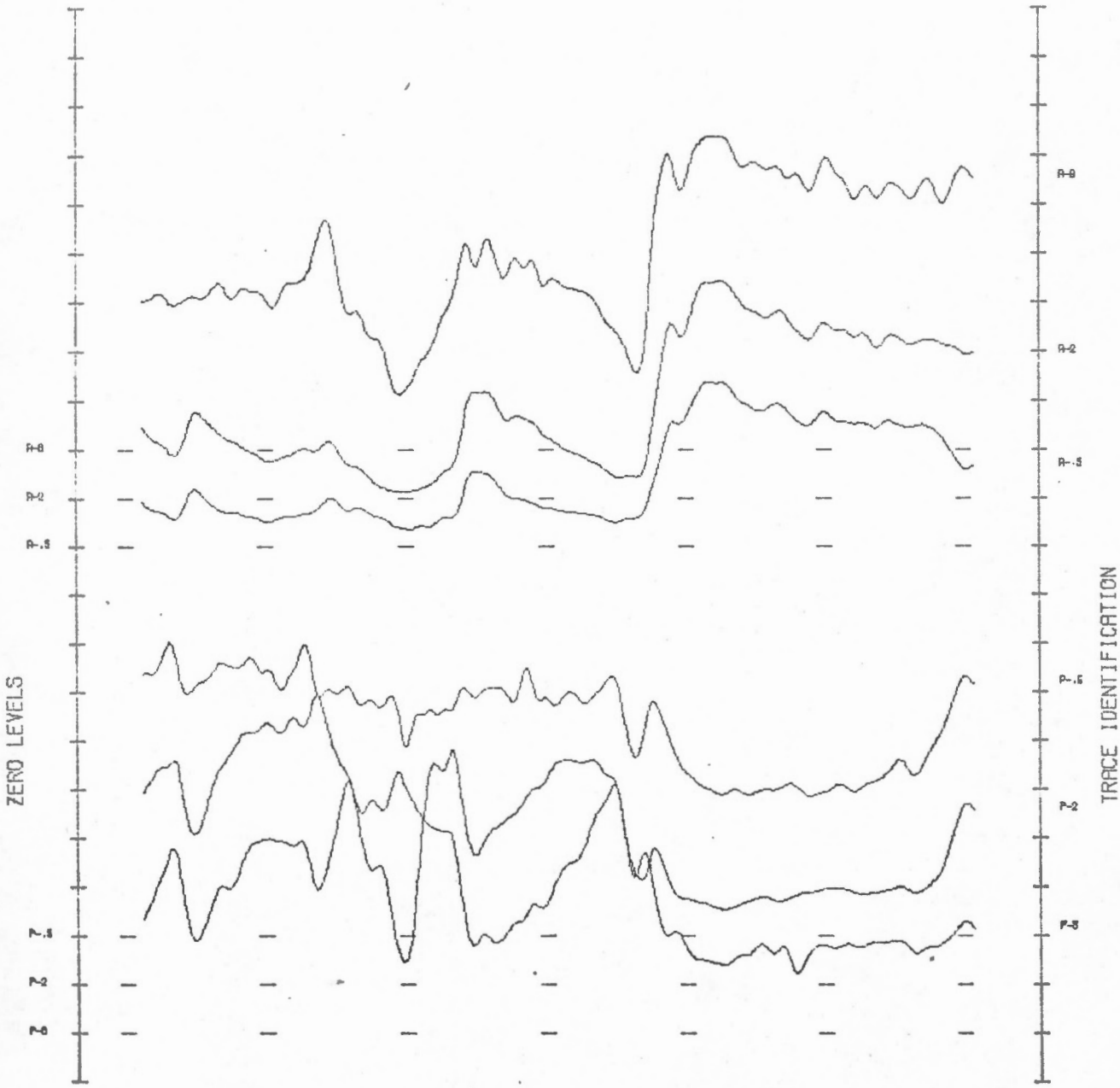
HAWKESBURY LINE 2

FIDS 2860 2880 2900 2920 2940 2960 2980 3000 3020 3040

KM 0 1 2 3 4 5 6 7 8 9 10 11 12

FILTERED AND ALTITUDE CORRECTED COMPONENTS OF THE SECONDARY FIELD

500 PPM, .2 RAD.



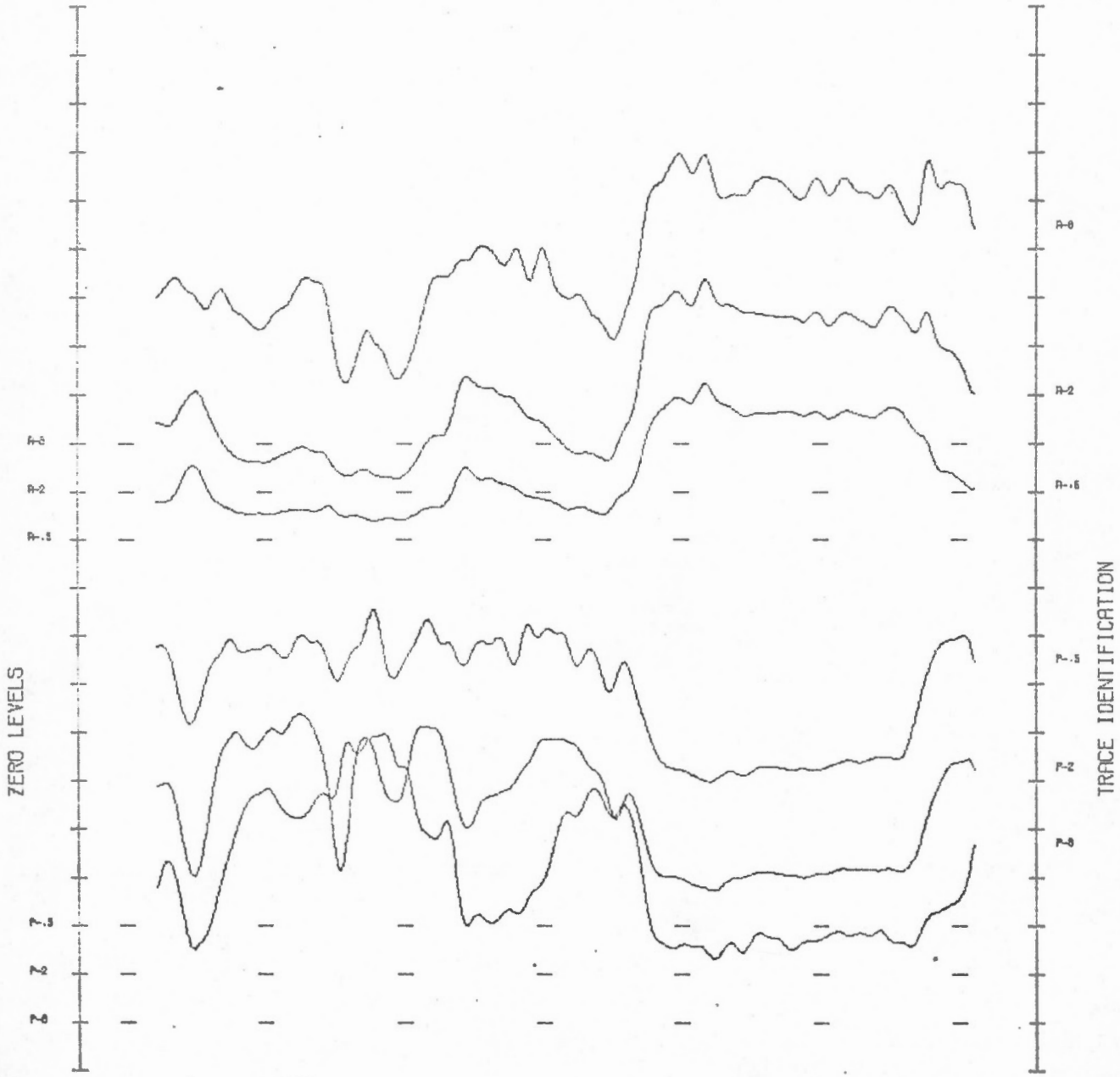
HAWKESBURY LINE 3

FIDS 2760 2740 2720 2700 2680 2660 2640 2620 2600 2580

KM 0 1 2 3 4 5 6 7 8 9 10 11 12

FILTERED AND ALTITUDE CORRECTED COMPONENTS OF THE SECONDARY FIELD

500 PPM..2 RAD.



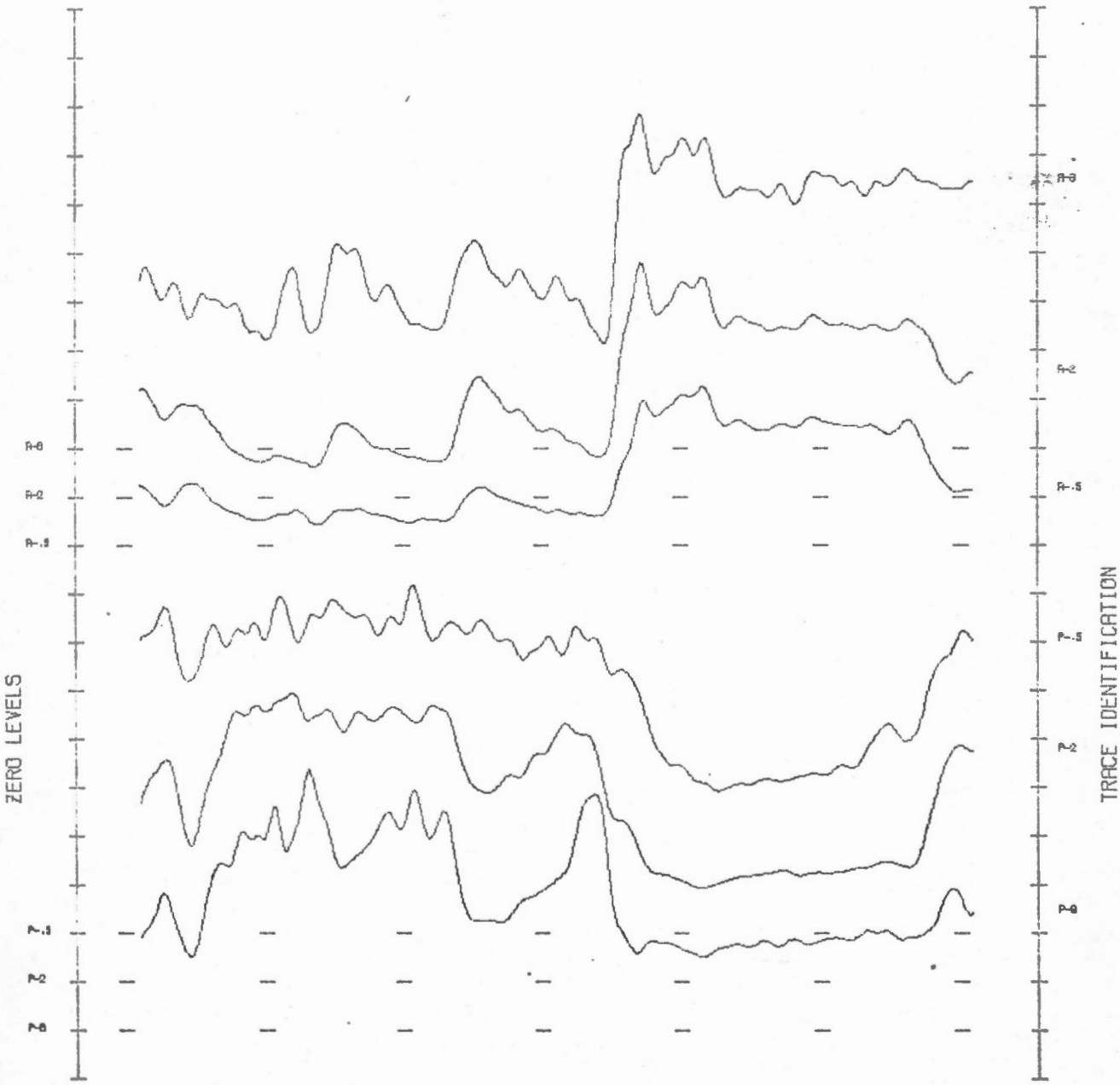
HAWKESBURY LINE 4

FIDS 2240 2260 2280 2300 2320 2340 2360 2380 2400 2420 2440

KM 0 1 2 3 4 5 6 7 8 9 10 11 12

FILTERED AND ALTITUDE CORRECTED COMPONENTS OF THE SECONDARY FIELD

500 PPM, .2 RAD.



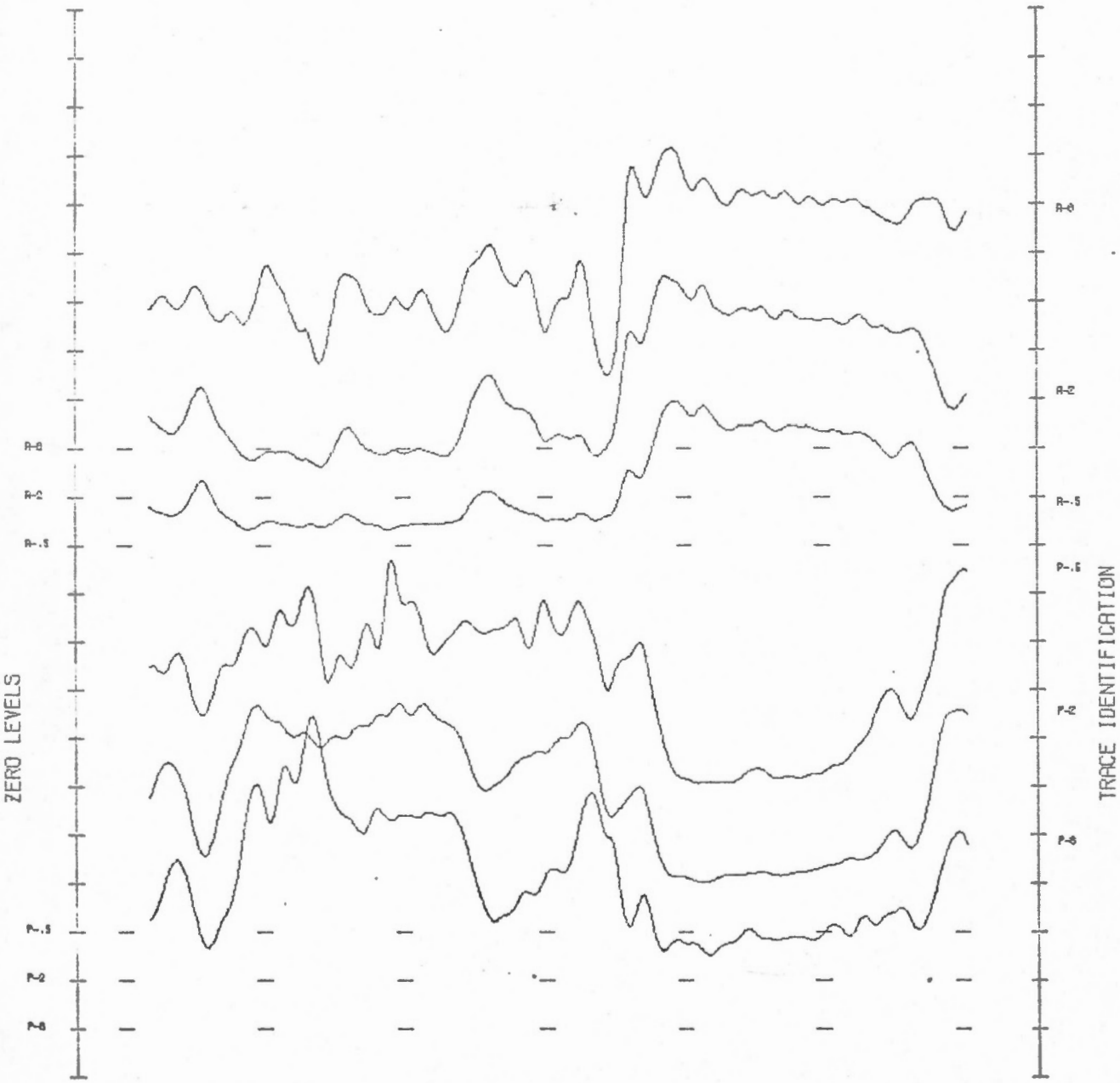
HAWKESBURY LINE 5

FIDS 2120 2100 2080 2060 2040 2020 2000 1980 1960 1940

KM 0 1 2 3 4 5 6 7 8 9 10 11 12

FILTERED AND ALTITUDE CORRECTED COMPONENTS OF THE SECONDARY FIELD

500 PPM..2 RAD.



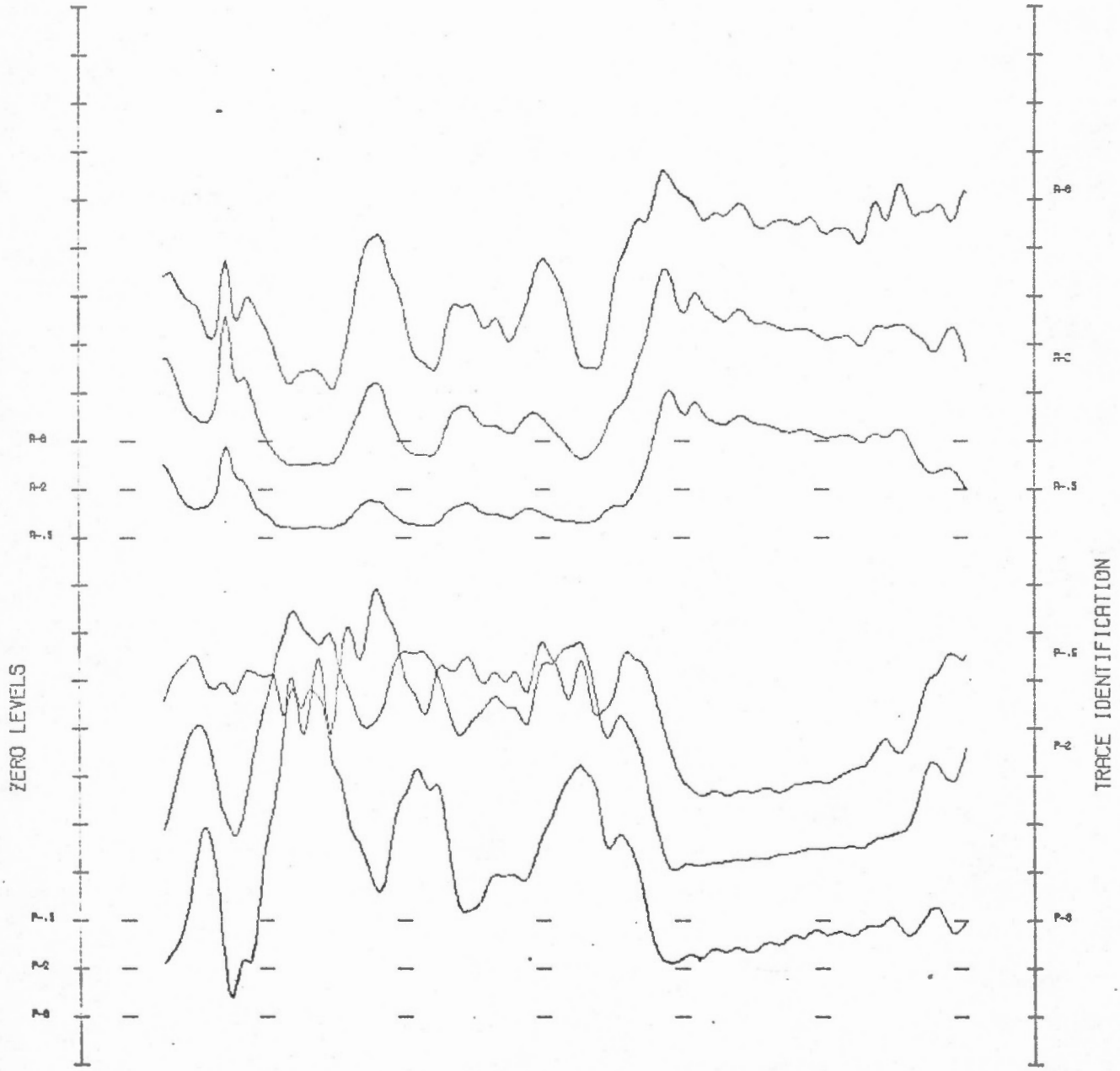
HAWKESBURY LINE 6

FIDS 1820 1800 1780 1760 1740 1720 1700 1680 1660 1640

KM 0 1 2 3 4 5 6 7 8 9 10 11 12

FILTERED AND ALTITUDE CORRECTED COMPONENTS OF THE SECONDARY FIELD

500 PPM..2 RAD.



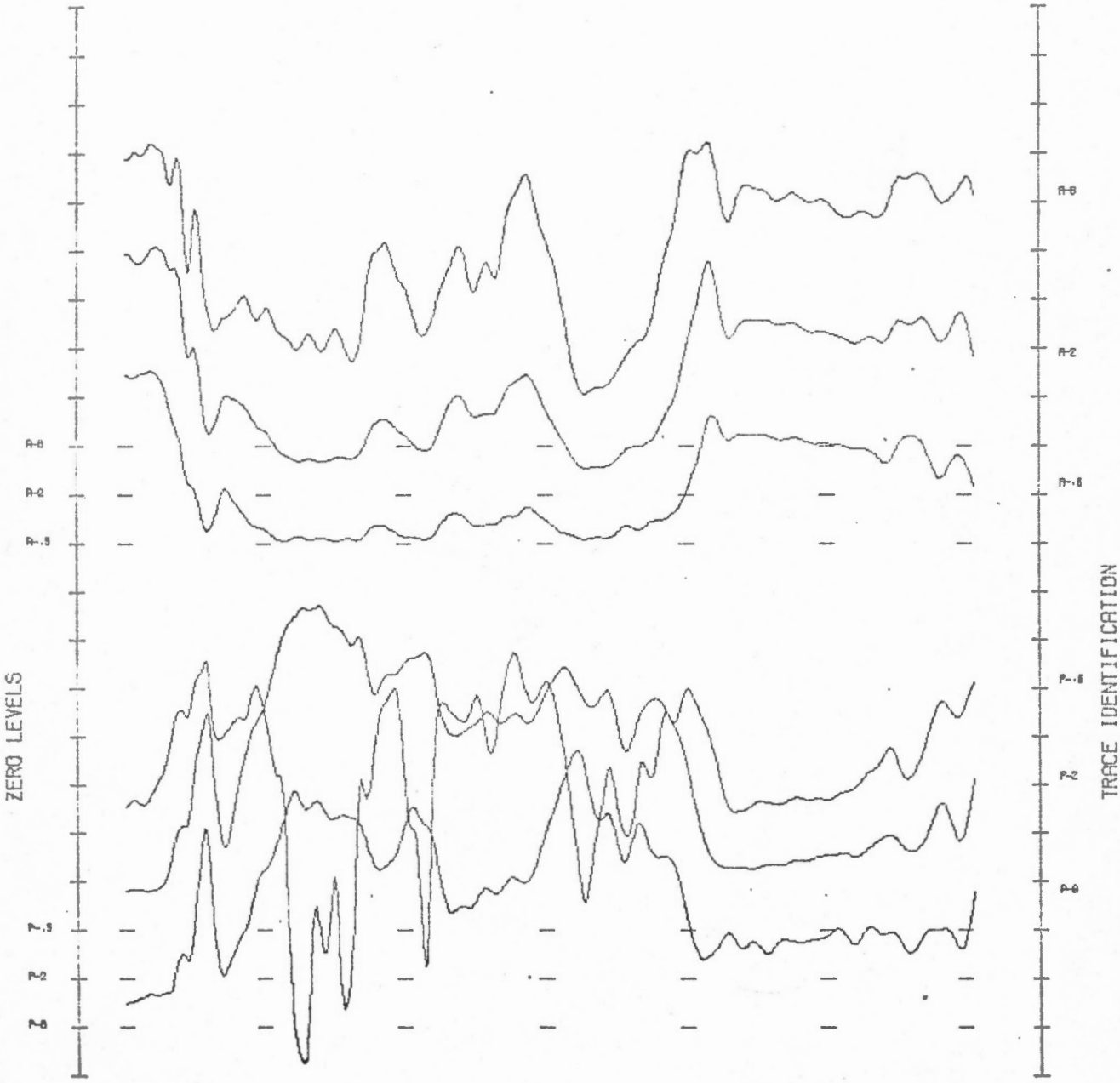
HAWKESBURY LINE 7

FIDS 1300 1320 1340 1360 1380 1400 1420 1440 1460 1480 1500

KM 0 1 2 3 4 5 6 7 8 9 10 11 12

FILTERED AND ALTITUDE CORRECTED COMPONENTS OF THE SECONDARY FIELD

500 PPM..2 RAD.



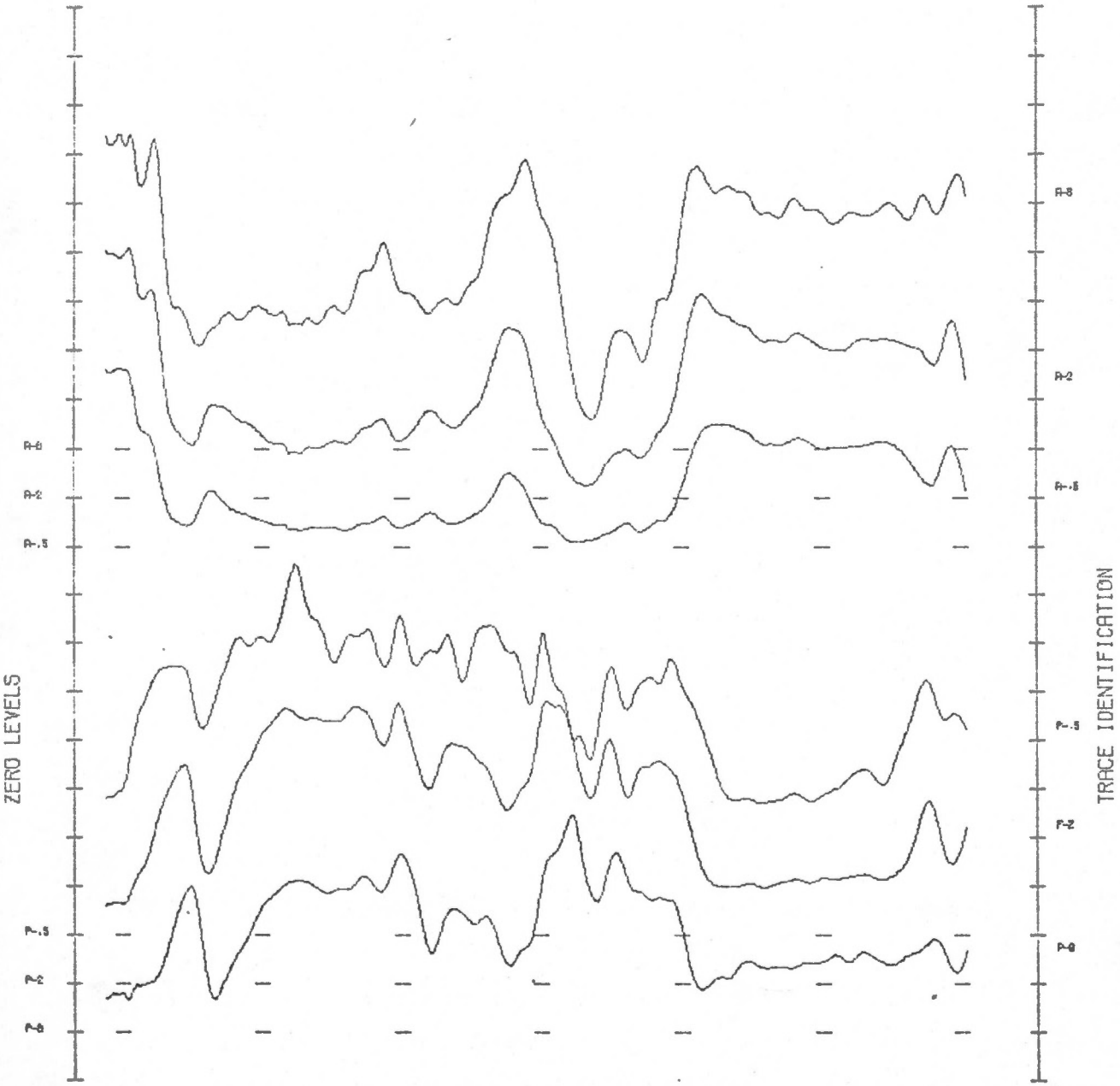
HAWKESBURY LINE 208

FIDS 1180 1160 1140 1120 1100 1080 1060 1040 1020 1000

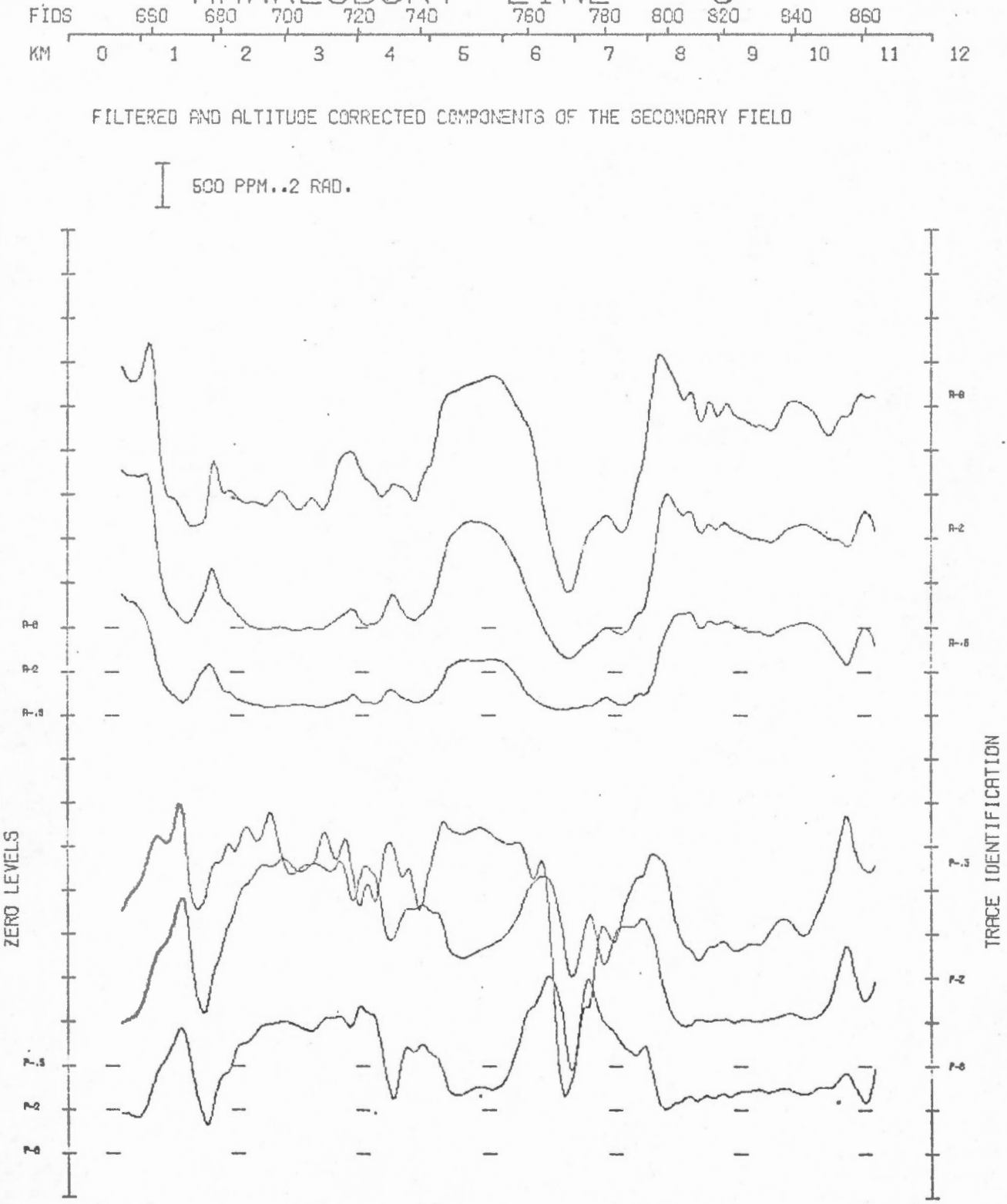
KM 0 1 2 3 4 5 6 7 8 9 10 11 12

FILTERED AND ALTITUDE CORRECTED COMPONENTS OF THE SECONDARY FIELD

500 PPM..2 RAD.



HAWKESBURY LINE 8



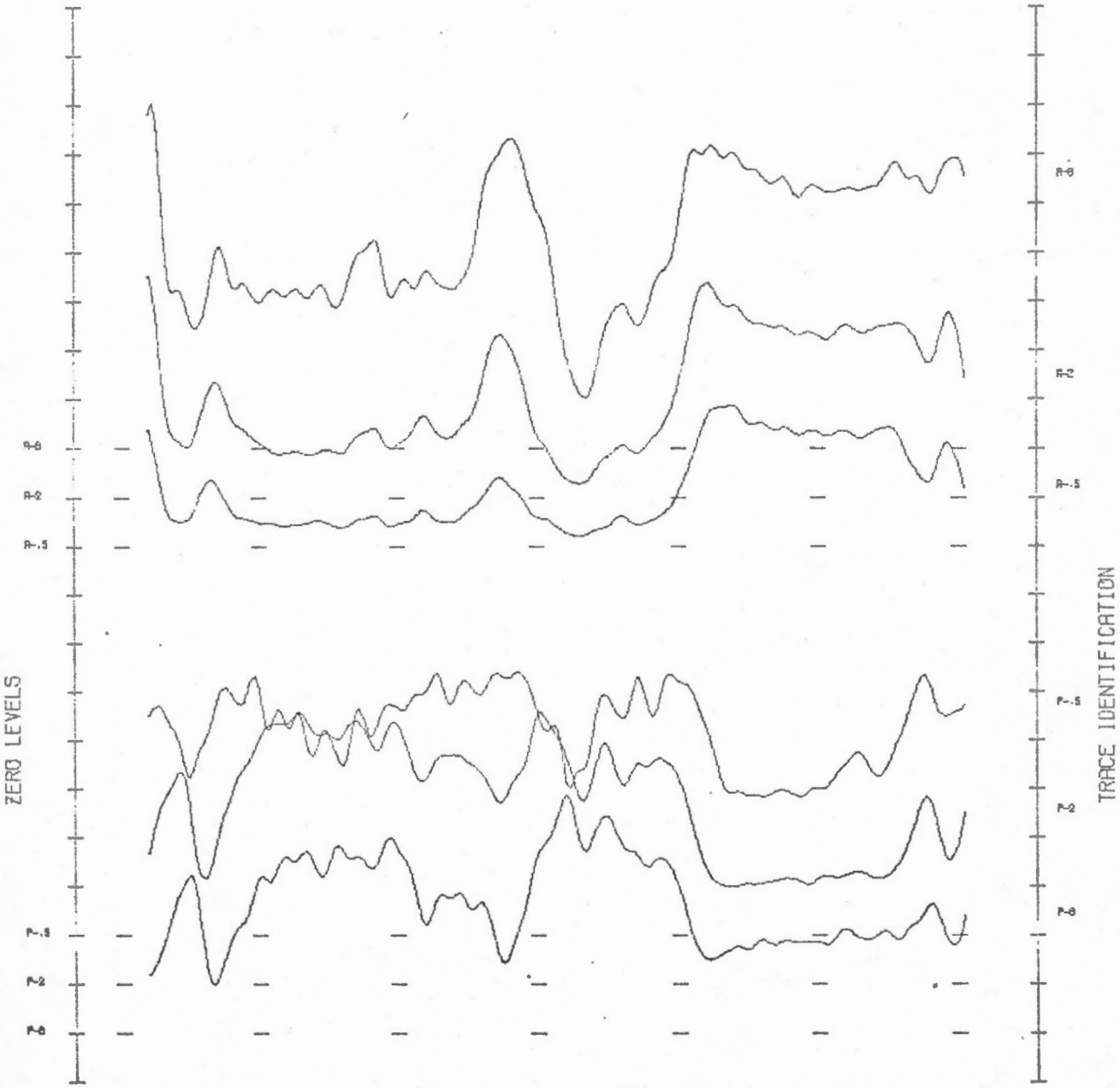
HAWKESBURY LINE 108

FIDS 520 500 480 460 440 420 400 380 360 340

KM 0 1 2 3 4 5 6 7 8 9 10 11 12

FILTERED AND ALTITUDE CORRECTED COMPONENTS OF THE SECONDARY FIELD

500 PPM..2 RAD.



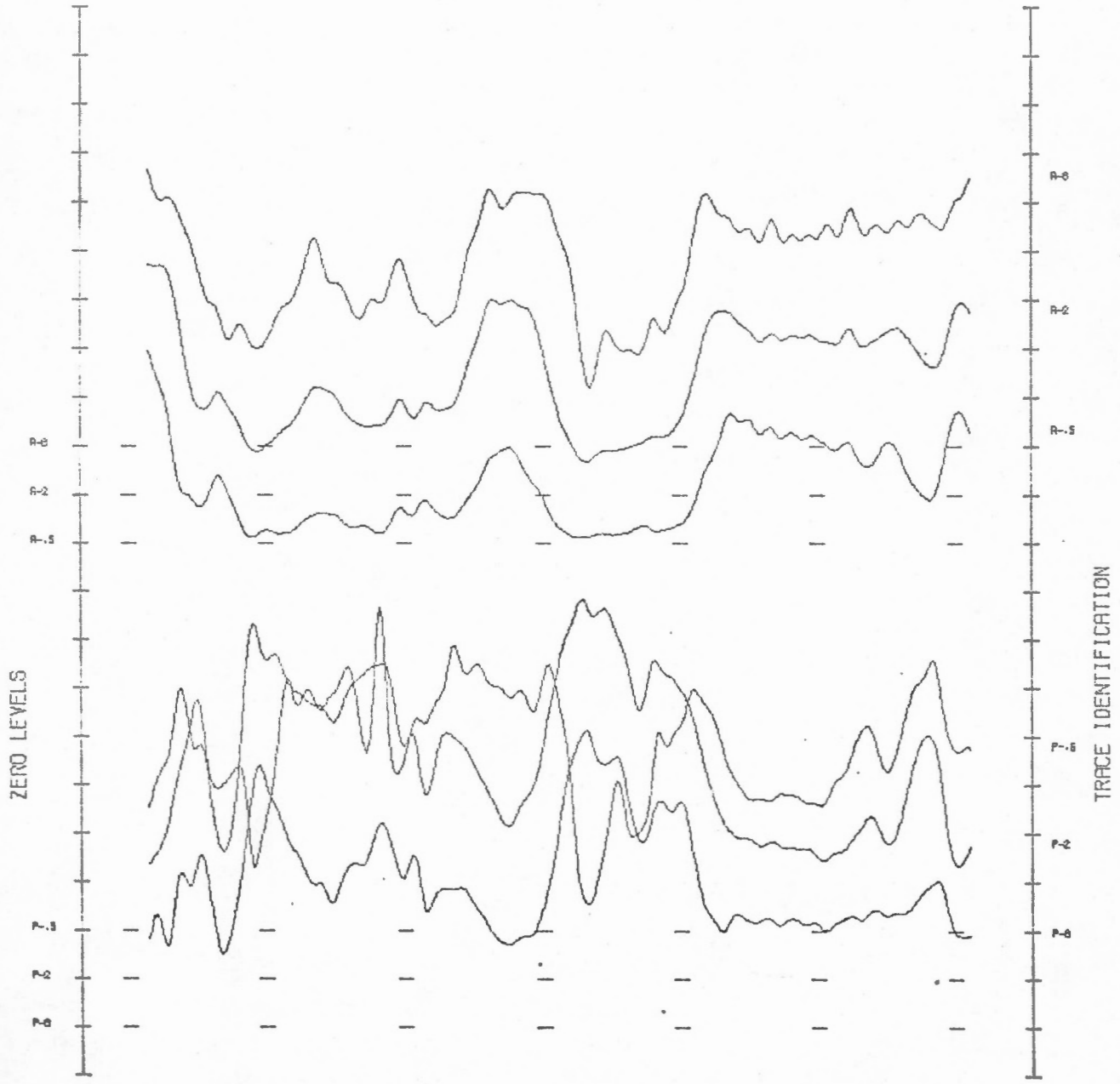
HAWKESBURY LINE 9

FIDS 500 480 460 440 420 400 380 360 340 320

KM 0 1 2 3 4 5 6 7 8 9 10 11 12

FILTERED AND ALTITUDE CORRECTED COMPONENTS OF THE SECONDARY FIELD

500 PPM, .2 RAD.



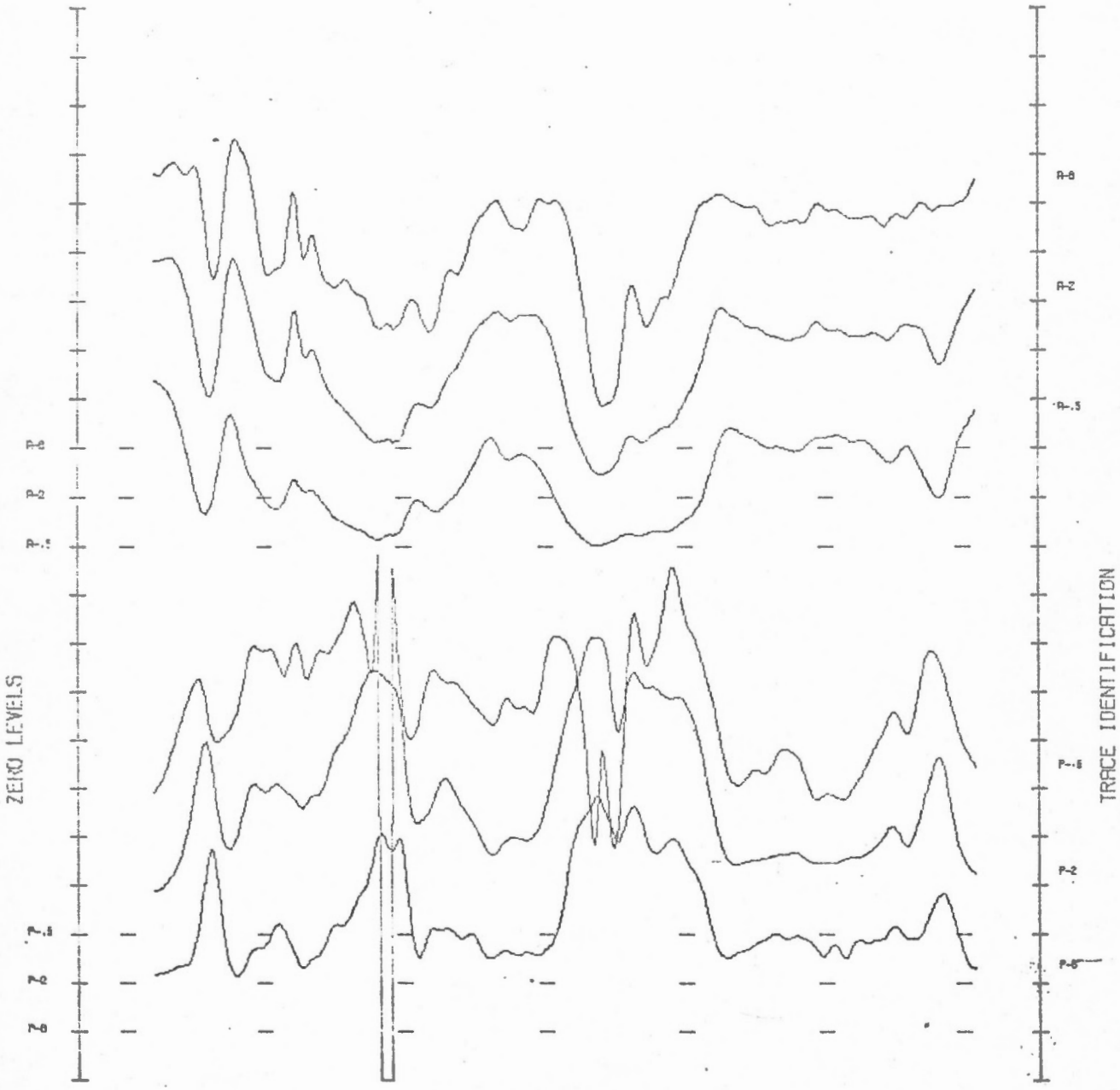
HAWKESBURY LINE 10

FIDS 1080 1060 1040 1020 1000 980 960 940 920 900 880

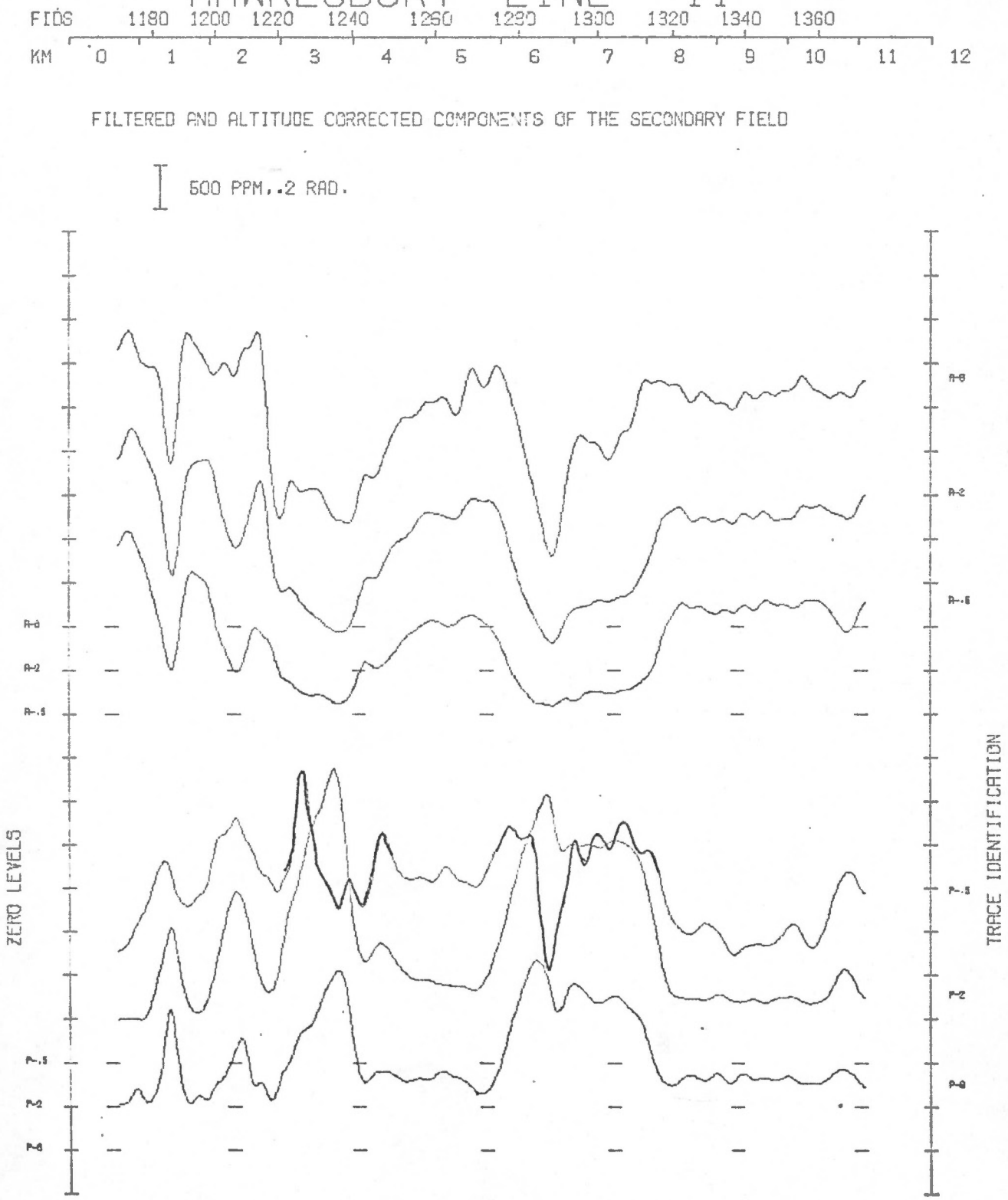
KM 0. 1 2 3 4 5 6 7 8 9 10 11 12

FILTERED AND ALTITUDE CORRECTED COMPONENTS OF THE SECONDARY FIELD

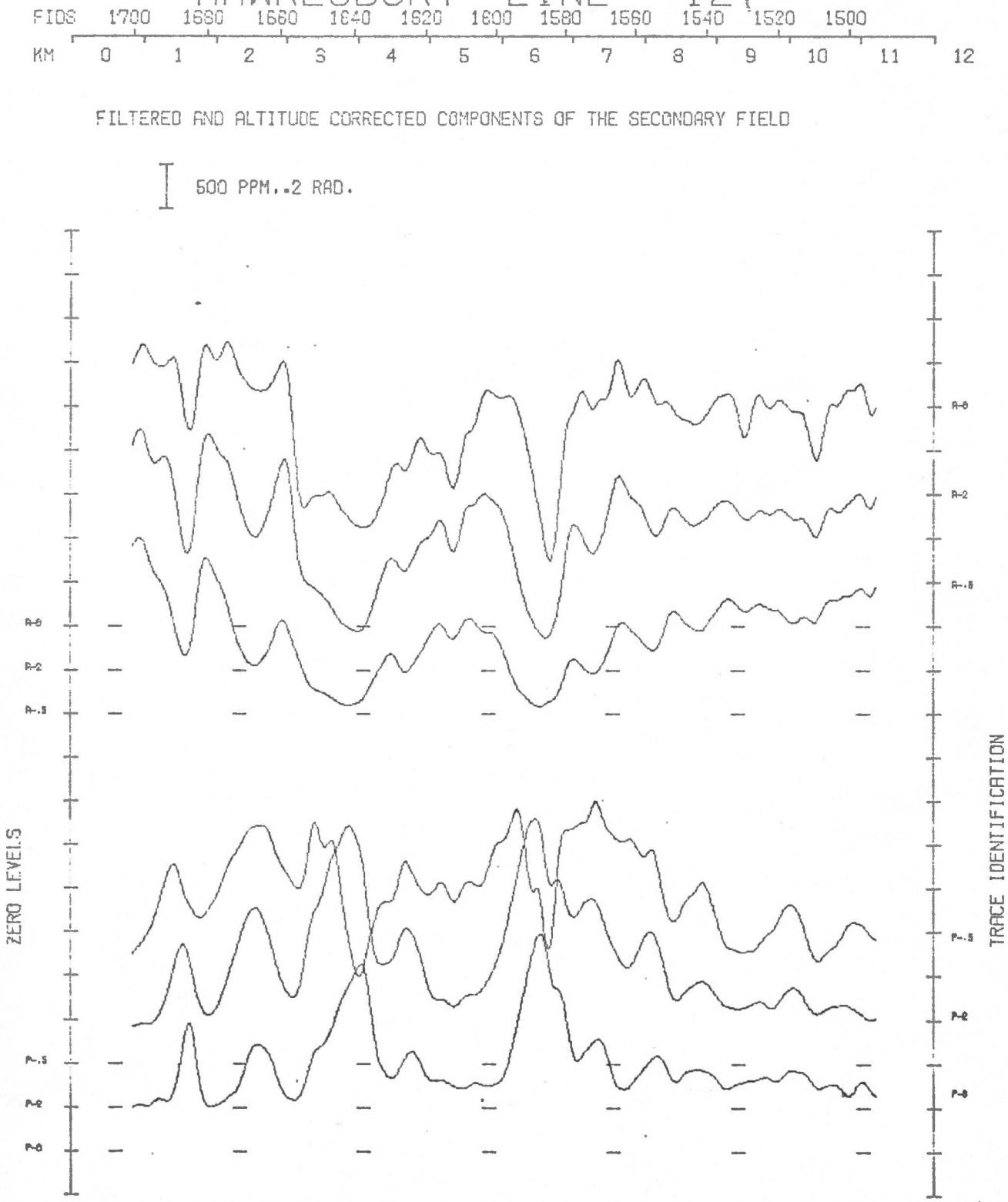
500 PPM..2 RAD.



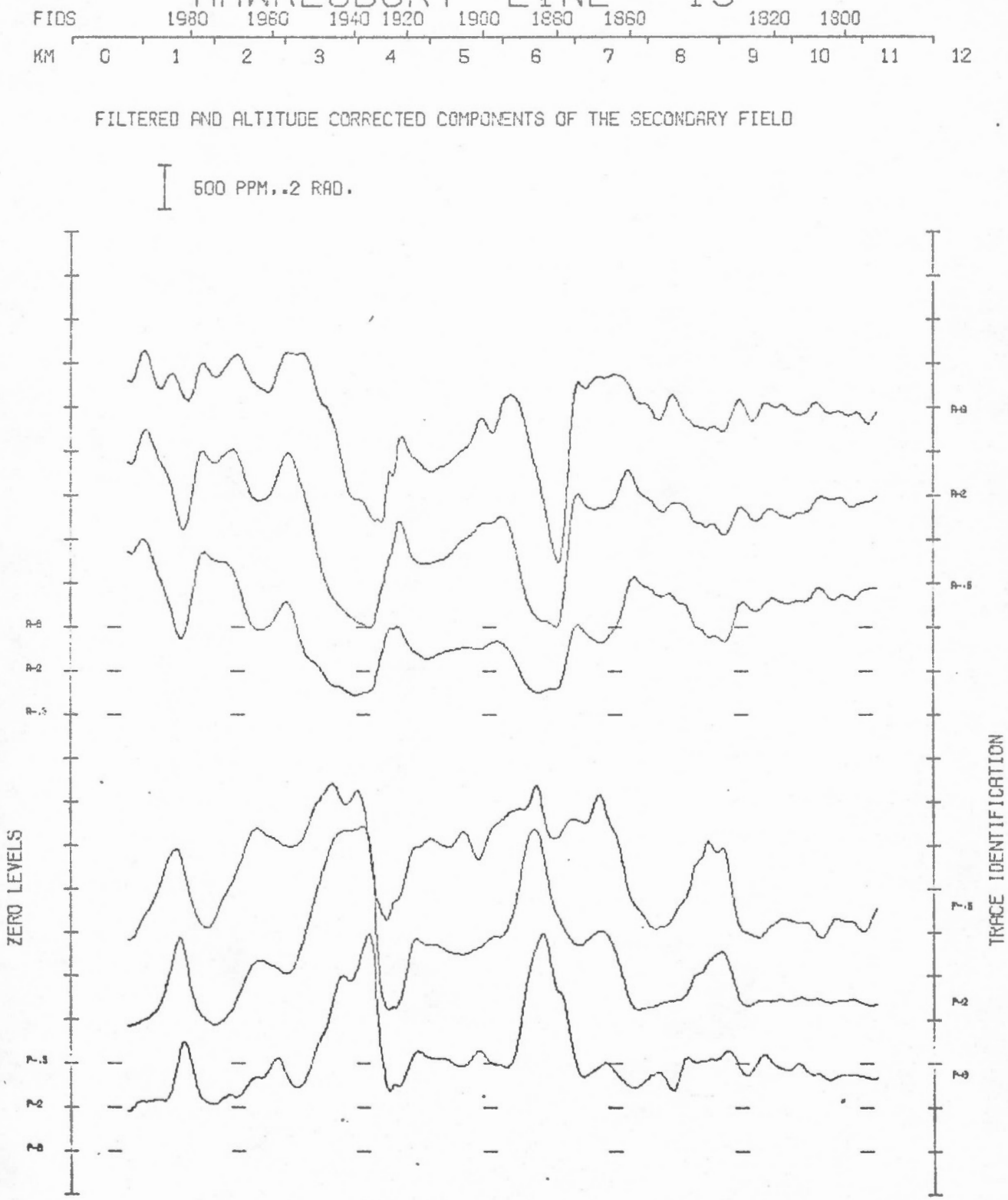
HAWKESBURY LINE 11



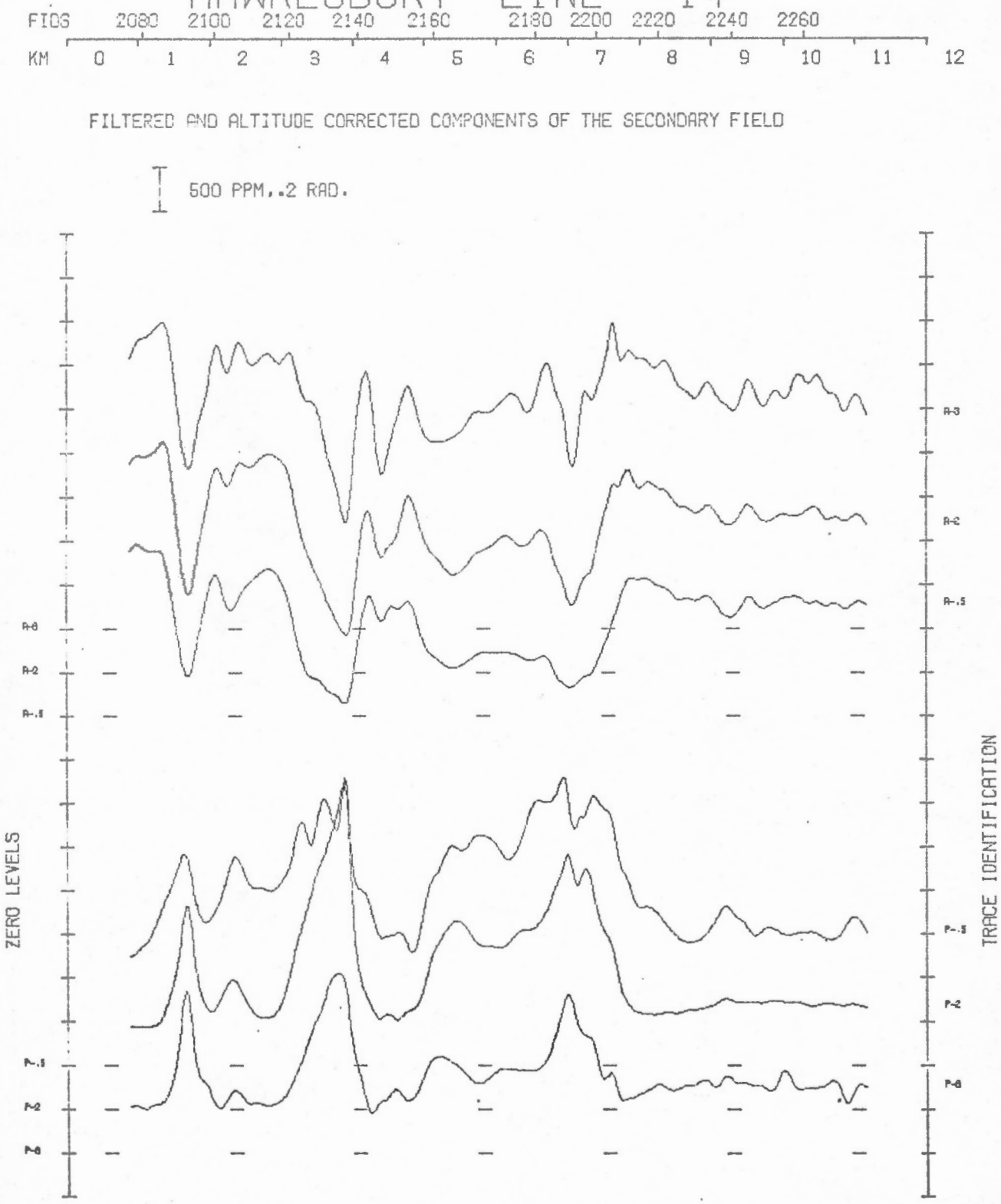
HAWKESBURY LINE 12



HAWKESBURY LINE 13



HAWKESBURY LINE 14



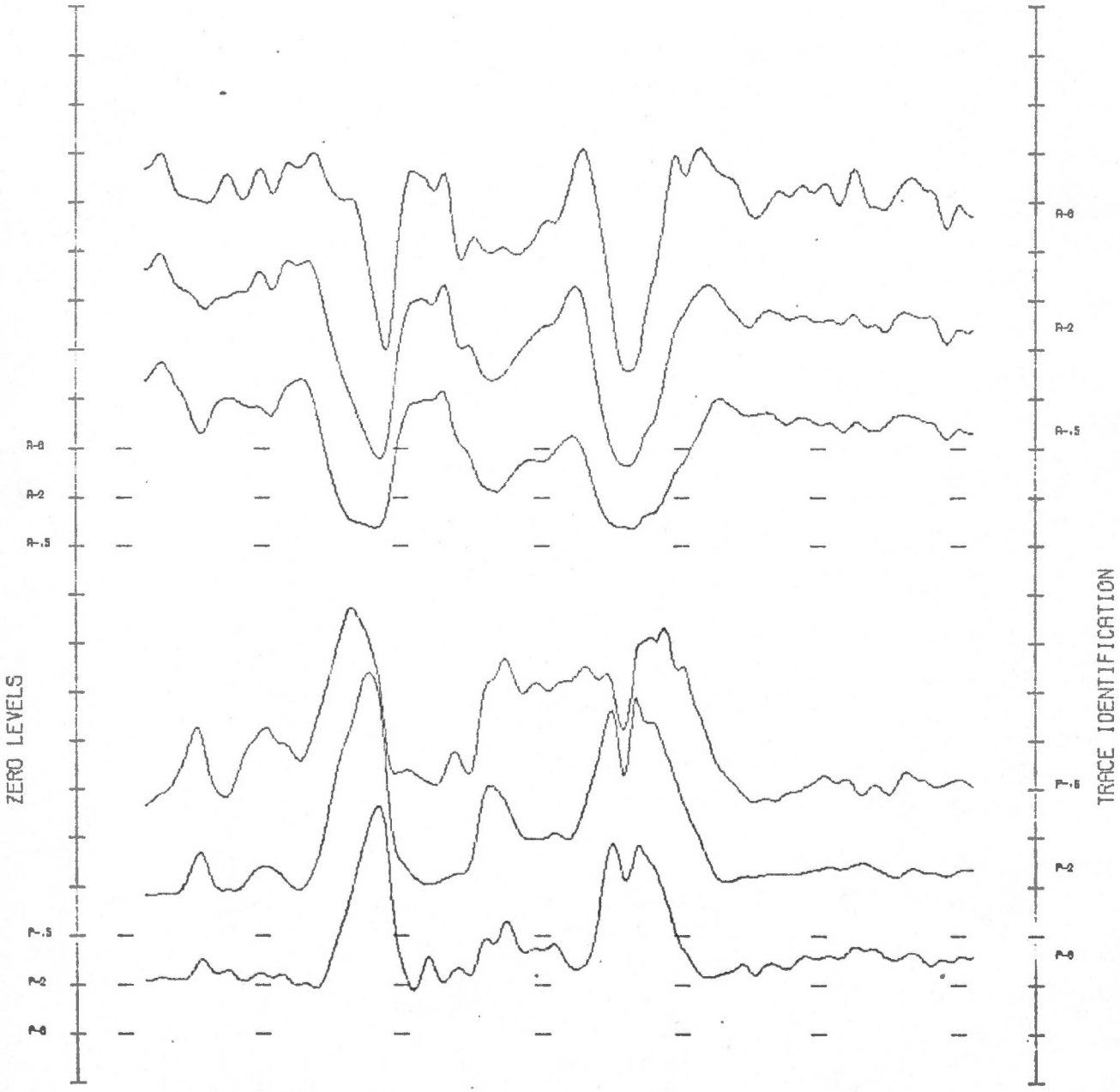
HAWKESBURY LINE 15

FIDS 2580 2560 2540 2520 2500 2480 2460 2440 2420 2400

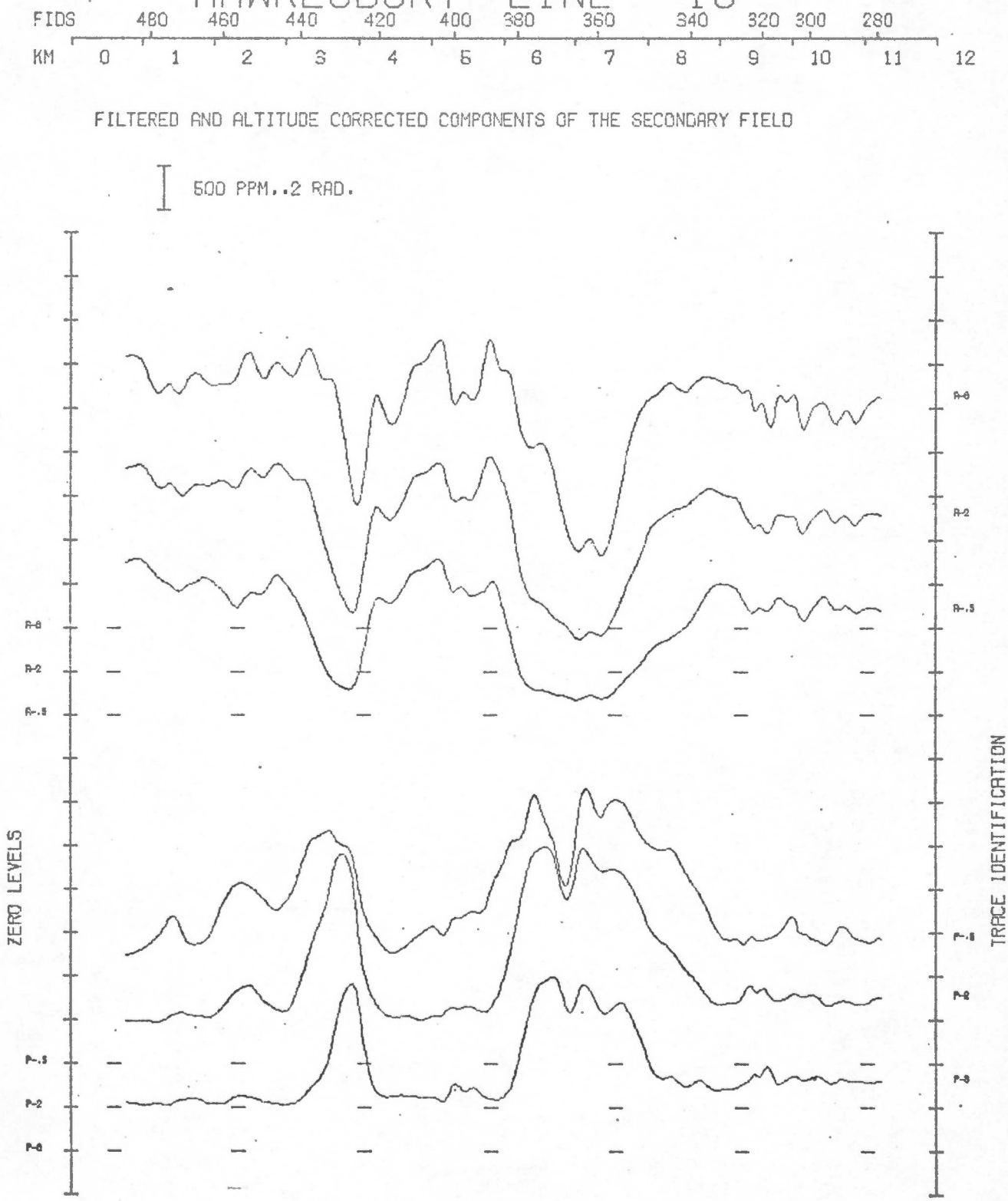
KM 0 1 2 3 4 5 6 7 8 9 10 11 12

FILTERED AND ALTITUDE CORRECTED COMPONENTS OF THE SECONDARY FIELD

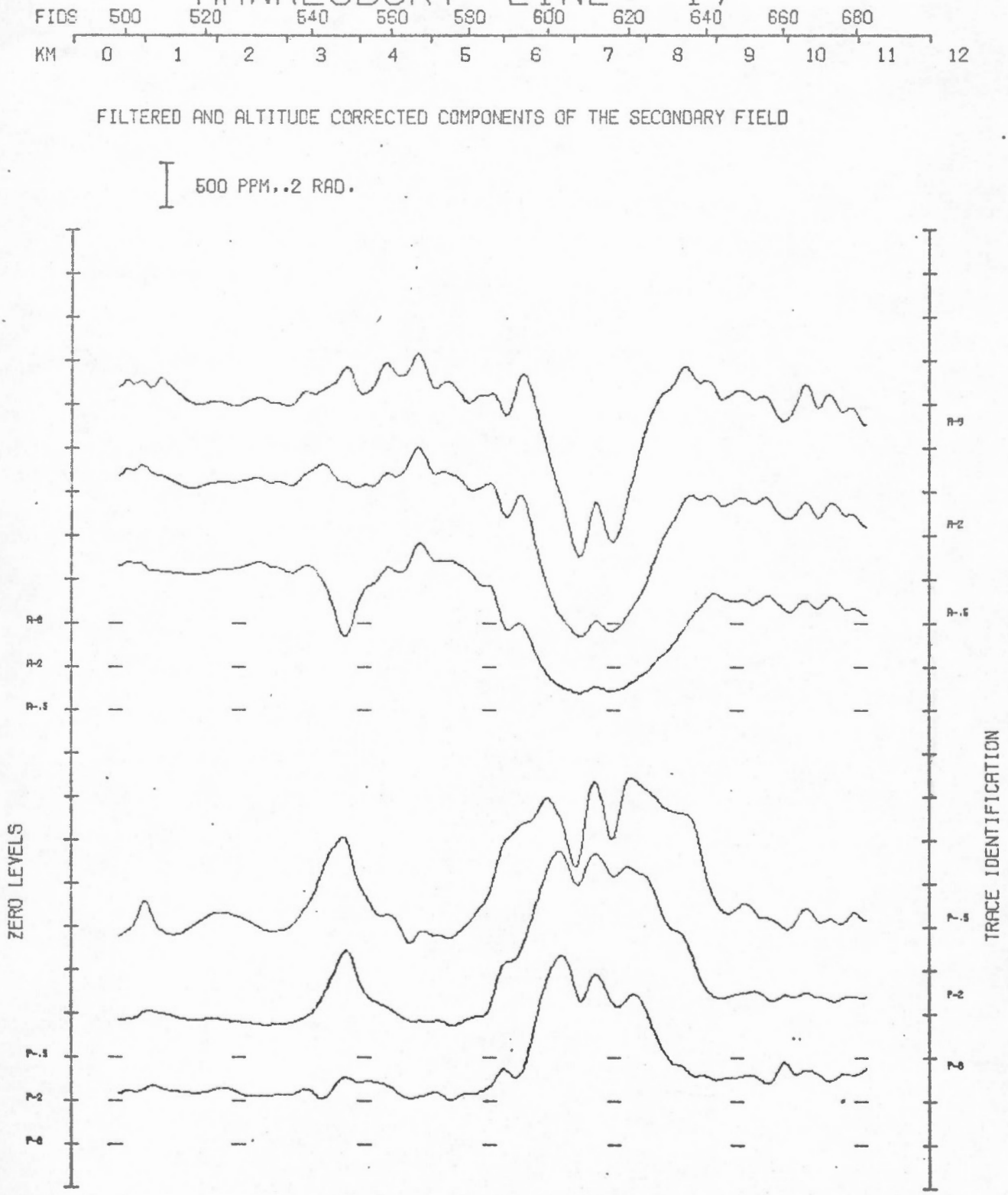
500 PPM..2 RAD.



HAWKESBURY LINE 16



HAWKESBURY LINE 17



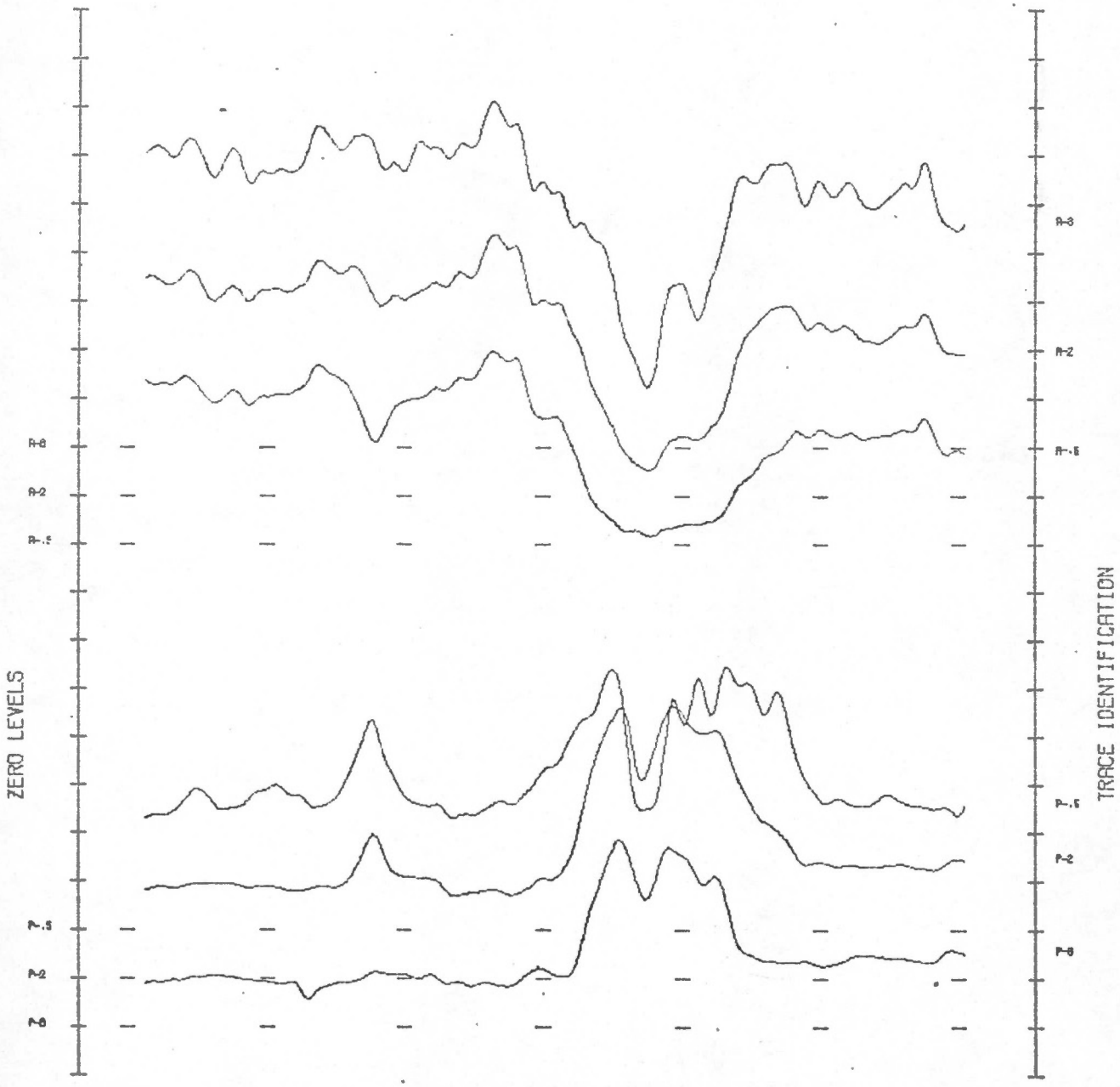
HAWKESBURY LINE 18

FIDS 1080 1100 1120 1140 1160 1180 1200 1220 1240 1260

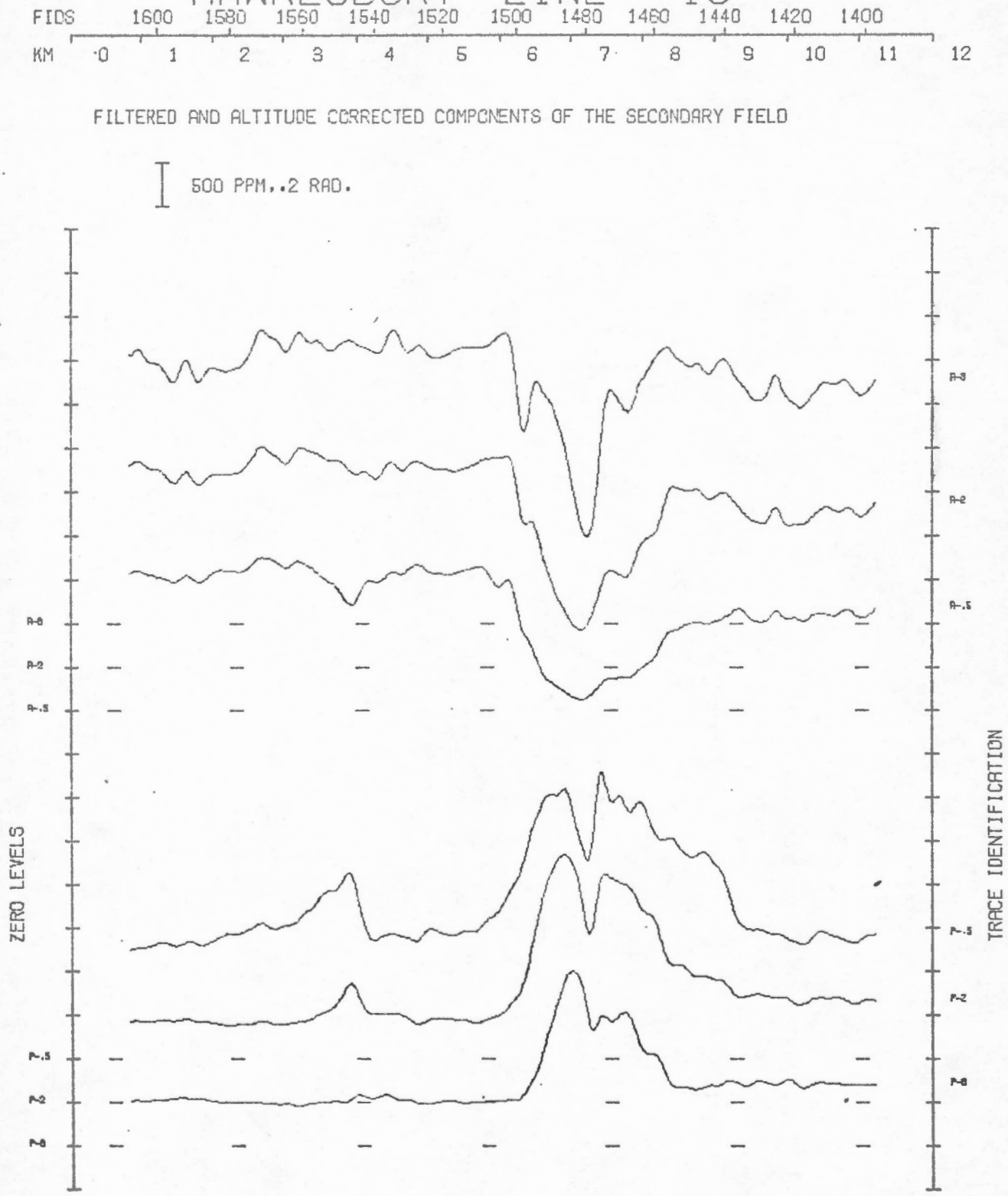
KM 0 1 2 3 4 5 6 7 8 9 10 11 12

FILTERED AND ALTITUDE CORRECTED COMPONENTS OF THE SECONDARY FIELD

500 PPM..2 RAD.



HAWKESBURY LINE 19



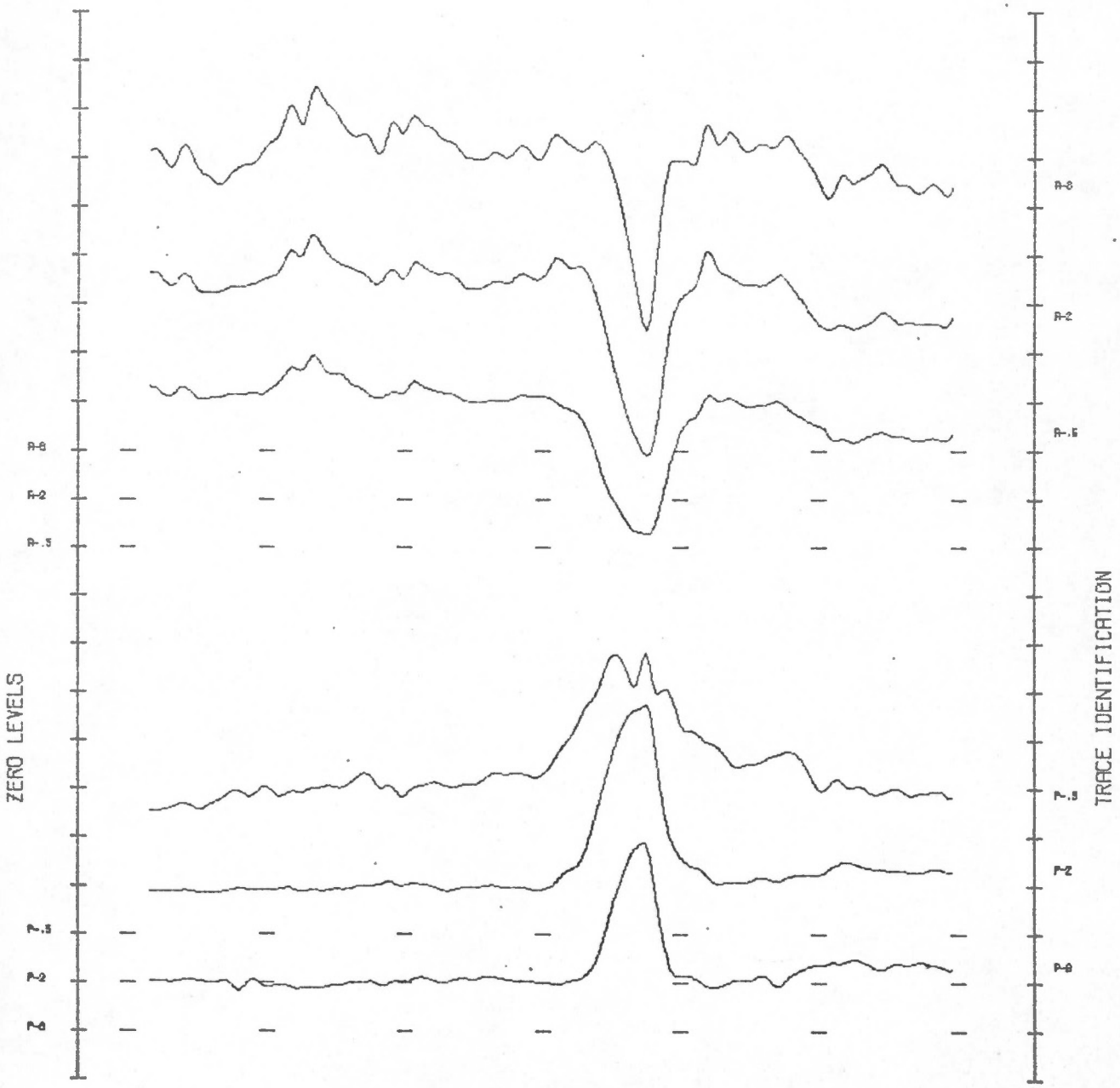
HAWKESBURY LINE 20

FIDS 1700 1720 1740 1760 1780 1800 1820 1840 1860 1880

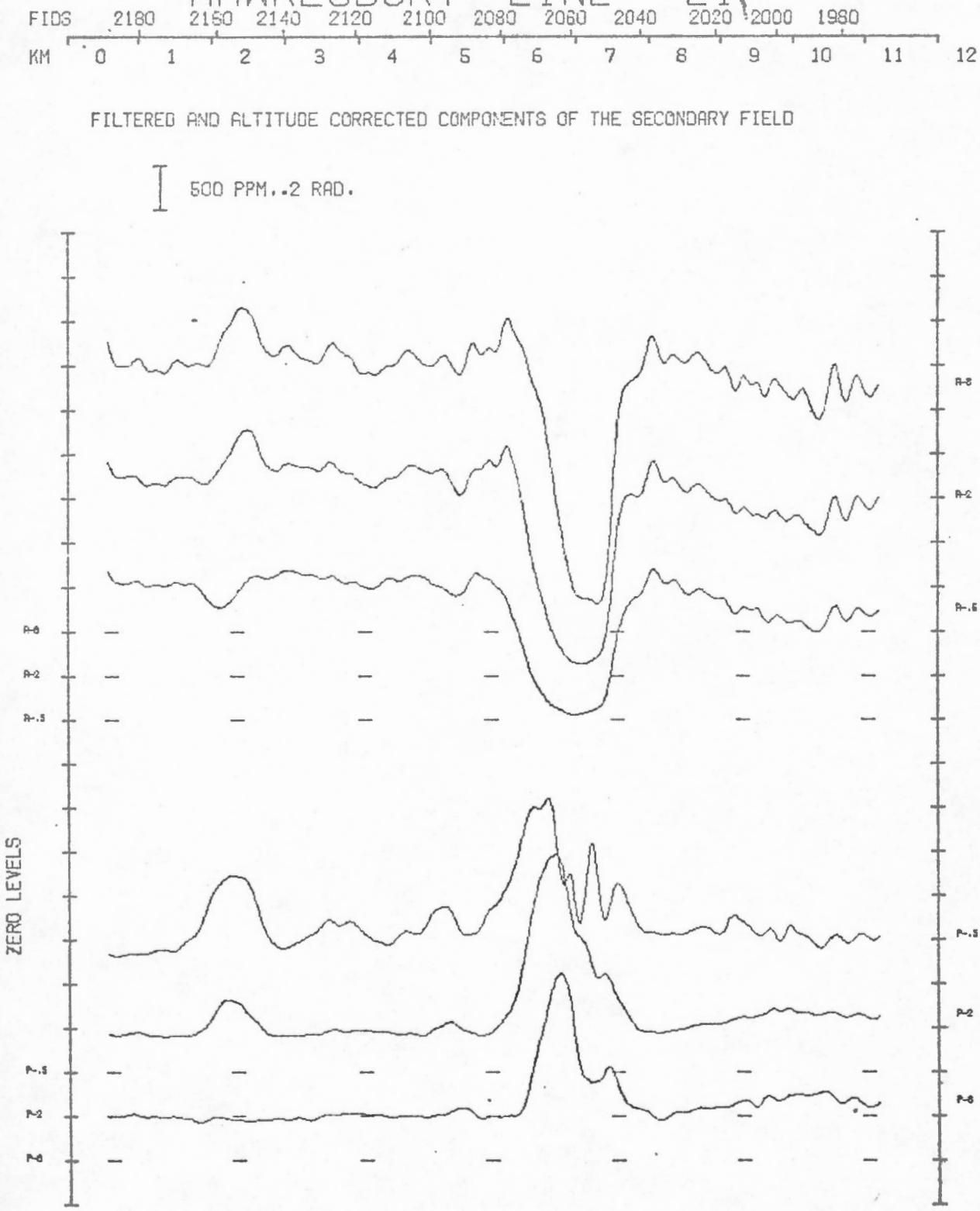
KM 0 1 2 3 4 5 6 7 8 9 10 11 12

FILTERED AND ALTITUDE CORRECTED COMPONENTS OF THE SECONDARY FIELD

500 PPM..2 RAD.



HAWKESBURY LINE 21



APPENDIX 6

Interpretation Program and Sample

```
      PROGRAM LINGRAF (INPUT,TAPE1,OUTPUT,TAPE2)
      INTEGER FID(500), COORDY(500),TESLIGN,D1(500),D2(500),D3(500),D4(5
     100),D5(500),TESDEBU
      REAL ALT(500),T(500),SIGMA(500),TSIGMA(500),DH(500),FREQ(500),PHAS
     1E(500)
      DATA TESDEBU /0/
  102 FORMAT (1X,I6)
      CALL LIMITE (400.)
      CALL PLOT (0.,-.5,-3)
 1999 READ 102,LINE
      PRINT 102,LINE
      IF (LINE .EQ. 0) GO TO 200
      GO TO 001
  301 TESDEBU =1
      GO TO 40
  001 TESLIGN=0
      J=0
      IF (TESDEBU .EQ. 0) GO TO 301
      GO TO 302
  040 READ (1) I1,I2,I3,I4,I5,I6,I7,I8,I9,I10,I11,I12
      IF (EOF(1) .NE. 0) GO TO 41
  302 LIGNE=I2
      IF(LIGNE .NE. LINE .AND. TESLIGN .EQ. 0) GO TO 40
      IF (LIGNE .NE. LINE .AND. TESLIGN .EQ. 1) GO TO 41
      TESLIGN =1
      J=J+1
      FID(J)=I3
      COORDY(J)=I5
      ALT(J)=I6
      AMP5=I7*I7+I8*I8
      AMP5=SQRT(AMP5)
      PHI5=I5
      PHI5=PHI5/I7
      PHI5=ATAN(PHI5)
      AMP20=I9*I9+I10*I10
      AMP20=SQRT(AMP20)
      PHI20=I10
      PHI20=PHI20/I9
      PHI20=ATAN(PHI20)
      AMP80=I11*I11+I12*I12
      AMP80=SQRT(AMP80)
      PHI80=I12
      PHI80=PHI80/I11
      PHI80=ATAN(PHI80)
      CALL INEMAUT (LINE,FID(J),AMP5,PHI5,AMP20,PHI20,AMP80,PHI80,D1(J),
     1D2(J),D3(J),D4(J),D5(J),T(J),SIGMA(J),TSIGMA(J),DH(J),FREQ(J),PHAS
     2E(J))
      IF (DH(J) .LT. -9.99) DH(J)=-9.99
      GO TO 040
  041 CALL SOGRAFC (LINE,FID,COORDY,T,SIGMA,TSIGMA,DH,FREQ,D1,D2,D3,D4,
     1D5,J)
      GO TO 1999
  200 CALL ENDPLT
      STOP
      END
```

SYMBOLIC REFERENCE MAP (R=1)

ENTRY POINTS
10213 LINGRAF

VARIABLES	SN	TYPE	RELOCATION				
17355	ALT	REAL	ARRAY	10475	AMP20	REAL	
10473	AMP5	REAL		10477	AMP80	REAL	
11465	COORDY	INTEGER	ARRAY	23275	DH	REAL	ARRAY
12451	D1	INTEGER	ARRAY	13435	D2	INTEGER	ARRAY
14421	D3	INTEGER	ARRAY	15405	D4	INTEGER	ARRAY
16371	D5	INTEGER	ARRAY	10501	FID	INTEGER	ARRAY
24261	FREQ	REAL	ARRAY	10456	I1	INTEGER	
10467	I10	INTEGER		10470	I11	INTEGER	
10471	I12	INTEGER		10457	I2	INTEGER	
10460	I3	INTEGER		10461	I4	INTEGER	
10462	I5	INTEGER		10463	I6	INTEGER	
10464	I7	INTEGER		10465	I8	INTEGER	
10466	I9	INTEGER		10455	J	INTEGER	
10472	LIGNE	INTEGER		10454	LINE	INTEGER	
25245	PHASE	REAL	ARRAY	10476	PHI20	REAL	
10474	PHI5	REAL		10500	PHI80	REAL	
21325	SIGMA	REAL	ARRAY	20341	T	REAL	ARRAY
10411	TESDEBU	INTEGER		10453	TESLIGN	INTEGER	
22311	TSIGMA	REAL	ARRAY				

FILE NAMES		MODE								
0	INPUT	FMT	4102	OUTPUT	FMT	2041	TAPE1	UNFMT	6143	TAP

EXTERNALS	TYPE	ARGS				
ATAN	REAL	1	LIBRARY	ENDPLT		0
EOF	REAL	1		INEMAUT		19
LIMITE		1		PLOT		3
SUGRAFC		14		SQRT	REAL	1 LIBRARY

STATEMENT LABELS

10231	1		10234	40	10330	41
10412	102	FMT	10333	200	10227	301
10241	302		10221	1999		

STATISTICS

PROGRAM LENGTH	160248	7188
BUFFER LENGTH	102058	4229

```
      SUBROUTINE INTERPO (VAR1,VAR,VAR2,FONC2,INT,FONC1)
      IMPLICIT REAL (A-Z)
  001 FORMAT (4X,"INTERPROBL",6(4X,F12.5))
  002 FORMAT (4X,"INTER=OK",6(4X,F12.5))
      AFONC1=ABS(FONC1)
      IF(AFONC1 .LT. .00001) PRINT 001,VAR1,VAR,VAR2,FONC2,INT,FONC1
      RFONC=FONC2/FONC1
      IF (RFONC .LT. .0000001)  PRINT  001,VAR1,VAR,VAR2,FONC2,INT,FONC1
      LNRFONC=ALOG (RFONC)
      DVAR=VAR2-VAR1
      ADVAR=ABS(DVAR)
      IF(ADVAR .LT. .000001) PRINT 001,VAR1,VAR,VAR2,FONC2,INT,FONC1
      RVAR=(VAR-VAR1)/DVAR
      EFONC=LNRFONC*RVAR
      TEFONC=ABS(EFONC)
      IF (TEFONC .LT. .0000001) GO TO 003
      IF (TEFONC .GT. 300.) GO TO 004
      INT=FONC1*EXP(EFONC)
      RETURN
  003 INT=FONC1
      RETURN
  004 PRINT 001,VAR1,VAR,VAR2,FONC2,INT,FONC1
      RETURN
      END
```

```
SYMBOLIC REFERENCE MAP (R=1)

ENTRY POINTS
    3  INTERPO

VARIABLES      SN  TYPE              RELOCATION
  140  ADVAR       REAL                                134  AFONC1     REAL
  137  DVAR        REAL                                142  EFONC      REAL
    0  FONC1       REAL                     F.P.         0  FONC2      REAL                    F.P.
    0  INT         REAL                     F.P.       136  LNRFONC   REAL
  135  RFONC       REAL                                141  RVAR       REAL
  143  TEFONC      REAL                                  0  VAR        REAL                    F.P.
    0  VAR1        REAL                     F.P.         0  VAR2       REAL                    F.P.

FILE NAMES          MODE
     OUTPUT         FMT

EXTERNALS           TYPE    ARGS
     ALOG           REAL      1 LIBRARY                    EXP        REAL        1 LIBRARY

INLINE FUNCTIONS    TYPE    ARGS
     ABS            REAL      1  INTRIN

STATEMENT LABELS
   54  1        FMT                          60  2        FMT  NO REFS                    36  3
   51  4
```

STATISTICS
PROGRAM LENGTH 1448 100

```
      SUBROUTINE CHERCHE (X,Y,K,VAR,S1,S2,S3,S4,DIAGS)
      IMPLICIT REAL (A-Z)
      INTEGER W,X,Y,Z,K,L,P,A,B,C,DIAGS
      REAL DDH(25),BBD(8,25,14),DDB(8,14),AMP(8,25,14),FAC(8,25,14),MAT(
     125),SORTIE(25),PHASE(8),DSURBI(8),PHASET(9)
      COMMON DSURBI,DSURB,DSURB2,FAC,BBD,W
      DATA    D1/17,D2/17,DDH/-80.,-40.,-20.,-10.,-5.,0.01,5.,10.,
     115.,20.,25.,30.,35.,40.,45.,50.,55.,60.,65.,70.,75.,80.,85.,90.,
     295./,L/1/,DSURBI/.0707,.1,.14142,.2,.28284,.4,.5657,.8/,PHASE/.326
     36,.4,.49,.6,.73495,.9,1.10227,1.35/,PHASET/.2951,.36144,.4427,.542
     42,.6640,.8132,.9960,1.22,1.494/
  001 FORMAT (4X,"CHERCHE",3(3X,I2),5(3X,F12.5),3X,I2)
  220 FORMAT(F7.1,F6.4,F7.5)
  240 FORMAT (2X,"DH=",F6.2,"D/B=",F7.4,"AMPL=",F7.1,"B*D=",F7.5,"FACT="
     1,F6.4)
      IF (K .EQ. 0) GO TO 200
      IF (K .EQ.1) GO TO 080
      IF (K .EQ. 2) GO TO 100
      IF (K .EQ. 3) GO TO 300
      IF (K .EQ. 4) GO TO 400
  005 DIAGS=0
      IF(X .GT. MAX) GO TO 006
      IF( X .LT. MIN) GO TO 007
      GO TO 008
  006 DIAGS=D1
      RETURN
  007 DIAGS=D2
      RETURN
  008 Z=X+1
      TEST1=VAR-MAT(Z)
      TEST2=VAR-MAT(X)
      IF(L .EQ. -1) GO TO 500
      IF (TEST1) 010,020,030
  030 X=X+1
      GO TO 005
  020 X=Z
      Z=X+1
  060 S1=SORTIE(X)
      S2=SORTIE(Z)
      S3=MAT(X)
      S4=MAT(Z)
      RETURN
  010 IF (TEST2) 040,060,060
  040 Y=X-1
      GO TO 005
  500 IF( TEST1) 030,020,510
  510 IF(TEST2) 060,060,040
  080 DO 090 A=1,14
      MAT(A)=FAC(W,Y,A)
  090 SORTIE (A)=DDB(W,A)
      MAX=13
      MIN=1
      D1=4
      D2=5
      L=-1
      GO TO 005
  100 DO 110 A=1,25
```

```
      P=Y+1
      CALL INTERPO (DSURB1,DSURB,DSURB2,AMP(W,A,P),AMPLI,AMP(W,A,Y))
      MAT(A)=AMPLI
      SORTIE(A)=DDH(A)
  110 CONTINUE
      MAX=24
      MIN=1
      D1=1
      D2=2
      L=-1
      GO TO 005
  300 DO 310 A=1,25
      SORTIE (A) =DDH(A)
  310 MAT(A)=AMP(W,A,Y)
      MAX=24
      MIN=1
      D1=1
      D2=2
      L=-1
      GO TO 005
  400 DO 410 A=1,8
  410 SORTIE (A)=PHASE(A)
      DO 411 A=1,9
  411 MAT(A)=PHASET(A)
      MAX=8
      MIN=1
      D1=5
      D2=6
      L=+1
      GO TO 005
  200 DO 210 A=1,8
      DO 210 B=1,25
      DO 210 C=1,14
  210 READ (2) AMP(A,B,C),FAC(A,B,C),BBD(A,B,C)
      DO 205 A=1,8
      DB=DSURBI(A)
      INCR=.52
      DO 205 B=1,14
      DDB(A,B)=DB
      MINCR=1.+INCR
      DB=DB*MINCR
      INCR=INCR*.924
  205 CONTINUE
      RETURN
      END
```

SYMBOLIC REFERENCE MAP (R=1)

ENTRY POINTS
3 CHERCHE

VARIABLES		SN	TYPE		RELOCATION					
334	A		INTEGER			560	AMP	REAL	ARRAY	
343	AMPLI		REAL			335	B	INTEGER		
5363	BRD		REAL	ARRAY	/ /	336	C	INTEGER		
344	DB		REAL			400	DDB	REAL	ARRAY	
347	DDM		REAL	ARRAY		0	DIAGS	INTEGER		F.P.
1	DSORB		REAL		/ /	6232	DSURBI	REAL	ARRAY	
0	DSURBI		REAL		/ /	2	DSURB2	REAL		/ /
276	D1		REAL			277	D2	REAL		
3	FAC		REAL	ARRAY	/ /	345	INCR	REAL		
0	K		INTEGER		F.P.	300	L	INTEGER		
6140	MAT		REAL	ARRAY		337	MAX	REAL		
340	MIN		REAL			346	MINCR	REAL		
333	P		INTEGER			6222	PHASE	REAL	ARRAY	
6242	PHASET		REAL	ARRAY		6171	SORTIE	REAL	ARRAY	
0	S1		REAL		F.P.	0	S2	REAL		F.P.
0	S3		REAL		F.P.	0	S4	REAL		F.P.
341	TEST1		REAL			342	TEST2	REAL		
0	VAR		REAL		F.P.	12743	W	INTEGER		/ /
0	X		INTEGER		F.P.	0	Y	INTEGER		F.P.
332	Z		INTEGER							

FILE NAMES	MODE
TAPE2	UNFMT

EXTERNALS	TYPE	ARGS
INTERPO		6

STATEMENT LABELS

301	1	FMT NO REFS	25	5		33	6		
36	7		41	8		70	10		
54	20		52	30		72	40		
57	60		100	80		0	90		
124	100		0	110		220	200		
0	205		0	210		306	220	FMT	
311	240	FMT NO REFS	152	300		0	310		
174	400		0	410		0	411		
74	500		0	510	INACTIVE				

LOOPS	LABEL		INDEX	FROM-TO	LENGTH	PROPERTIES		
107	90		A	48 50	48	INSTACK		
125	110	*	A	57 62	168		EXT REFS	
160	310		A	69 71	48	INSTACK		
177	410		A	78 79	38	INSTACK		
205	411		A	80 81	38	INSTACK		
221	210	*	A	88 91	238		EXT REFS	NOT INNER
222	210	*	B	89 91	178		EXT REFS	NOT INNER
223	210	*	C	90 91	148		EXT REFS	
245	205	*	A	92 100	218		NOT INNER	
254	205		B	95 100	68	INSTACK		

COMMON BLOCKS	LENGTH
/ /	5604

STATISTICS

PROGRAM LENGTH	62758	3261
CM BLANK COMMON LENGTH	127400	5604

```
      SUBROUTINE INEMAUT (LIGNE,FID,AMP5,PHI5,AMP20,PHI20,AMP80,PHI80,
     1DIAG1,DIAG2,DIAG3,DIAG4,DIAG5,T,SIGMA,TSIGMA,DH,FREK,PHARES)
      IMPLICIT REAL (A-Z)
      INTEGER  DIAG1,DIAG2,DIAG3,DIAG4,DIAG5,I,III,J,M,Q,P,N,K,LIGNE,
     1FID,W,X,Y,JND,IND1,WIND(8),FLAG,JND,IMIN
      REAL FIEST(8)
      REAL FAC(8,25,14),BBD(8,25,14),PHASE(8),FACTCM(8),FACTTH(8)
      COMMON DSURB1,DSURB,DSURB2,FAC,BBD,W
      DATA      X/1/,Y/1/,I/1/,J/1/,K/1/,M/1/,PHASE/.3266,.4,.49,.6,.734
     195,.9,1.10227,1.35/,FACTCM/3.4,3.25,3.1,3.0,2.83,2.78,2.8,3.17/,FAC
     2TTH/1.86,1.82,1.80,1.76,1.72,1.68,1.69,1.78/
  010 FORMAT (2X,I3,F6.1,3(F6.1,F7.3))
  011 FORMAT (90X,I4,2X,I5  ,"INVERSION PHASE-FREQUENCE")
  012 FORMAT (1H1,3X,"LIGNE",4X,"FID",7X,"T",6X,"SIGMA",4X,"SIGMA-T",
     13X,"DELTA-H",4X,"DIAGNOSTIQUES",4X,"PHASE")
  013 FORMAT (90X,I4,2X,I5,"FACT=",E10.3)
  014 FORMAT (90X,I4,2X,I5  ,"N=",I2,"I=",I2,"J=",I2)
  015 FORMAT (90X,I4,2X,I5  ,"PHI20=",F7.3,"PHI80=",F7.3)
  016 FORMAT (4X,"APPEL A CHERCHE DEPUIS 260 M=100 2")
  017 FORMAT (4X, "APPEL A CHERCHE DEPUIS 260 M=0")
  018 FORMAT (90X,I3,1X,I4,"INVERSION PHASE-FREQ. A 500 HERTZ ")
  019 FORMAT (6X,F4.2)
  020 FORMAT (1H1,5X,19HPHASE D"OPERATION =,F4.2)
  410 FORMAT (4X,I4,2X,I6,4X,F5.1,4X,F7.2,2(4X,F5.1),5(2X,I2),4X,F4.2)
 1223 FORMAT (90X,I4,2X,I5,2X,E10.3)
      FLAG=0
      IND1=0
      IND=1
      IF(K .EQ. 1) GO TO 1104
  411 IF (X .GT. 7) X=7
      IF (X .LT. 1) X=1
      CALL CHERCHE (X,Y,4,PHI20,PHARES,PHIP,PHIT1,PHIT2,DIAG5)
      W=X
      IF (DIAG5 .EQ. 0) GO TO 412
      IF (DIAG5 .EQ. 5 ) W=8
      IF (DIAG5 .EQ. 6) W=1
      PHARES=PHASE(W)
  412 IF (PHI20 .GT. PHI5 .AND. PHI80 .LT. PHI20) GO TO 1108
      GO TO 1105
 1108 DIAG1=2
      PRINT 018,LIGNE,FID
      DIAG3=0
      GO TO 102
 1104 CALL CHERCHE (1,2,0,VAR,S1,S2,S3,S4,DIAG5)
      PRINT 012
      X=2
      GO TO 411
 1105 IF (PHI20 .GT. PHI5 .OR. PHI80 .GT. PHI20) GO TO 101
      DIAG1=0
      GO TO 102
  101 PRINT 011,LIGNE,FID
      DIAG1=1
      DIAG2=0
      DIAG3=0
      DIAG4=0
      DIAG5=0
      GO TO 400
```

```
  102 DIAG2=0
      IF(AMP5 .LT. 200.) DIAG2=1
      IF (AMP20 .LT. 200.) DIAG2=2
      IF (AMP80 .LT. 200.) DIAG2=3
      IF (DIAG2 .GT. 1) GO TO 403
      IF (DIAG1 .EQ. 2) GO TO 1106
      IF( PHARES-PHI5) 120,120,110
  110 DIAG3=1
      GO TO 200
  120 DIAG3=0
      IF (PHARES .LT.PHI5 .AND. PHARES .GT.PHI20) GO TO 200
 1106 IF (PHARES .LE. PHI20 .AND. PHARES .GE. PHI80) GO TO 250
      IF (PHARES-PHI80) 130,250,250
  130 DIAG3=2
      GO TO 250
  200 CALL INTERPO (PHI20,PHARES,PHI5,500.,FRES,2000.)
      IF (AMP5 .LT. 1.) AMP5=1.
      CALL INTERPO (PHI20,PHARES,PHI5,AMP5,AMPES,AMP20)
      GO TO 210
  250 CALL INTERPO (PHI80,PHARES,PHI20,AMP20,AMPES,AMP80)
      CALL INTERPO (PHI80,PHARES,PHI20,2000.,FRES,8000.)
  210 IF (PHI20 .LT. .01 .OR. PHI80 .LT. .01) PRINT 015,LIGNE,FIO,PHI20,
     1PHI80
      FAC10=TAN(PHI5)/TAN(PHI20)
      FAC40=TAN(PHI20)/TAN(PHI80)
      IF (FAC10 .LT. 0. .OR. FAC40 .LT. 0.) DIAG1=3
      IF (DIAG1 .EQ. 3) GO TO 403
      IF (DIAG1 .EQ. 2) FACT=FAC40
      IF (DIAG1 .EQ. 2 )GO TO 212
      CALL INTERPO (1000.,FRES,4000.,FAC40,FACT,FAC10)
  212 X=0
      IF (FLAG .EQ. 1 ) GO TO 1211
      A=ALOG(FRES)-7.6009025
      FTEST(IND)=ABS(A)
      IF ( FTEST(IND) .LE. .2231436 ) GO TO 1211
      IF (IND1 .EQ. 3 .OR. IND .EQ. 8) GO TO 1220
      JND=IND-1
      IF (JND .EQ. 0 ) GO TO 1200
      IF (FTEST(IND) .LE. FTEST(JND)) GO TO 1202
      IF (FTEST(IND) .GT. FTEST(JND)) GO TO 1203
 1202 IF (IND1 .EQ. 0) GO TO 1200
      IF (IND1 .EQ. 2 ) GO TO 1201
 1203 IF (IND1 .EQ. 0) GO TO 1201
 1200 IF (IND1 .EQ. 2 ) IND1=3
      IF (W .EQ. 8 .AND. JND .LT. 2) GO TO 1201
      IF (W .EQ. 8 .AND. JND .GE. 2 ) GO TO 1220
      IND=IND+1
      W=W+1
      WIND(IND)=W
      PHARES=PHASE(W)
      GO TO 412
 1201 IND1=2
      IF (W .EQ. 1) GO TO 1220
      IND=IND+1
      W=W-1
      WIND(IND)=W
      PHARES=PHASE(W)
```

```
      GO TO 412
 1220 MIN=FTEST(IND)
      IMIN=IND
      JND=IND-1
 1222 IF (JND .EQ. 0) GO TO 1221
      IF (FTEST(JND) .LT. MIN) GO TO 1224
      GO TO 1225
 1224 MIN=FTEST(JND)
      IMIN=JND
 1225 JND=JND-1
      GO TO 1222
 1221 W=WIND(IMIN)
      PHAPES=PHASE(W)
      FLAG=1
      GO TO 412
 1211 T11=1
      IF (FACT -FACTTH(W))   220,225,230
  220 DIAG4=1
      J=14
      M=1
      LFAC=FACTTH(W)*.9
      IF(FACT .LT. LFAC) PRINT 013,LIGNE,FID,FACT
      IF (FACT .LT. LFAC) DIAG4=-1
      GO TO 260
  225 DIAG4=2
      J=14
      M=1
      GO TO 260
  230 FACTCI=FACTTH(W)*1.05
      IF (FACT-FACTCI) 235,240,240
  235 DIAG4=3
      J=14
      M=1
      GO TO 260
  240 FACTCI=FACTCM(W)*.95
      IF (FACT-FACTCI) 245,245,270
  270 IF (FACT-FACTCM(W)) 275,276,280
  275 DIAG4=4
      J=1
      M=2
      GO TO 260
  276 DIAG4=5
      J=1
      M=2
      GO TO 260
  280 DIAG4=6
      GFAC=FACTCM(W)*1.1
      IF(FACT .GT. GFAC) PRINT 013,LIGNE,FID,FACT
      IF (FACT .GT. GFAC) DIAG4=-2
      J=1
      M=2
      GO TO 260
  245 DIAG4=0
      IF (J .LT. 1) J=1
      IF (J .EQ. 14) J=13
      CALL CHERCHE (J,I,1,FACT,DSURB1,DSURB2,FAC1,FAC2,DIAG5)
      IF(DIAG5 .NE. 0 ) GO TO 400
```

```
      CALL INTERPO (FAC1,FACT[illegible]AC2, DSURB2,DSURB,DSURB1)
      P=3
  260 IF (M .EQ. 1 .OR. M .EQ. 2 ) GO TO 1100
      IF (I .LT. 1) I=1
      IF (I .GT. 24) I=24
      CALL CHERCHE (I,J,2,AMPES,DDH1,DDH2,AMP1,AMP2,DIAG5)
      GO TO 1101
 1100 CONTINUE
      IF (I .LT. 1) I=1
      IF (I .GT. 24) I=24
      CALL CHERCHE (I,J,3,AMPES,DDH1,DDH2,AMP1,AMP2,DIAG5)
 1101 IF (DIAG5 .NE. 0 ) GO TO 400
      M=M+1
      IF (M .GT. 2) GO TO 1102
      IF (I .NE. III ) GO TO 1211
 1103 TEST=DDH2-(.01)
      TEST=ABS(TEST)
      IF (TEST .LT. .0000001) DDH2= -.01
      CALL INTERPO (AMP1,AMPES,AMP2,DDH2,DH,DDH1)
      Q=I+1
      P=J+1
      IF(Q .EQ. 1 .OR. M.EQ. 2 ) GO TO 262
      GO TO 263
  262 BD1=BBD(W,I,J)
      BD2=BBD(W,Q,J)
      GO TO 261
  263 CALL INTERPO (DSURB1,DSURB,DSURB2,BBD(W,I,P),BD1,BBD(W,I,J))
      CALL INTERPO (DSURB1,DSURB,DSURB2,BBD(W,Q,P),BD2,BBD(W,Q,J))
  261 CALL INTERPO (AMP1,AMPES,AMP2,BD2,BD,BD1)
      IF (M .EQ. 1) GO TO 300
      IF (M .EQ. 2) GO TO 310
      IF (M .EQ. 3) GO TO 320
  300 SIGMA =BD*BD*801.266065/FRES
      T=44.5
      TSIGMA=SIGMA*44.5
      GO TO 420
  310 TSIGMA=BD*7123.255318/FRES
      T=0
      SIGMA=90.
      GO TO 420
  320 TSIGMA=BD*7123.255318/FRES
      T=DSURB*8.80
      SIGMA=TSIGMA/T
  420 DH=DH/3.28
      SIGMA =ALOG(SIGMA)
      SIGMA=SIGMA/2.302585093
  400 IF(DIAG1 .EQ. 1 .OR. DIAG5 .NE. 0) GO TO 401
  402 PRINT 410,LIGNE,FID,T,SIGMA,TSIGMA,DH,DIAG1,DIAG2,DIAG3,DIAG4,DIAG
     15,PHASES
      FREK=FRES
      IF (TSIGMA .LT. .1 ) TSIGMA=.1
      TSIGMA=ALOG(TSIGMA)
      TSIGMA=TSIGMA/2.302585093
      RETURN
  401 T=0
      SIGMA=0
      TSIGMA=0
```

```
                    DH=0
 230                GO TO 402
            403     DIAG3=0
                    DIAG4=0
                    DIAG5=0
                    GO TO 401
 235       1102     PRINT 314,LIGNE,FID,M,I,J
                    GO TO 1103
                    END
```

SYMBOLIC REFERENCE MAP (R=1)

ENTRY POINTS
3 INEMAUT

VARIABLES	SN	TYPE	RELOCATION						
1311	A	REAL			1305	AMPES	REAL		
1322	AMP1	REAL			1323	AMP2	REAL		
0	AMP20	REAL		F.P.	0	AMP5	REAL		F.P.
0	AMP80	REAL		F.P.	5363	BBD	REAL	ARRAY	/ /
1327	BD	REAL			1325	BD1	REAL		
1326	BD2	REAL			1320	DDH1	REAL		
1321	DDH2	REAL			0	DH	REAL		F.P.
0	DIAG1	INTEGER		F.P.	0	DIAG2	INTEGER		F.P.
0	DIAG3	INTEGER		F.P.	0	DIAG4	INTEGER		F.P.
0	DIAG5	INTEGER		F.P.	1	DSURB	REAL		/ /
0	DSURB1	REAL		/ /	2	DSURB2	REAL		/ /
3	FAC	REAL	ARRAY	/ /	1310	FACT	REAL		
1314	FACTCI	REAL			1360	FACTCM	REAL	ARRAY	
1370	FACTTH	REAL	ARRAY		1316	FAC1	REAL		
1306	FAC10	REAL			1317	FAC2	REAL		
1307	FAC40	REAL			0	FID	INTEGER		F.P.
1271	FLAG	INTEGER			0	FREK	REAL		F.P.
1307	FRE5	REAL			1340	FTEST	REAL	ARRAY	
1315	GFAC	REAL			1025	I	INTEGER		
1263	III	INTEGER			1273	IMIN	INTEGER		
1267	IND	INTEGER			1270	IND1	INTEGER		
1026	J	INTEGER			1272	JND	INTEGER		
1027	K	INTEGER			1313	LFAC	REAL		
0	LIGNE	INTEGER		F.P.	1030	M	INTEGER		
1312	MIN	REAL			1266	N	INTEGER		
1265	P	INTEGER			0	PHARES	REAL		F.P.
1350	PHASE	REAL	ARRAY		1274	PHIP	REAL		
1275	PHIT1	REAL			1276	PHIT2	REAL		
0	PHI20	REAL		F.P.	0	PHI5	REAL		F.P.
0	PHI80	REAL		F.P.	1264	Q	INTEGER		
0	SIGMA	REAL		F.P.	1300	S1	REAL		
1301	S2	REAL			1302	S3	REAL		
1303	S4	REAL			0	T	REAL		F.P.
1324	TEST	REAL			0	TSIGMA	REAL		F.P.
1277	VAR	REAL			12743	W	INTEGER		/ /
1330	WITD	INTEGER	ARRAY		1023	X	INTEGER		
1024	Y	INTEGER							

FILE NAMES MODE
OUTPUT FMT

EXTERNALS TYPE ARGS
ALOG REAL 1 LIBRARY
INTERPO 6
CHERCHE 9
TAN REAL 1 LIBRARY

INLINE FUNCTIONS TYPE ARGS
ABS REAL 1 INTRIN

STATEMENT LABELS

1031	10	FMT	NO REFS	1035	11	FMT		1043	12	FMT
1056	13	FMT		1062	14	FMT		1067	15	FMT
1075	16	FMT	NO REFS	1103	17	FMT	NO REFS	1110	18	FMT
1117	19	FMT	NO REFS	1121	20	FMT	NO REFS	64	101	
73	102			0	110		INACTIVE	121	120	
0	130		INACTIVE	135	200			177	210	
234	212			0	220		INACTIVE	352	225	
356	230			0	235		INACTIVE	366	240	
422	245			160	250			440	260	
542	261			512	262			522	263	
0	270		INACTIVE	0	275		INACTIVE	400	276	
404	280			551	300			557	310	
565	320			600	400			620	401	
605	402			624	403			1126	410	FMT
11	411			35	412			573	420	
454	1100			465	1101			627	1102	
472	1103			47	1104			56	1105	
126	1106			42	1108			262	1200	
277	1201			256	1202			261	1203	
332	1211			307	1220			324	1221	
313	1222			1134	1223	FMT	NO REFS	317	1224	
322	1225									

COMMON BLOCKS LENGTH
/ / 5604

STATISTICS

PROGRAM LENGTH	14008	768
CM BLANK COMMON LENGTH	12744B	5604

```
      SUBROUTINE SOGRAFC (LIGNE,FID,COORDY,T,SIGMA,TSIGMA,DH,FREQ,DIAG1
     1DIAG2,DIAG3,DIAG4,DIAG5,M)
      INTEGER FID(500),COORDY(500),DIAG1(500),DIAG2(500),DIAG3(500),DIAG
     14(500),DIAG5(500),N,M,TI(500),IJ(500)
      REAL XX(500),T(500),SIGMA(500),TSIGMA(500),DH(500),FREQ(500)
      J=0
      CALL SYMBOL (1.5,9.5,.25,10HHAWKESBURY,0.,10)
      CALL SYMBOL (4.,9.5,.25,4HLINE,0.,4)
      CALL NUMBER (5.2,9.5,.25,LIGNE,0.,2HI3)
      CALL SYMBOL (.2,9.35,.1,4HFIDS,0.,4)
      CALL SYMBOL (.2,9.05,.1,2HKM,0.,2)
      CALL SYMBOL (1.5,8.55,.15,11HCONDUCTANCE,0.,11)
      CALL SYMBOL (.05,7.5,.1,1HS,90.,1)
      CALL SYMBOL (1.5,6.05,.15,21HAPPARENT CONDUCTIVITY,0.,21)
      CALL SYMBOL (.05,5.,.1,3HS/M,90.,6)
      CALL SYMBOL (1.5,3.55,.15,5HDEPTH,0.,5)
      CALL SYMBOL (.05,2.35,.1,6HMETERS,90.,6)
      CALL SYMBOL (1.5,1.55,.15,9HFREQUENCY,0.,9)
      CALL SYMBOL (.05,.9,.1,3HKHZ,90.,3)
      CALL SYMBOL (.25,8.5,.1,2H.1,0.,2)
      CALL SYMBOL (.25,8.0,.1,2H1.,0.,2)
      CALL SYMBOL (.15,7.5,.1,3H10.,0.,3)
      CALL SYMBOL (.05,7.0,.1,4H100.,0.,4)
      CALL SYMBOL (.05,6.,.1,4H.001,0.,4)
      CALL SYMBOL (.15,5.5,.1,3H.01,0.,3)
      CALL SYMBOL (.25,5.,.1,2H.1,0.,2)
      CALL SYMBOL (.25,4.5,.1,2H1.,0.,2)
      CALL SYMBOL (.15,4.,.1,3H10.,0.,3)
      CALL SYMBOL (.25,3.5,.1,1H0,0.,1)
      CALL SYMBOL (.25,3.,.1,2H10,0.,2)
      CALL SYMBOL (.25,2.5,.1,2H20,0.,2)
      CALL SYMBOL (.25,2.,.1,2H30,0.,2)
      CALL SYMBOL (.25,1.5,.1,2H32,0.,2)
      CALL SYMBOL (.35,1.,.1,1H2,0.,1)
      CALL SYMBOL (.05,.5,.1,4H.125,0.,4)
      CALL PLOT (.45,.5,3)
      CALL PLOT (.55,.5,2)
      CALL PLOT (.55,1.,3)
      CALL PLOT (.45,1.,2)
      CALL PLOT (.45,1.5,3)
      CALL PLOT (.55,1.5,2)
      CALL PLOT (.7,1.,3)
      CALL PLOT (7.25,1.,2)
      N=3
      X=.7
      DO 500 K=1,54
      CALL PLOT (X,.75,N)
      IF (N .EQ. 3) GO TO 499
      X=X+.2
      N=3
      GO TO 500
  499 N=2
      X=X+.05
  500 CONTINUE
      N=3
      X=.7
      DO 510 K=1,54
```

```
      CALL PLOT (X,1.25,N)
      IF (N.EQ. 3) GO TO 509
      X=X+.2
      N=3
      GO TO 510
  509 N=2
      X=X+.05
  510 CONTINUE
      CALL PLOT (.5,1.5,3)
      CALL PLOT (.5,.5,2)
      CALL PLOT (.45,2.,3)
      CALL PLOT (.55,2.,2)
      CALL PLOT (.45,2.5,3)
      CALL PLOT (.55,2.5,2)
      CALL PLOT (.45,3.,3)
      CALL PLOT (.55,3.,2)
      CALL PLOT (.45,3.5,3)
      CALL PLOT (.55,3.5,2)
      CALL PLOT (.5,3.5,3)
      CALL PLOT (.5,2.,2)
      CALL PLOT (.45,4.,3)
      CALL PLOT (.55,4.,2)
      CALL PLOT (.55,4.5,3)
      CALL PLOT (.45,4.5,2)
      CALL PLOT (.45,5.,3)
      CALL PLOT (.55,5.,2)
      CALL PLOT (.55,5.5,3)
      CALL PLOT (.45,5.5,2)
      CALL PLOT (.45,6.,3)
      CALL PLOT (.55,6.,2)
      CALL PLOT (.5,6.,3)
      CALL PLOT (.5,4.,2)
      CALL PLOT (.55,6.5,3)
      CALL PLOT (.45,6.5,2)
      CALL PLOT (.45,7.0,3)
      CALL PLOT (.55,7.0,2)
      CALL PLOT (.45,7.5,3)
      CALL PLOT (.55,7.5,2)
      CALL PLOT (.45,8.,3)
      CALL PLOT (.55,8.,2)
      CALL PLOT (.55,8.5,3)
      CALL PLOT (.45,8.5,2)
      CALL PLOT (.5,8.5,3)
      CALL PLOT (.5,6.5,2)
      DO 60 I=1,13
      X=.5+(I-1)*.57504
      CALL PLOT (X,9.2,3)
   60 CALL PLOT (X,9.25,2)
      CALL PLOT (.5,9.25,3)
      CALL PLOT (7.4,9.25,2)
      DO 65 I=1,13
      J=I-1
      X=.55+J*.57504
   65 CALL NUMBER (X,9.05,.1,J,0.,2HI2)
      L=0
      DO 75 K=1,M
      II(K)=0
```

```
      IF (DIAG1(K) .EQ. 1 .OR. DIAG1(K) .EQ. 3 .OR. DIAG2(K) .GT. 1 .OR.
     1DIAG5(K) .NE. 0 ) TI(K)=1
      IF (FREQ(K) .GT. 8000. .OR. FREQ(K) .LT. 500. ) TI(K)=1
      X=COORLY(K)
      X=((X-5040000.)/1739.)+.5
      XX(K)=X
      IESFID=FID(K)/20.
      ITESFID=FID(K)/20
      TESFID=IESFID-ITESFID
      IF (TESFID .LT. .01) GO TO 76
      L=0
      GO TO 75
   76 IF (L .EQ. 1) GO TO 75
      CALL PLOT (XX(K),9.25,3)
      CALL PLOT (XX(K),9.3,2)
      L=1
      Z=X-.2
      CALL NUMBER (Z,9.35,.1,FID(K),0.,2HI4)
   75 CONTINUE
      N=3
      DO 250 K=1,M
      TJ(K)=0
      IF (TI(K) .EQ. 1 .OR. DIAG4(K) .GT. 3 .OR. DIAG4(K) .EQ. -2 .OR.
     1DIAG4(K) .EQ. 0 ) TJ(K) =1
      IF(TJ(K) .EQ. 1 .AND. DIAG4(K) .NE. 0) GO TO 249
      IF (TT(K) .EQ. 1) GO TO 249
      Y=4.5-(SIGMA(K)/2.)
      CALL PLOT (XX(K),Y,N)
      N=2
      GO TO 250
  249 N=3
  250 CONTINUE
      N=3
      DO 280 K=1,M
      IF (TT(K) .EQ. 1 .OR. DIAG4(K) .EQ. 1 .OR. DIAG4(K) .EQ.2.OR. DIAG
     14(K) .EQ.3 .OR.DIAG4(K) .EQ. -1) GO TO 279
      Y=8.-(ISIGMA(K)/2.)
      IF (Y .LT. 6.25) Y=6.25
      CALL PLOT (XX(K),Y,N)
      N=2
      GO TO 280
  279 N=3
  280 CONTINUE
      N=3
      DO 100 K=1,M
      IF (TJ(K) .EQ. 1) GO TO 99
      IF (SIGMA(K) .LT. -1.) GO TO 99
      Y=3.5-(DH(K)/20.)
      IF (Y .GT. 3.75) Y=3.75
      CALL PLOT (XX(K),Y,N)
      N=2
      GO TO 100
   99 N=3
  100 CONTINUE
      N=3
      DO 110 K=1,M
      IF (TI(K) .EQ. 1) GO TO 109
```

```
                    Y=(ALOG(FREQ(K))/5.5452)-.371
                    IF (Y .GT. 1.75) Y=1.75
                    IF (Y .LT. .25) Y=.25
  175               CALL PLOT (XX(K),Y,N)
                    N=2
                    GO TO 110
                109 N=3
                110 CONTINUE
  180               CALL PLOT (10.,0.,-3)
                    RETURN
                    END
```

SYMBOLIC REFERENCE MAP (R=1)

ENTRY POINTS
3 SOGRAFC

VARIABLES	SN	TYPE		RELOCATION					
0	COORDY	INTEGER	ARRAY	F.P.	0	DM	REAL	ARRAY	F.P.
0	DIAG1	INTEGER	ARRAY	F.P.	0	DIAG2	INTEGER	ARRAY	F.P.
0	DIAG3	INTEGER	ARRAY	F.P.	0	DIAG4	INTEGER	ARRAY	F.P.
0	DIAG5	INTEGER	ARRAY	F.P.	0	FID	INTEGER	ARRAY	F.P.
0	FREQ	REAL	ARRAY	F.P.	1550	I	INTEGER		
1554	ITESFID	INTEGER			1551	J	INTEGER		
1547	K	INTEGER			1552	L	INTEGER		
0	LTGHE	INTEGER		F.P.	0	M	INTEGER		F.P.
1545	N	INTEGER			0	SIGMA	REAL	ARRAY	F.P.
0	T	REAL	ARRAY	F.P.	1553	TESFID	REAL		
1557	TI	INTEGER	ARRAY		2543	TJ	INTEGER	ARRAY	
0	ISIGMA	REAL	ARRAY	F.P.	1546	X	REAL		
3527	XX	REAL	ARRAY		1556	Y	REAL		
1555	Z	REAL							

EXTERNALS	TYPE	ARGS			
ALOG	REAL	1	LIBRARY	NUMBER	6
PLOT		3		SYMBOL	6

STATEMENT LABELS

0	60	0	65	406	75
370	76	520	99	521	100
547	109	550	110	442	249
443	250	473	279	474	280
144	499	147	500	164	509
167	510				

LOOPS	LABEL		INDEX	FROM-TO	LENGTH	PROPERTIES
135	500	*	K	46 54	158	EXT REFS
155	510	*	K	57 65	158	EXT REFS
302	60	*	I	102 105	138	EXT REFS
321	65	*	I	108 111	118	EXT REFS
338	75	*	K	113 133	558	EXT REFS
413	250	*	K	135 146	338	EXT REFS
450	280	*	K	148 157	278	EXT REFS

21	1984	44.5	-.63	10.3	[illegible]	0	0	0	0	-1	0	.49
21	1985	44.5	-.63	10.5	[illegible].1	0	0	0	0	-1	0	.49
21	1985	44.5	-.61	10.8	10.1	0	0	0	0	-1	0	.49
21	1986	44.5	-.60	11.1	10.7	0	0	0	0	-1	0	.49
21	1986	44.5	-.60	11.2	10.9	0	0	0	0	-1	0	.49
21	1987	44.5	-.60	11.2	10.8	0	0	0	0	-1	0	.49
21	1987	44.5	-.61	11.0	10.4	0	0	0	0	-1	0	.49
21	1988	44.5	-.62	10.7	9.9	0	0	0	0	-1	0	.49
21	1988	44.5	-.63	10.3	9.2	0	0	0	0	-1	0	.49
21	1989	44.5	-.65	10.1	8.7	0	0	0	0	-1	0	.49
21	1989	44.5	-.66	9.8	8.1	0	0	0	0	-1	0	.49
21	1990	44.5	-.66	9.7	7.6	0	0	0	0	-1	0	.49
21	1990	44.5	-.66	9.7	7.2	0	0	0	0	-1	0	.49
21	1991	44.5	-.66	9.8	6.9	0	0	0	0	-1	0	.49
21	1991	44.5	-.65	9.9	6.8	0	0	0	0	-1	0	.49
21	1992	44.5	-.65	10.0	6.6	0	0	0	0	-1	0	.49
21	1992	44.5	-.64	10.1	6.5	0	0	0	0	-1	0	.49
21	1993	44.5	-.65	10.0	6.4	0	0	0	0	-1	0	.49
21	1993	44.5	-.65	9.9	6.3	0	0	0	0	-1	0	.49
21	1994	44.5	-.66	9.6	6.2	0	0	0	0	-1	0	.49
21	1994	44.5	-.68	9.3	6.1	0	0	0	0	-1	0	.49
21	1995	44.5	-.69	9.1	6.1	0	0	0	0	-1	0	.49
21	1995	44.5	-.70	8.8	6.1	0	0	0	0	-1	0	.49
21	1996	44.5	-.71	8.7	6.1	0	0	0	0	-1	0	.49
21	1996	44.5	-.71	8.7	6.2	0	0	0	0	-1	0	.49
21	1997	44.5	-.70	8.9	6.3	0	0	0	0	-1	0	.49
21	1997	44.5	-.69	9.2	6.3	0	0	0	0	-1	0	.49
21	1998	44.5	-.67	9.5	6.3	0	0	0	0	-1	0	.49
21	1998	44.5	-.66	9.8	6.3	0	0	0	0	-1	0	.49

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21	1999	44.5	-.65	9.9	5.7	0	0	0	-1	0	.49
21	2000	44.5	-.66	9.7	5.5	0	0	0	-1	0	.49
21	2000	44.5	-.67	9.4	5.0	0	0	0	-1	0	.49
21	2001	44.5	-.68	9.2	4.9	0	0	0	-1	0	.49
21	2001	44.5	-.69	9.2	5.0	0	0	0	-1	0	.49
21	2002	44.5	-.49	9.2	5.3	0	0	0	-1	0	.49
21	2002	44.5	-.68	9.3	5.8	0	0	0	-1	0	.49
21	2003	44.5	-.67	9.5	6.2	0	0	0	-1	0	.49
21	2003	44.5	-.66	9.8	6.6	0	0	0	-1	0	.49
21	2004	44.5	-.64	10.1	6.9	0	0	0	-1	0	.49
21	2004	44.5	-.63	10.4	6.9	0	0	0	-1	0	.49
21	2005	44.5	-.62	10.7	6.9	0	0	0	-1	0	.49
21	2005	44.5	-.61	10.8	6.7	0	0	0	-1	0	.49
21	2006	44.5	-.61	10.9	6.6	0	0	0	-1	0	.49
21	2006	44.5	-.61	11.0	6.6	0	0	0	-1	0	.49
21	2007	44.5	-.60	11.1	6.7	0	0	0	-1	0	.49
21	2007	44.5	-.60	11.2	6.8	0	0	0	-1	0	.49
21	2008	44.5	-.60	11.3	6.8	0	0	0	-1	0	.49
21	2008	44.5	-.60	11.3	6.8	0	0	0	-1	0	.49
21	2009	44.5	-.60	11.3	6.6	0	0	0	1	0	.49
21	2009	44.5	-.60	11.3	5.4	0	0	0	1	0	.49
21	2010	44.5	-.60	11.2	6.1	0	0	0	1	0	.49
21	2010	44.5	-.60	11.1	5.7	0	0	0	1	0	.49
21	2011	44.5	-.61	11.0	5.6	0	0	0	1	0	.49
21	2011	44.5	-.61	10.9	5.6	0	0	0	1	0	.49
21	2012	44.5	-.62	10.8	5.8	0	0	0	1	0	.49
21	2012	44.5	-.62	10.7	6.1	0	0	0	1	0	.49
21	2013	44.5	-.62	10.7	6.3	0	0	0	1	0	.49
21	2013	44.5	-.62	10.7	6.5	0	0	0	1	0	.49
21	2014	44.5	-.62	10.8	6.5	0	0	0	3	0	.49
21	2014	44.5	-.61	10.9	6.3	0	0	0	3	0	.49
21	2015	44.5	-.61	11.0	6.0	0	0	0	3	0	.49
21	2015	44.5	-.59	11.3	5.3	0	0	0	3	0	.40
21	2016	44.5	-.58	11.6	5.1	0	0	0	3	0	.40
21	2016	44.5	-.57	11.9	4.9	0	0	0	1	0	.40
21	2017	44.5	-.56	12.2	4.9	0	0	0	1	0	.40
21	2017	44.5	-.56	12.4	4.9	0	0	0	1	0	.40
21	2018	44.5	-.55	12.5	5.1	0	0	0	1	0	.40
21	2018	44.5	-.55	12.6	5.2	0	0	0	1	0	.40
21	2019	44.5	-.55	12.7	5.3	0	0	0	1	0	.40
21	2019	44.5	-.54	12.7	5.3	0	0	0	1	0	.40
21	2020	44.5	-.54	12.7	5.2	0	0	0	1	0	.40
21	2020	44.5	-.54	12.8	5.1	0	0	0	1	0	.40
21	2021	44.5	-.54	13.0	5.0	0	0	0	1	0	.40
21	2021	44.5	-.53	13.1	4.8	0	0	0	1	0	.40
21	2022	44.5	-.53	13.2	4.6	0	0	0	1	0	.40

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21	2023	44.5	-.51	13.9	3.[illegible]	0	0	0	1	0	.40	
21	2024	44.5	-.51	13.8	[illegible]	0	0	0	1	0	.40	
21	2025	44.5	-.50	14.0	[illegible]	0	0	0	1	0	.40	
21	2025	44.5	-.50	14.1	4.0	0	0	0	1	0	.40	
21	2026	44.5	-.50	14.2	4.3	0	0	0	1	0	.40	
21	2026	44.5	-.49	14.3	4.7	0	0	0	1	0	.40	
21	2027	44.5	-.49	14.5	5.0	0	0	0	1	0	.40	
21	2027	44.5	-.48	14.7	5.2	0	0	0	1	0	.40	
21	2028	44.5	-.48	14.9	5.3	0	0	0	1	0	.40	
21	2028	44.5	-.47	15.1	5.2	0	0	0	1	0	.40	
21	2029	44.5	-.46	15.4	5.0	0	0	0	1	0	.40	
21	2029	44.5	-.45	15.7	4.7	0	0	0	1	0	.40	
21	2030	44.5	-.45	16.0	4.4	0	0	0	1	0	.40	
21	2030	44.5	-.44	16.1	4.1	0	0	0	1	0	.40	
21	2031	44.5	-.44	16.3	4.0	0	0	0	1	0	.40	
21	2031	44.5	-.43	16.4	4.1	0	0	0	1	0	.40	
21	2032	44.5	-.43	16.4	4.3	0	0	0	1	0	.40	
21	2032	44.5	-.43	16.5	4.6	0	0	0	3	0	.40	
21	2033	44.5	-.43	16.7	4.7	0	0	0	3	0	.40	
21	2033	44.5	-.42	16.9	4.7	0	0	0	3	0	.40	
21	2034	44.5	-.41	17.1	4.5	0	0	0	3	0	.40	
21	2034	44.5	-.41	17.4	4.0	0	0	0	3	0	.40	
21	2035	44.5	-.40	17.8	3.5	0	0	0	3	0	.40	
21	2035	44.5	-.39	17.9	3.1	0	0	0	3	0	.40	
21	2036	44.5	-.39	18.0	2.8	0	0	0	3	0	.40	
21	2036	44.5	-.40	17.9	2.7	0	0	0	3	0	.40	
21	2037	44.5	-.40	17.6	3.0	0	0	0	3	0	.40	
21	2037	44.5	-.41	17.2	3.5	0	0	0	3	0	.40	
21	2038	44.5	-.42	16.8	4.1	0	0	0	3	0	.40	
21	2038	44.5	-.43	16.4	4.8	0	0	0	1	0	.40	
21	2039	44.5	-.44	16.1	5.4	0	0	0	1	0	.40	
21	2039	44.5	-.45	15.8	5.9	0	0	0	1	0	.40	
21	2040	44.5	-.46	15.6	6.1	0	0	0	3	0	.40	
21	2040	44.5	-.47	15.2	6.1	0	0	0	3	0	.40	
21	2041	44.5	-.48	14.9	5.9	0	0	0	3	0	.40	
21	2041	44.5	-.50	14.2	5.5	0	0	0	3	0	.40	
21	2042	44.5	-.53	13.2	5.0	0	0	0	3	0	.40	
21	2042	44.5	-.56	12.3	4.6	0	0	0	3	0	.40	
21	2043	41.9	-.61	10.2	4.3	0	0	0	0	0	.49	
21	2043	41.2	-.64	9.5	4.0	0	0	0	0	0	.49	
21	2044	40.4	-.66	8.8	3.8	0	0	0	0	0	.49	
21	2044	40.2	-.69	8.3	3.8	0	0	0	0	0	.49	
21	2045	40.8	-.72	7.8	3.8	0	0	0	0	0	.49	
21	2045	42.8	-.76	7.4	4.0	0	0	0	0	0	.49	
21	2046	44.5	-.80	7.1	4.6	0	0	0	3	0	.49	
21	2046	57.0	-.86	7.8	5.6	0	0	0	0	0	.60	
21	2047	44.5	-.90	5.6	7.2	0	0	0	3	0	.60	
21	2047	44.5	-.96	4.9	9.7	0	0	0	1	0	.60	
21	2048	44.5	-1.04	4.1	12.9	0	0	0	-1	0	.60	
21	2048	44.5	-1.15	3.2	17.0	0	0	0	-1	0	.60	
21	2049	44.5	-1.26	2.4	22.3	0	0	0	-1	0	.60	
21	2049	44.5	-1.36	1.9	28.6	0	0	0	-1	0	.60	
21	2050	0.0	0.00	0.0	0.0	0	0	0	-1	1	.60	
21	2050	0.0	0.00	0.0	0.0	0	0	0	-1	1	.60	

21 2048FACT
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21 2051FACT

21	2052	0.0	0.00	0.0	0.0	0	1	0	1	1	.60	
21	2052	0.0	0.00	0.0	0.0	0	1	0	0	1	.60	
21	2053	0.0	0.00	0.0	0.0	0	2	0	0	0	.73	
21	2053	0.0	0.00	0.0	0.0	0	2	0	0	0	.73	
21	2054	0.0	0.00	0.0	0.0	0	2	0	0	0	.73	
21	2054	0.0	0.00	0.0	0.0	0	2	0	0	0	.73	
21	2055	0.0	0.00	0.0	0.0	0	2	0	0	0	.73	
21	2055	0.0	0.00	0.0	0.0	0	2	0	0	0	.73	
21	2056	0.0	0.00	0.0	0.0	0	2	0	0	0	.73	21 2056INVERS
21	2056	0.0	0.00	0.0	0.0	2	2	0	0	0	.73	21 2057INVERS
21	2057	0.0	0.00	0.0	0.0	2	2	0	0	0	.73	21 2057INVERS
21	2057	0.0	0.00	0.0	0.0	2	2	0	0	0	.73	21 2058INVERS
21	2058	0.0	0.00	0.0	0.0	2	2	0	0	0	.90	21 2058INVERS
21	2058	0.0	0.00	0.0	0.0	2	2	0	0	0	.90	21 2059INVERS
21	2059	0.0	0.00	0.0	0.0	2	2	0	0	0	.90	21 2059INVERS
21	2059	0.0	0.00	0.0	0.0	2	2	0	0	0	.90	21 2060INVERS
21	2060	0.0	0.00	0.0	0.0	2	2	0	0	0	.90	21 2060INVERS
21	2060	0.0	0.00	0.0	0.0	2	2	0	0	0	.90	21 2061INVERS
												21 2061INVERS
												21 2061INVERS
												21 2061INVERS
												21 2061INVERS
												21 2061INVERS
21	2061	44.5	-2.17	.3	28.6	2	1	0	1	0	1.10	21 2061INVERS
												21 2061INVERS
												21 2061INVERS
												21 2061INVERS
												21 2061INVERS
												21 2061INVERS
21	2061	44.5	-2.21	.3	16.4	2	1	0	1	0	1.10	21 2062INVERS
21	2062	0.0	0.00	0.0	0.0	2	1	0	0	4	1.10	21 2062INVERS
21	2062	176.2	-2.22	1.1	3.7	2	1	0	0	0	1.10	21 2063INVERS
												21 2063INVERS
												21 2063INVERS
												21 2063INVERS
												21 2063INVERS
												21 2063INVERS
21	2063	137.0	-2.18	.9	1.6	2	1	0	0	0	1.10	21 2063INVERS
												21 2063INVERS
												21 2063INVERS
												21 2063INVERS
												21 2063INVERS
												21 2063INVERS
21	2063	107.0	-2.13	.8	.0	2	1	0	0	0	1.10	21 2064INVERS
												21 2064INVERS
												21 2064INVERS
												21 2064INVERS
												21 2064INVERS

21	2064	72.3	-2.00	.7	.0	2	1	0	0	0	1.10
21	2065	61.5	-1.93	.7	.0	2	1	0	0	0	1.10
21	2065	44.5	-2.07	.4	-7.7	0	1	0	3	0	1.10
21	2066	145.7	-2.03	1.4	-8.0	0	1	0	0	0	1.10
21	2066	141.0	-1.99	1.4	-8.6	0	0	0	0	0	1.10
21	2067	140.2	-1.96	1.6	-9.6	0	0	0	0	0	1.10
21	2067	44.5	-1.93	.5	-10.9	0	0	0	3	0	1.10
21	2068	44.5	-1.89	.6	-11.7	0	0	0	3	0	1.10
21	2068	44.5	-1.83	.7	-10.5	0	0	0	1	0	1.10
21	2069	44.5	-1.76	.8	-8.8	0	0	0	1	0	1.10
21	2069	40.0	-1.46	1.4	-.4	0	0	0	0	0	.90
21	2070	42.7	-1.44	1.5	-1.6	0	0	0	0	0	.90
21	2070	43.5	-1.40	1.7	-1.8	0	0	0	0	0	.90
21	2071	42.6	-1.35	1.9	-1.9	0	0	0	0	0	.90
21	2071	42.9	-1.29	2.2	-1.7	0	0	0	0	0	.90
21	2072	46.1	-1.24	2.7	-1.1	0	0	0	0	0	.90
21	2072	18.9	-.90	2.4	3.2	0	0	0	0	0	.73
21	2073	21.9	-.89	2.8	2.0	0	0	0	0	0	.73
21	2073	26.0	-.89	3.4	1.7	0	0	0	0	0	.73
21	2074	15.6	-.66	3.4	3.5	0	0	0	0	0	.60
21	2074	19.4	-.68	4.0	2.5	0	0	0	0	0	.60
21	2075	22.8	-.69	4.7	2.0	0	0	0	0	0	.60
21	2075	25.6	-.68	5.3	1.8	0	0	0	0	0	.60
21	2076	20.3	-.58	5.3	1.8	0	0	0	0	0	.49
21	2076	21.9	-.57	5.9	.8	0	0	0	0	0	.49
21	2077	23.5	-.55	6.6	.1	0	0	0	0	0	.49
21	2077	24.6	-.54	7.1	.1	0	0	0	0	0	.49
21	2078	25.5	-.53	7.5	.1	0	0	0	0	0	.49
21	2078	26.1	-.52	7.8	.5	0	0	0	0	0	.49
21	2079	27.4	-.52	8.2	1.6	0	0	0	0	0	.49
21	2079	23.1	-.48	7.6	2.1	0	0	0	0	0	.40
21	2080	23.7	-.47	8.0	2.8	0	0	0	0	0	.40
21	2080	24.8	-.46	8.6	3.2	0	0	0	0	0	.40
21	2081	25.2	-.45	9.0	3.4	0	0	0	0	0	.40
21	2081	25.3	-.43	9.4	3.5	0	0	0	0	0	.40
21	2082	25.4	-.42	9.7	3.4	0	0	0	0	0	.40
21	2082	25.4	-.41	9.9	3.4	0	0	0	0	0	.40
21	2083	25.5	-.40	10.1	3.4	0	0	0	0	0	.40
21	2083	25.8	-.40	10.3	3.6	0	0	0	0	0	.40
21	2084	26.4	-.39	10.6	3.8	0	0	0	0	0	.40
21	2084	27.3	-.39	11.0	4.1	0	0	0	0	0	.40
21	2085	28.7	-.40	11.5	4.2	0	0	0	0	0	.40
21	2085	30.3	-.40	12.1	4.1	0	0	0	0	0	.40
21	2086	32.1	-.46	11.1	4.0	0	0	0	0	0	.40
21	2086	33.9	-.63	8.0	3.8	0	0	0	0	0	.40
21	2087	44.5	-.39	18.2	3.6	0	0	0	3	0	.40
21	2087	44.5	-.40	17.9	3.7	0	0	0	3	0	.40
21	2088	44.5	-.41	17.5	3.9	0	0	0	1	0	.40
21	2088	44.5	-.42	17.1	4.3	0	0	0	1	0	.40
21	2089	44.5	-.43	16.7	4.7	0	0	0	1	0	.40
21	2089	44.5	-.44	16.3	5.2	0	0	0	1	0	.40

21	2091	44.5	-.48	14.6	5.4	0	0	0	1	0	.40
21	2092	44.5	-.50	14.1	5.[illegible]	0	0	0	1	0	.40
21	2092	44.5	-.51	13.6	[illegible]	0	0	0	3	0	.40
21	2093	44.5	-.52	13.3	4.[illegible]	0	0	0	3	0	.40
21	2093	32.7	-.66	7.1	3.7	0	0	0	0	0	.40
21	2094	31.0	-.54	8.9	3.4	0	0	0	0	0	.40
21	2094	29.7	-.54	8.7	3.2	0	0	0	0	0	.40
21	2095	28.8	-.52	8.6	3.1	0	0	0	0	0	.40
21	2095	28.2	-.51	8.7	3.1	0	0	0	0	0	.40
21	2096	27.8	-.50	8.9	3.1	0	0	0	0	0	.40
21	2096	27.6	-.49	9.0	3.2	0	0	0	0	0	.40
21	2097	27.6	-.48	9.2	3.3	0	0	0	0	0	.40
21	2097	27.5	-.47	9.4	3.5	0	0	0	0	0	.40
21	2098	27.6	-.46	9.6	3.6	0	0	0	0	0	.40
21	2098	27.8	-.45	9.8	3.8	0	0	0	0	0	.40
21	2099	28.2	-.45	10.1	3.9	0	0	0	0	0	.40
21	2099	28.7	-.44	10.4	4.0	0	0	0	0	0	.40
21	2100	29.3	-.43	10.8	4.1	0	0	0	0	0	.40
21	2100	30.1	-.42	11.3	4.1	0	0	0	0	0	.40
21	2101	30.8	-.41	11.9	4.1	0	0	0	0	0	.40
21	2101	31.8	-.43	11.7	4.1	0	0	0	0	0	.40
21	2102	32.8	-.53	9.8	4.0	0	0	0	0	0	.40
21	2102	33.9	-.62	8.0	3.9	0	0	0	0	0	.40
21	2103	44.5	-.38	18.6	3.7	0	0	0	3	0	.40
21	2103	44.5	-.38	18.5	3.5	0	0	0	3	0	.40
21	2104	44.5	-.38	18.4	3.4	0	0	0	3	0	.40
21	2104	44.5	-.39	18.2	3.3	0	0	0	3	0	.40
21	2105	44.5	-.39	18.1	3.3	0	0	0	3	0	.40
21	2105	44.5	-.39	18.0	3.3	0	0	0	3	0	.40
21	2106	44.5	-.39	18.0	3.4	0	0	0	3	0	.40
21	2106	44.5	-.39	18.0	3.6	0	0	0	3	0	.40
21	2107	44.5	-.39	17.9	3.8	0	0	0	3	0	.40
21	2107	44.5	-.40	17.9	4.1	0	0	0	3	0	.40
21	2108	44.5	-.40	17.9	4.3	0	0	0	3	0	.40
21	2108	44.5	-.40	17.9	4.4	0	0	0	3	0	.40
21	2109	44.5	-.40	17.8	4.5	0	0	0	1	0	.40
21	2109	44.5	-.40	17.8	4.5	0	0	0	1	0	.40
21	2110	44.5	-.40	17.7	4.5	0	0	0	1	0	.40
21	2110	44.5	-.40	17.6	4.5	0	0	0	1	0	.40
21	2111	44.5	-.41	17.5	4.5	0	0	0	1	0	.40
21	2111	44.5	-.41	17.3	4.5	0	0	0	1	0	.40
21	2112	44.5	-.41	17.2	4.7	0	0	0	1	0	.40
21	2112	44.5	-.42	17.1	4.8	0	0	0	1	0	.40
21	2113	44.5	-.42	17.0	5.0	0	0	0	1	0	.40
21	2113	44.5	-.42	16.8	5.2	0	0	0	1	0	.40
21	2114	44.5	-.42	16.7	5.3	0	0	0	1	0	.40
21	2114	44.5	-.43	16.6	5.3	0	0	0	1	0	.40
21	2115	44.5	-.43	16.5	5.3	0	0	0	1	0	.40
21	2115	44.5	-.44	16.3	5.2	0	0	0	1	0	.40
21	2116	44.5	-.44	16.2	5.1	0	0	0	1	0	.40
21	2116	44.5	-.44	16.2	5.0	0	0	0	1	0	.40
21	2117	44.5	-.44	16.2	4.9	0	0	0	1	0	.40
21	2117	44.5	-.44	16.2	4.8	0	0	0	1	0	.40
21	2118	44.5	-.44	16.2	4.7	0	0	0	3	0	.40
21	2118	44.5	-.44	16.3	4.6	0	0	0	3	0	.40
21	2119	44.5	-.44	16.3	4.4	0	0	0	3	0	.40
21	2119	44.5	-.43	16.4	4.3	0	0	0	3	0	.40
21	2120	34.2	-.70	6.8	4.2	0	0	0	0	0	.40
21	2120	33.5	-.64	7.7	4.0	0	0	0	0	0	.40
21	2121	32.9	-.58	8.7	3.9	0	0	0	0	0	.40
21	2121	32.4	-.54	9.5	3.8	0	0	0	0	0	.40
21	2122	32.2	-.51	9.9	3.8	0	0	0	0	0	.40
21	2122	32.3	-.52	9.8	3.8	0	0	0	0	0	.40
21	2123	32.6	-.55	9.3	3.8	0	0	0	0	0	.40
21	2123	33.1	-.59	8.6	3.8	0	0	0	0	0	.40

21	2125	30.0	-.68	7.1	.5	0	0	0	0	0	0	2125
21	2125	33.6	-.65	7.6	5.0	0	0	0	0	0	.40	
21	2126	32.3	-.53	9.6	2.8	0	0	0	0	0	.40	
21	2126	31.5	-.44	11.3	2.6	0	0	0	0	0	.40	
21	2127	30.8	-.44	11.2	2.6	0	0	0	0	0	.40	
21	2127	30.4	-.44	11.1	2.7	0	0	0	0	0	.40	
21	2128	30.2	-.43	11.2	3.0	0	0	0	0	0	.40	
21	2128	31.1	-.43	11.6	3.2	0	0	0	0	0	.40	
21	2129	31.5	-.43	11.8	3.4	0	0	0	0	0	.40	
21	2129	32.0	-.47	10.7	3.6	0	0	0	0	0	.40	
21	2130	32.7	-.53	9.7	3.8	0	0	0	0	0	.40	
21	2130	33.1	-.57	8.9	3.9	0	0	0	0	0	.40	
21	2131	33.6	-.60	8.3	3.9	0	0	0	0	0	.40	
21	2131	33.9	-.63	7.9	3.8	0	0	0	0	0	.40	
21	2132	34.0	-.64	7.8	3.7	0	0	0	0	0	.40	
21	2132	34.3	-.66	7.4	3.6	0	0	0	0	0	.40	
21	2133	44.5	-.38	18.4	3.5	0	0	0	3	0	.40	
21	2133	44.5	-.38	18.5	3.5	0	0	0	3	0	.40	
21	2134	44.5	-.38	18.5	3.5	0	0	0	3	0	.40	
21	2134	44.5	-.38	18.7	3.6	0	0	0	3	0	.40	
21	2135	44.5	-.37	18.8	3.6	0	0	0	3	0	.40	
21	2135	44.5	-.37	19.0	3.7	0	0	0	1	0	.40	
21	2136	44.5	-.36	19.2	3.7	0	0	0	1	0	.40	
21	2136	44.5	-.36	19.4	3.7	0	0	0	1	0	.40	
21	2137	44.5	-.36	19.6	3.7	0	0	0	1	0	.40	
21	2137	44.5	-.35	19.8	3.6	0	0	0	1	0	.40	
21	2138	44.5	-.35	19.9	3.6	0	0	0	1	0	.40	
21	2138	44.5	-.35	20.0	3.6	0	0	0	1	0	.40	
21	2139	44.5	-.35	20.0	3.6	0	0	0	1	0	.40	
21	2139	44.5	-.35	20.0	3.6	0	0	0	1	0	.40	
21	2140	44.5	-.35	19.9	3.7	0	0	0	1	0	.40	
21	2140	44.5	-.35	19.8	3.8	0	0	0	1	0	.40	
21	2141	44.5	-.35	19.7	3.9	0	0	0	1	0	.40	
21	2141	44.5	-.36	19.6	4.1	0	0	0	1	0	.40	
21	2142	44.5	-.36	19.5	4.1	0	0	0	1	0	.40	
21	2142	44.5	-.36	19.3	4.2	0	0	0	1	0	.40	
21	2143	44.5	-.36	19.2	4.2	0	0	0	1	0	.40	
21	2143	44.5	-.37	19.1	4.1	0	0	0	1	0	.40	
21	2144	44.5	-.37	18.9	3.9	0	0	0	1	0	.40	
21	2144	44.5	-.38	18.6	3.7	0	0	0	3	0	.40	
21	2145	44.5	-.39	18.2	3.4	0	0	0	3	0	.40	
21	2145	34.0	-.65	7.5	3.1	0	0	0	0	0	.40	
21	2146	31.5	-.43	11.6	2.6	0	0	0	0	0	.40	
21	2146	29.8	-.44	10.9	2.1	0	0	0	0	0	.40	
21	2147	27.9	-.45	10.0	1.7	0	0	0	0	0	.40	
21	2147	25.3	-.45	9.0	1.3	0	0	0	0	0	.40	
21	2148	23.5	-.45	8.4	.4	0	0	0	0	0	.40	
21	2148	21.6	-.44	7.8	.1	0	0	0	0	0	.40	
21	2149	20.2	-.44	7.4	.1	0	0	0	0	0	.40	
21	2149	24.7	-.48	8.1	.0	0	0	0	0	0	.49	
21	2150	23.1	-.48	7.7	.0	0	0	0	0	0	.49	
21	2150	21.9	-.47	7.4	.0	0	0	0	0	0	.49	
21	2151	21.1	-.47	7.1	.0	0	0	0	0	0	.49	21 2151
21	2151	20.7	-.48	6.8	-.0	0	0	0	0	0	.49	
21	2152	19.9	-.48	6.6	-.0	0	0	0	0	0	.49	
21	2152	19.8	-.50	6.3	-.0	0	0	0	0	0	.49	
21	2153	19.8	-.51	6.1	-.0	0	0	0	0	0	.49	
21	2153	19.7	-.52	5.9	-.0	0	0	0	0	0	.49	21 2154
21	2154	19.5	-.53	5.8	.0	0	0	0	0	0	.49	
21	2154	19.8	-.54	5.7	.0	0	0	0	0	0	.49	
21	2155	19.6	-.55	5.6	.0	0	0	0	0	0	.49	
21	2155	19.5	-.56	5.5	.1	0	0	0	0	0	.49	

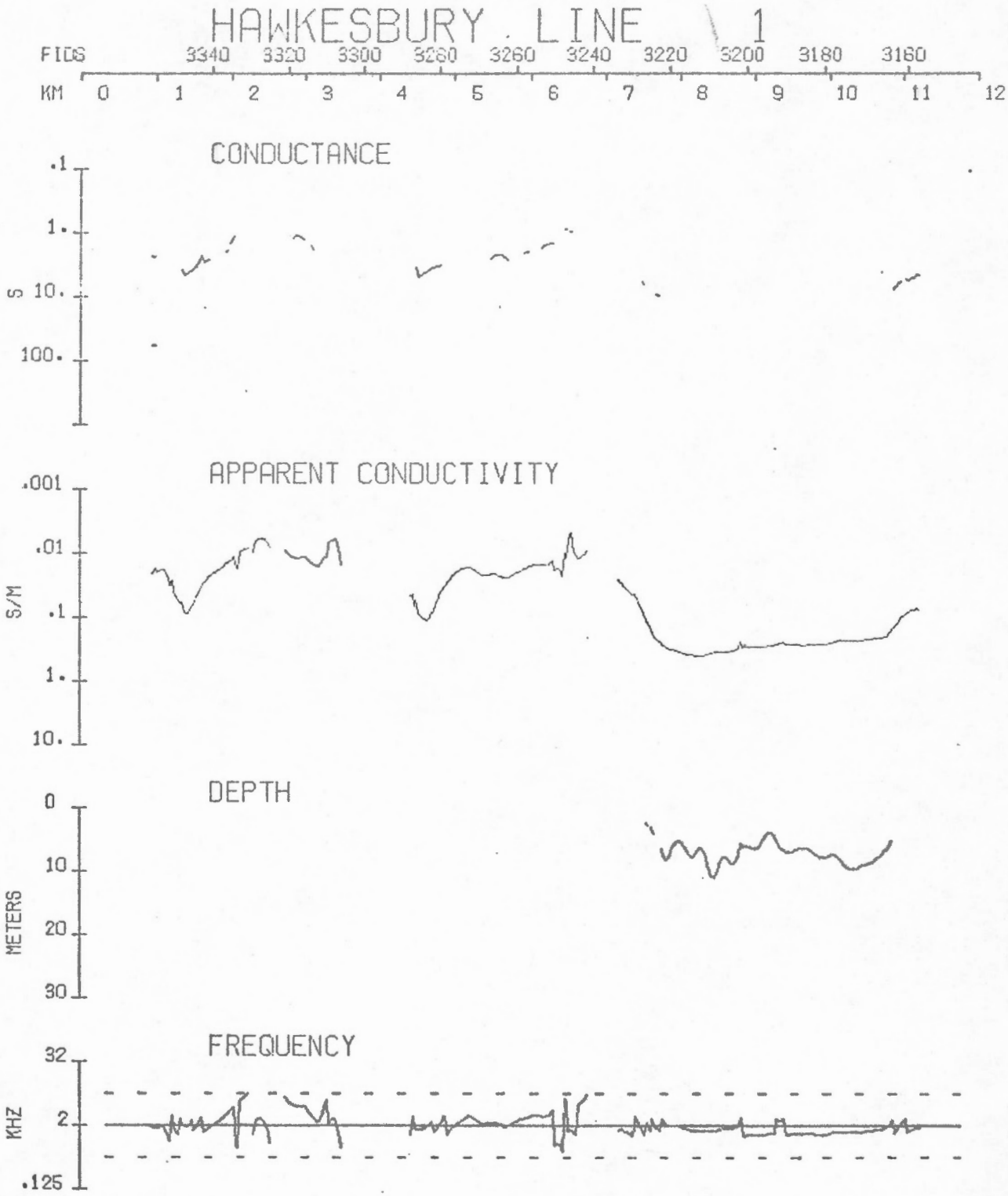
21	2158	21.8	-.60	5.5	1.0	0	0	0	0	0	.49	
21	158	22.9	-.61	5.7	[illegible]	0	0	0	0	0	.49	
21	2159	24.8	-.62	6.0	[illegible]	0	0	0	0	0	.49	
21	2159	26.1	-.61	6.4	1.8	0	0	0	0	0	.49	
21	2160	27.1	-.60	6.8	2.1	0	0	0	0	0	.49	
21	2160	27.9	-.59	7.2	2.8	0	0	0	0	0	.49	
21	2161	29.4	-.58	7.7	3.3	0	0	0	0	0	.49	
21	2161	30.1	-.57	8.1	3.8	0	0	0	0	0	.49	
21	2162	24.2	-.51	7.4	4.4	0	0	0	0	0	.40	
21	2162	25.9	-.50	8.2	4.6	0	0	0	0	0	.40	
21	2163	27.1	-.48	8.9	4.8	0	0	0	0	0	.40	
21	2163	28.5	-.47	9.6	4.9	0	0	0	0	0	.40	
21	2164	30.0	-.46	10.3	4.9	0	0	0	0	0	.40	
21	2164	31.6	-.47	10.6	4.8	0	0	0	0	0	.40	
21	2165	33.3	-.61	8.2	4.7	0	0	0	0	0	.40	
21	2165	34.7	-.73	6.5	4.6	0	0	0	0	0	.40	
21	2166	44.5	-.40	17.6	4.5	0	0	0	3	0	.40	
21	2166	44.5	-.39	17.9	4.5	0	0	0	3	0	.40	
21	2167	44.5	-.39	18.2	4.6	0	0	0	3	0	.40	
21	2167	44.5	-.38	18.4	4.7	0	0	0	3	0	.40	
21	2168	44.5	-.38	18.5	4.8	0	0	0	1	0	.40	
21	2168	44.5	-.38	18.7	4.9	0	0	0	1	0	.40	
21	2169	44.5	-.38	18.8	4.9	0	0	0	1	0	.40	
21	2169	44.5	-.37	18.9	4.9	0	0	0	1	0	.40	
21	2170	44.5	-.37	18.9	4.9	0	0	0	1	0	.40	
21	2170	44.5	-.37	19.1	5.0	0	0	0	1	0	.40	
21	2171	44.5	-.37	19.1	5.1	0	0	0	1	0	.40	
21	2171	44.5	-.37	19.2	5.2	0	0	0	1	0	.40	
21	2172	44.5	-.37	19.2	5.4	0	0	0	1	0	.40	
21	2172	44.5	-.37	19.1	5.7	0	0	0	1	0	.40	
21	2173	44.5	-.37	19.1	5.9	0	0	0	1	0	.40	
21	2173	44.5	-.37	19.1	5.9	0	0	0	1	0	.40	
21	2174	44.5	-.37	19.1	5.9	0	0	0	1	0	.40	
21	2174	44.5	-.37	19.1	5.8	0	0	0	1	0	.40	
21	2175	44.5	-.37	19.1	5.6	0	0	0	1	0	.40	
21	2175	44.5	-.37	19.1	5.6	0	0	0	1	0	.40	
21	2176	44.5	-.37	19.2	5.6	0	0	0	1	0	.40	
21	2176	44.5	-.37	19.1	5.7	0	0	0	1	0	.40	
21	2177	44.5	-.37	19.1	5.8	0	0	0	-1	0	.40	
21	2177	44.5	-.37	19.0	5.9	0	0	0	-1	0	.40	
21	2178	44.5	-.37	18.8	5.8	0	0	0	-1	0	.40	
21	2178	44.5	-.38	18.6	5.7	0	0	0	-1	0	.40	
21	2179	44.5	-.38	18.4	5.4	0	0	0	-1	0	.40	
21	2179	44.5	-.39	18.2	5.1	0	0	0	-1	0	.40	
21	2180	44.5	-.39	18.0	4.8	0	0	0	-1	0	.40	
21	2180	44.5	-.40	17.9	4.6	0	0	0	-1	0	.40	
21	2181	44.5	-.39	17.9	4.4	0	0	0	-1	0	.40	
21	2181	44.5	-.39	18.0	4.4	0	0	0	-1	0	.40	
21	2182	44.5	-.39	18.1	4.4	0	0	0	-1	0	.40	
21	2182	44.5	-.39	18.3	4.5	0	0	0	-1	0	.40	

21 2177FACT
21 2177FACT
21 2178FACT
21 2178FACT
21 2179FACT
21 2179FACT
21 2180FACT
21 2180FACT
21 2181FACT
21 2181FACT
21 2181FACT
21 2182FACT=
21 2182FACT=
21 2183FACT=
21 2183FACT=

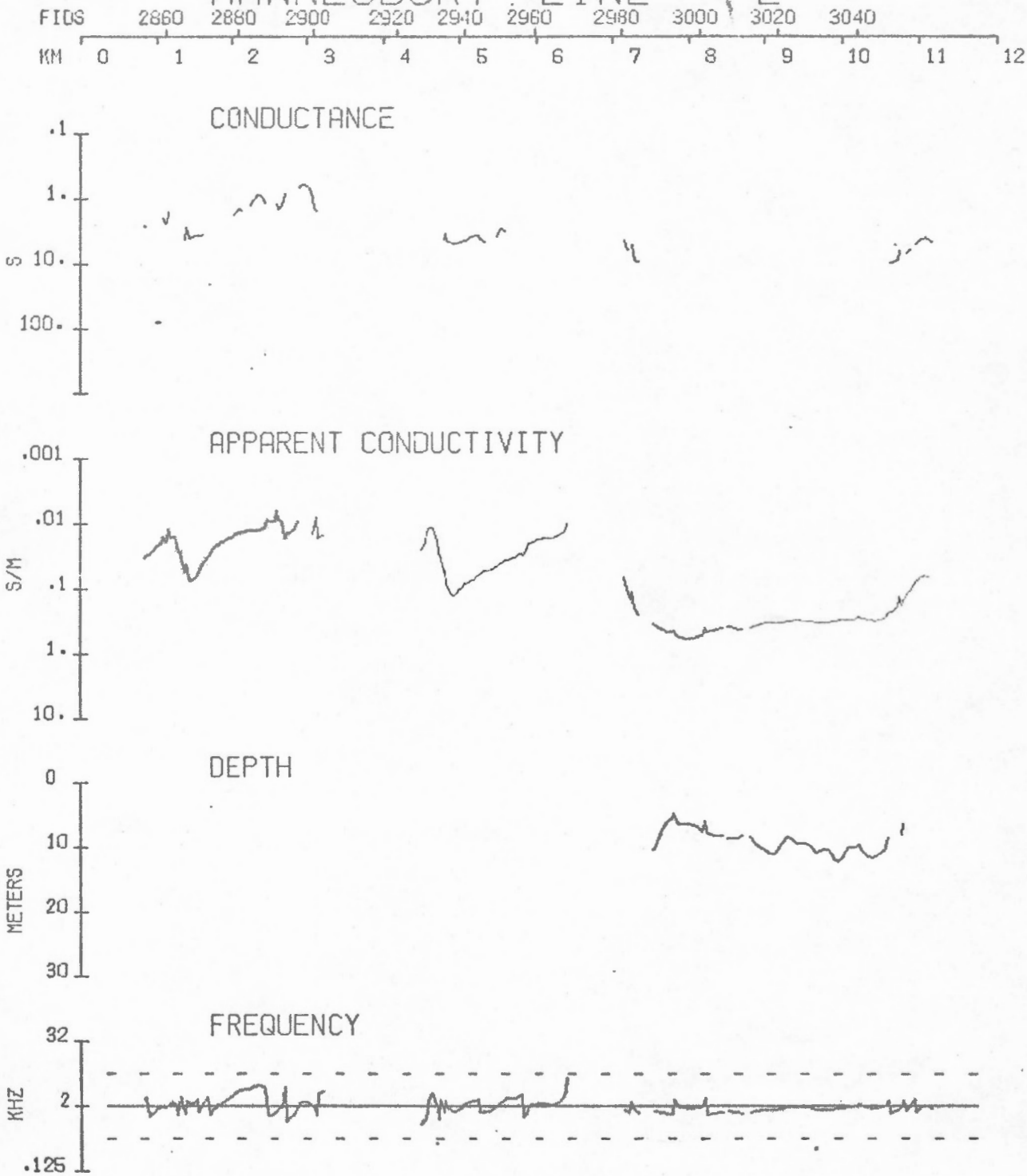
21	184	44.5	-.37	18.8	[illegible]	0	0	0	-1	0	.40	21 [illegible]
21	2184	44.5	-.37	19.0	[illegible]	0	0	0	-1	0	.40	21 2184FACT=
21	2185	44.5	-.36	19.3	5.1	0	0	0	-1	0	.40	21 2185FACT=
21	2185	44.5	-.36	19.5	5.2	0	0	0	-1	0	.40	21 2185FACT=
21	2186	44.5	-.35	19.7	5.1	0	0	0	-1	0	.40	21 2186FACT=
21	2186	44.5	-.35	19.9	5.0	0	0	0	-1	0	.40	21 2186FACT=
21	2187	44.5	-.35	19.9	4.7	0	0	0	-1	0	.40	21 2187FACT=
21	2187	44.5	-.35	19.9	4.3	0	0	0	-1	0	.40	21 2187FACT=
21	2188	44.5	-.35	19.8	3.8	0	0	0	-1	0	.40	21 2188FACT=
21	2188	44.5	-.35	19.7	3.3	0	0	0	-1	0	.40	21 2188FACT=
21	2189	44.5	-.35	19.8	3.1	0	0	0	-1	0	.40	21 2189FACT=

APPENDIX 7

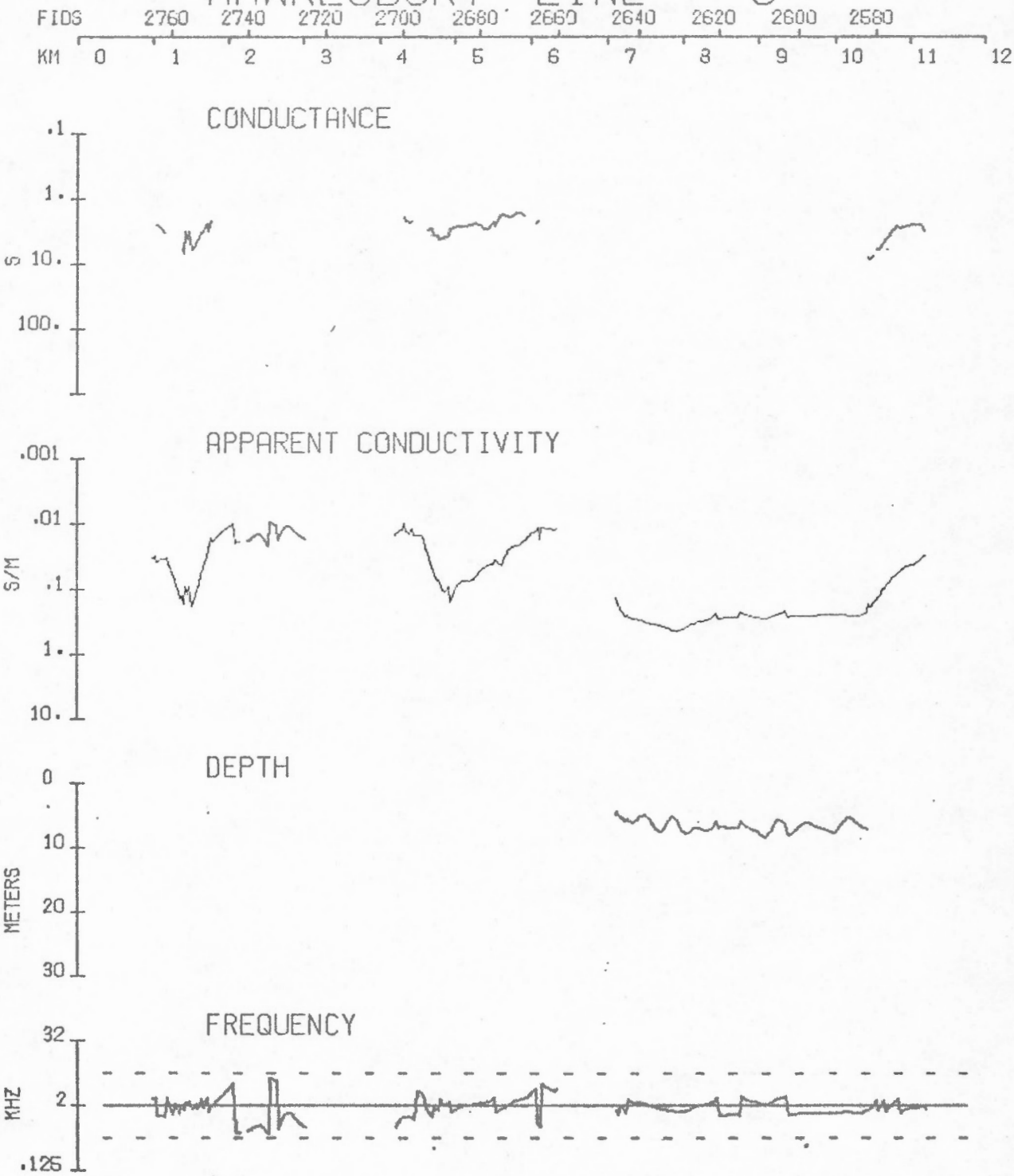
Interpretation Graphical Output

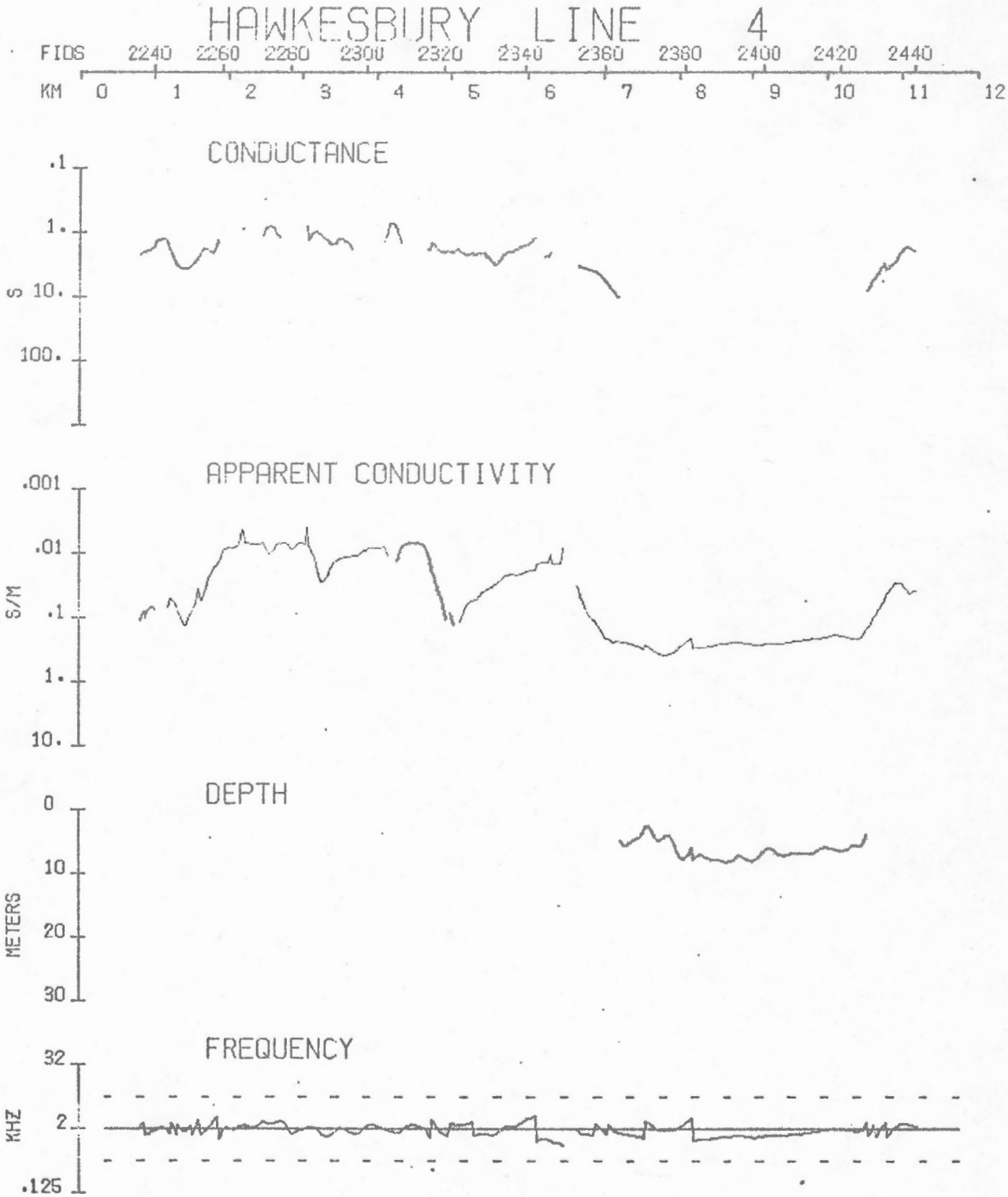

HAWKESBURY LINE 1
FIDS
3340 3320 3300 3280 3260 3240 3220 3200 3180 3160
KM
0 1 2 3 4 5 6 7 8 9 10 11 12
CONDUCTANCE
S
.1
1.
10.
100.
APPARENT CONDUCTIVITY
S/M
.001
.01
.1
1.
10.
DEPTH
METERS
0
10
20
30
FREQUENCY
KHZ
32
2
.125

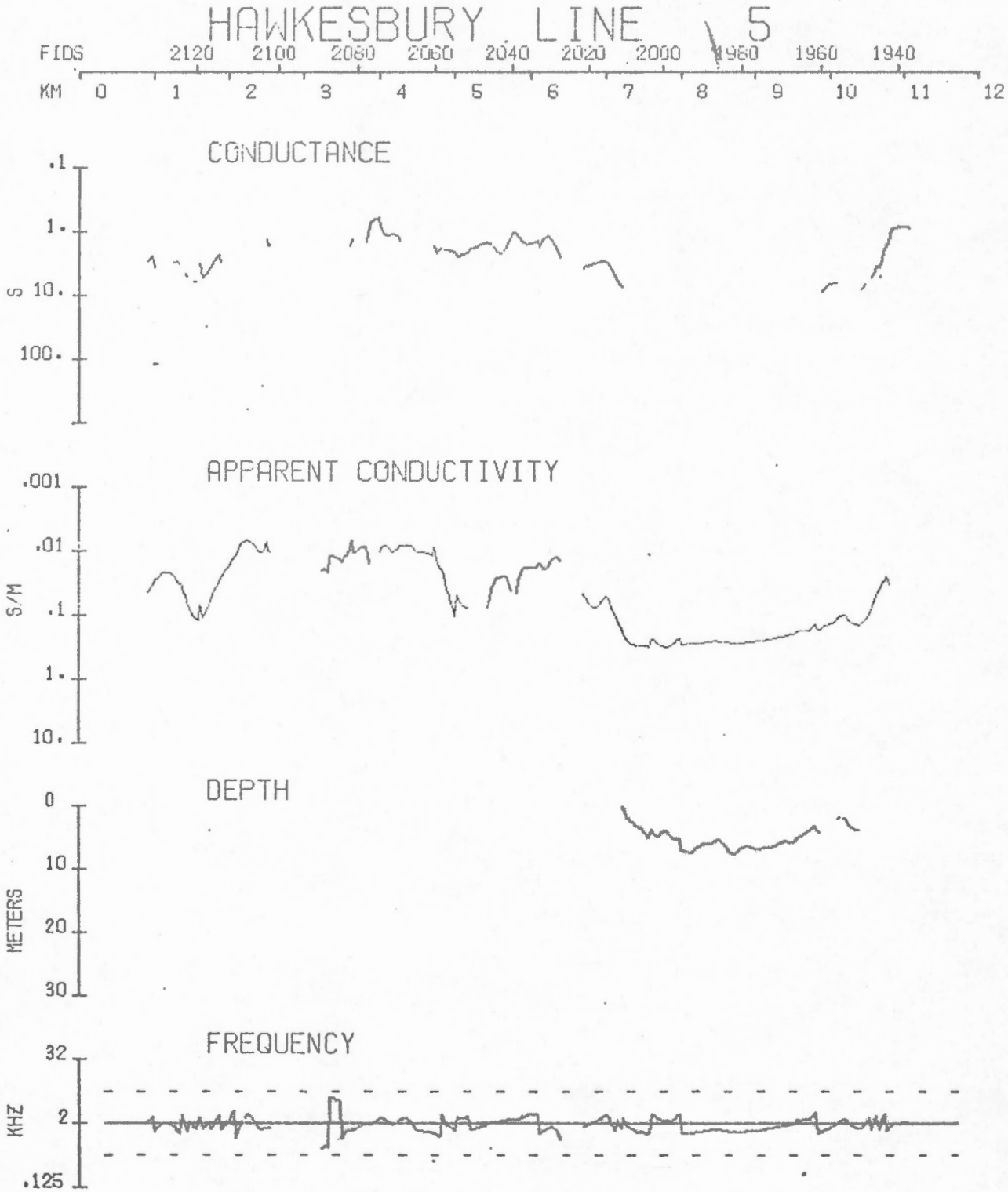
HAWKESBURY LINE 2



HAWKESBURY LINE 3




HAWKESBURY LINE 4
FIDS 2240 2260 2280 2300 2320 2340 2360 2380 2400 2420 2440
KM 0 1 2 3 4 5 6 7 8 9 10 11 12
CONDUCTANCE
.1
1.
S 10.
100.
APPARENT CONDUCTIVITY
.001
.01
S/M .1
1.
10.
DEPTH
0
10
METERS 20
30
FREQUENCY
32
KHZ 2
.125


HAWKESBURY LINE 5
FIDS
2120 2100 2080 2060 2040 2020 2000 1980 1960 1940
KM
0 1 2 3 4 5 6 7 8 9 10 11 12
CONDUCTANCE
.1
1.
S 10.
100.
APPARENT CONDUCTIVITY
.001
.01
S/M
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1.
10.
DEPTH
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METERS
20
30
FREQUENCY
32
KHZ
2
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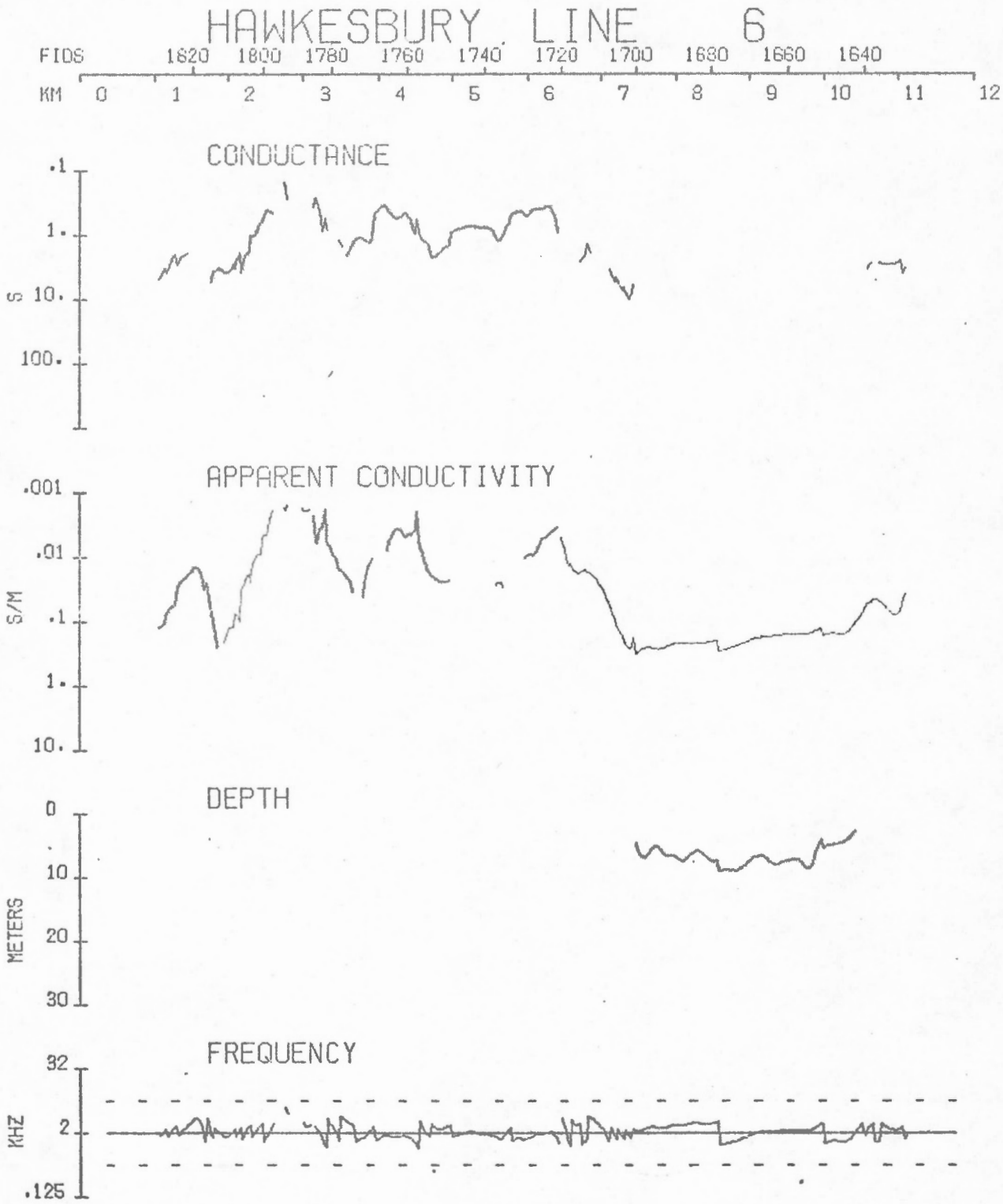
HAWKESBURY LINE 6
FIDS
1820 1800 1780 1760 1740 1720 1700 1680 1660 1640
KM
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CONDUCTANCE
S
.1
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APPARENT CONDUCTIVITY
S/M
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DEPTH
METERS
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30
FREQUENCY
KHZ
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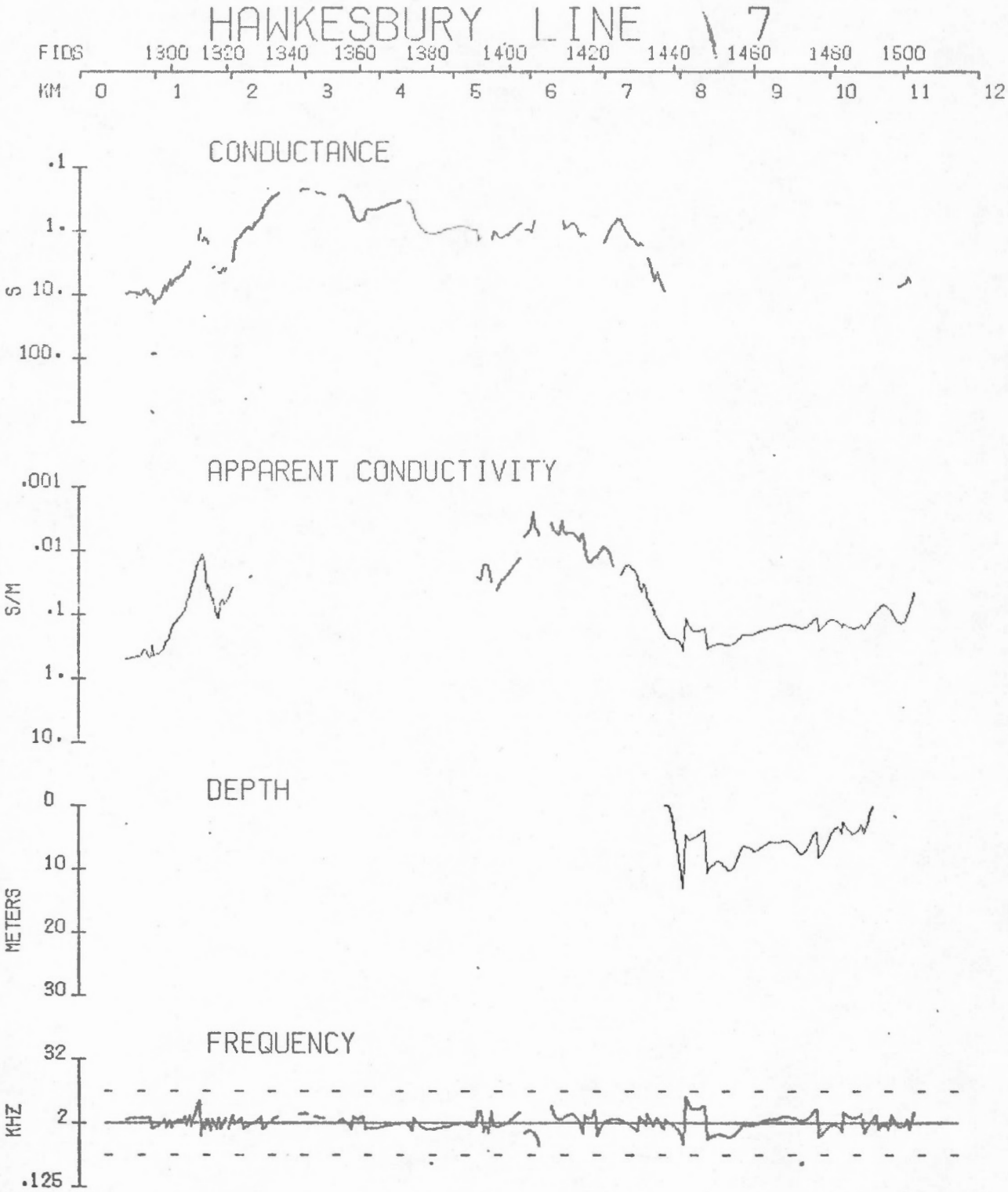
HAWKESBURY LINE 7
FIDS
1300 1320 1340 1360 1380 1400 1420 1440 1460 1480 1500
KM
0 1 2 3 4 5 6 7 8 9 10 11 12
CONDUCTANCE
S
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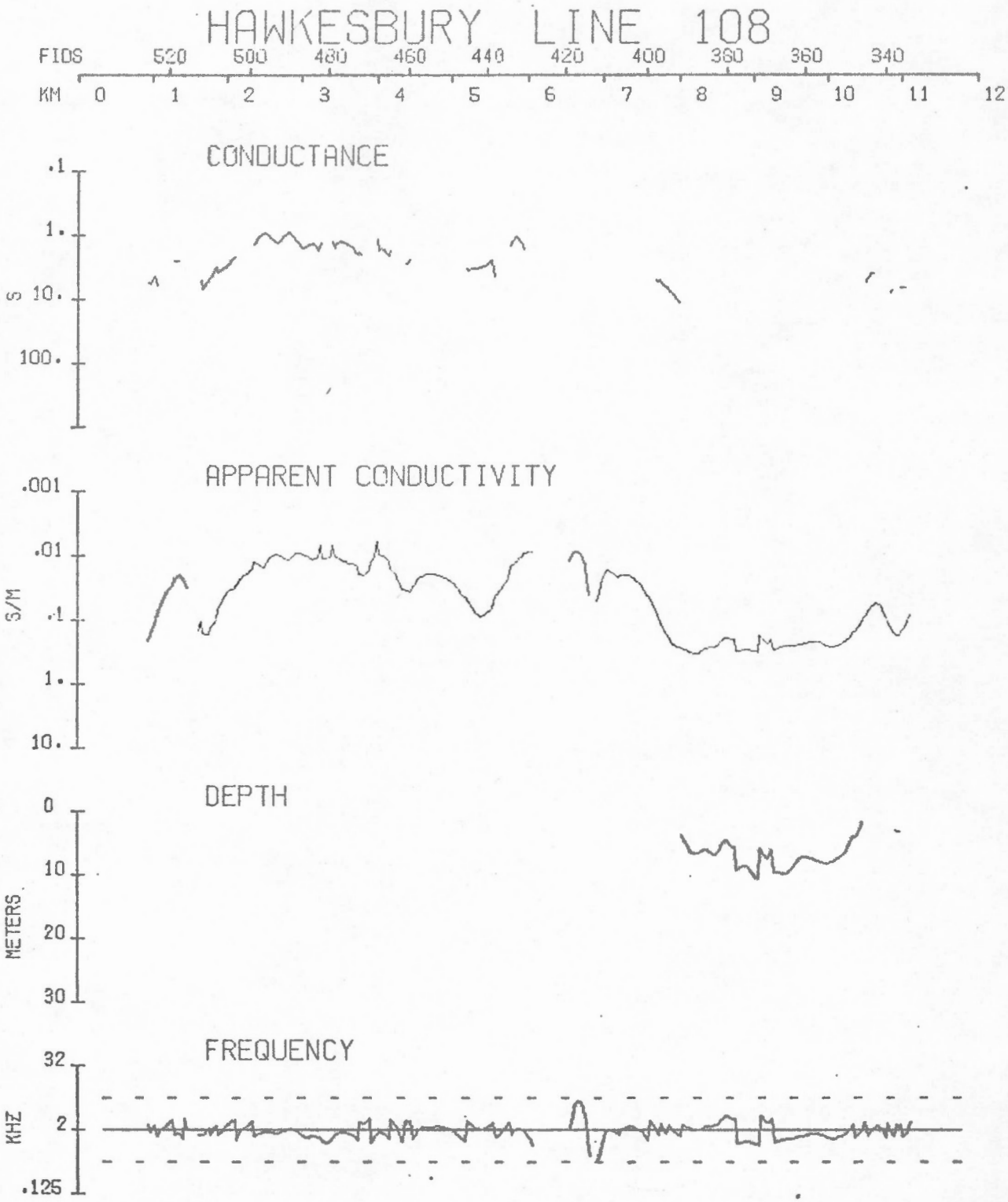
1.
10.
100.
APPARENT CONDUCTIVITY
S/M
.001
.01
.1
1.
10.
DEPTH
METERS
0
10
20
30
FREQUENCY
KHZ
32
2
.125


HAWKESBURY LINE 108
FIDS 520 500 480 460 440 420 400 380 360 340
KM 0 1 2 3 4 5 6 7 8 9 10 11 12
CONDUCTANCE
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S 10.
100.
APPARENT CONDUCTIVITY
.001
.01
S/M .1
1.
10.
DEPTH
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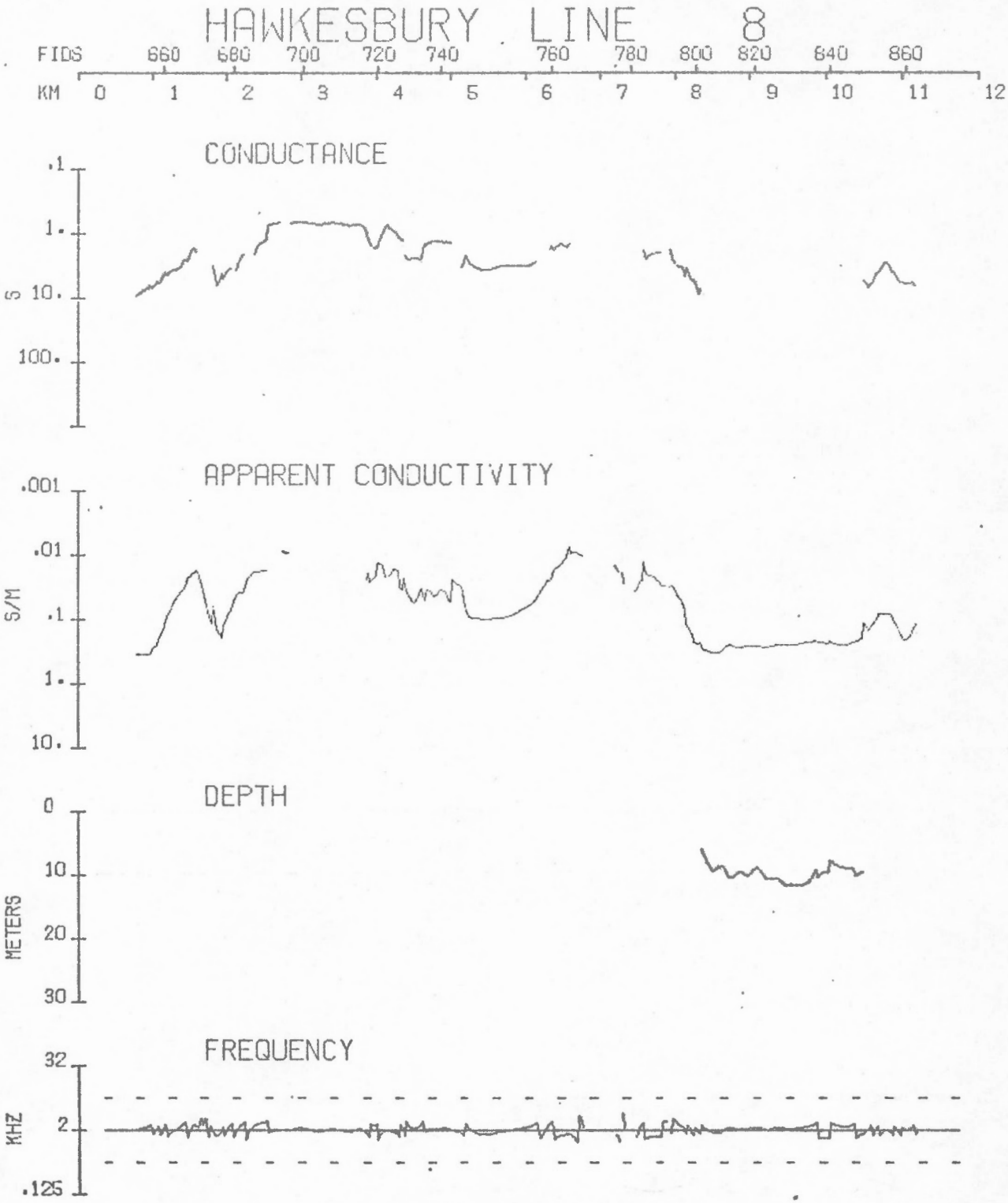
10
METERS 20
30
FREQUENCY
32
KHZ 2
.125


HAWKESBURY LINE 8
FIDS 660 680 700 720 740 760 780 800 820 840 860
KM 0 1 2 3 4 5 6 7 8 9 10 11 12
CONDUCTANCE
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1.
10.
100.
APPARENT CONDUCTIVITY
S/M
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DEPTH
METERS
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30
FREQUENCY
KHZ
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2
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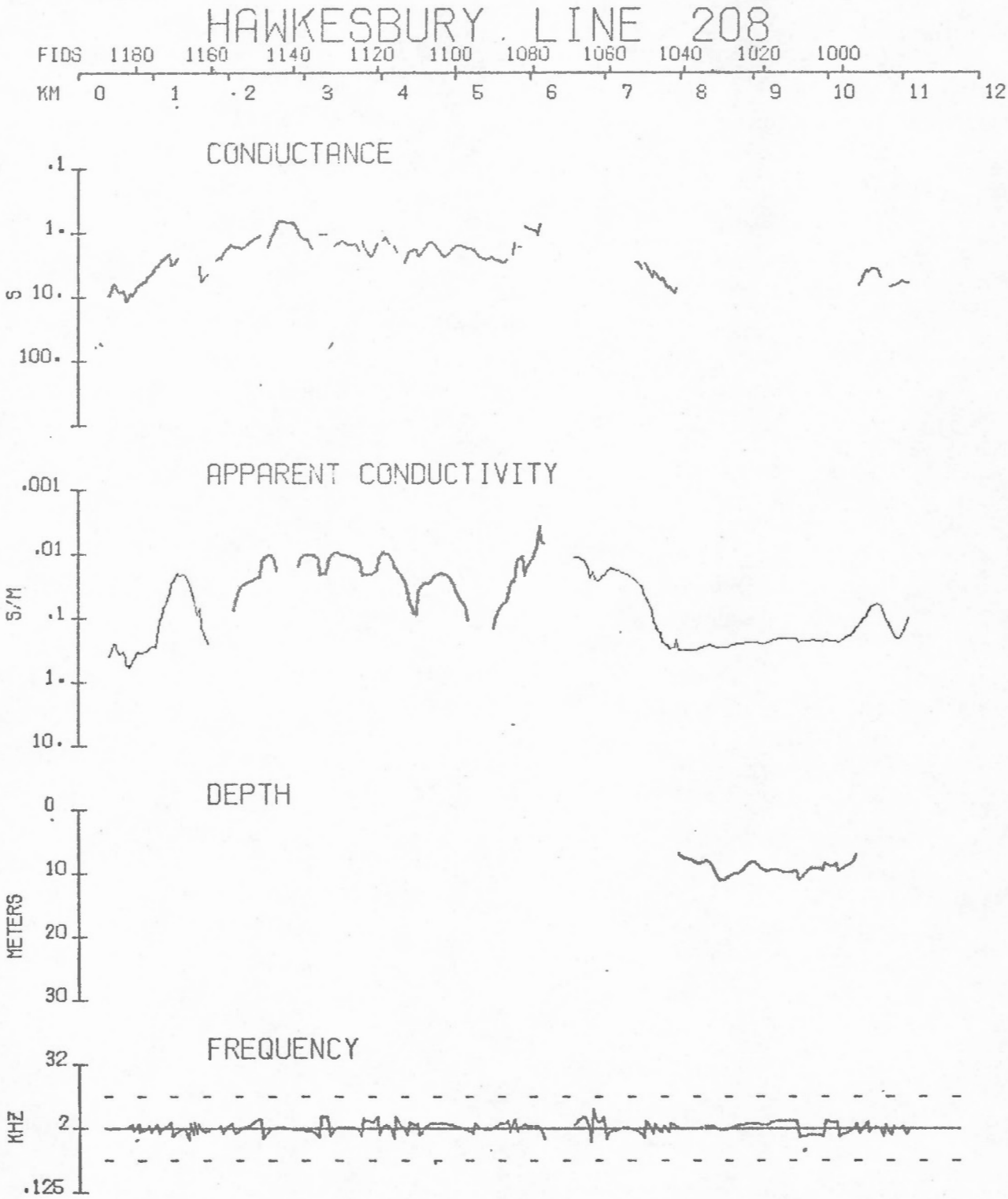
HAWKESBURY LINE 208
FIDS 1180 1160 1140 1120 1100 1080 1060 1040 1020 1000
KM 0 1 2 3 4 5 6 7 8 9 10 11 12
CONDUCTANCE
S
.1
1.
10.
100.
APPARENT CONDUCTIVITY
S/M
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.01
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DEPTH
METERS
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30
FREQUENCY
KHZ
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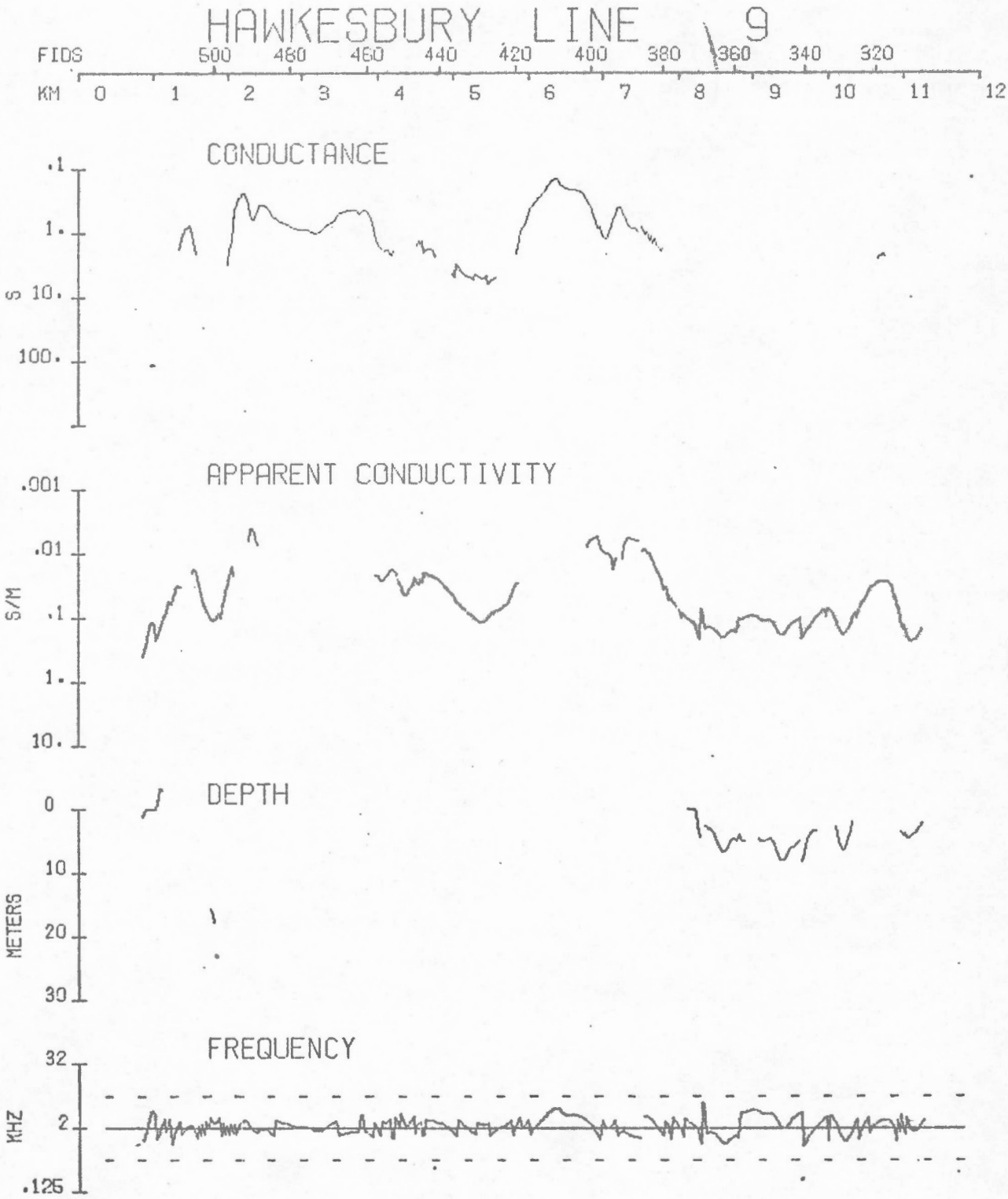
HAWKESBURY LINE 9
FIDS
500 480 460 440 420 400 380 360 340 320
KM
0 1 2 3 4 5 6 7 8 9 10 11 12
CONDUCTANCE
.1
1.
S 10.
100.
APPARENT CONDUCTIVITY
.001
.01
S/M
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DEPTH
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METERS
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30
FREQUENCY
32
KHZ
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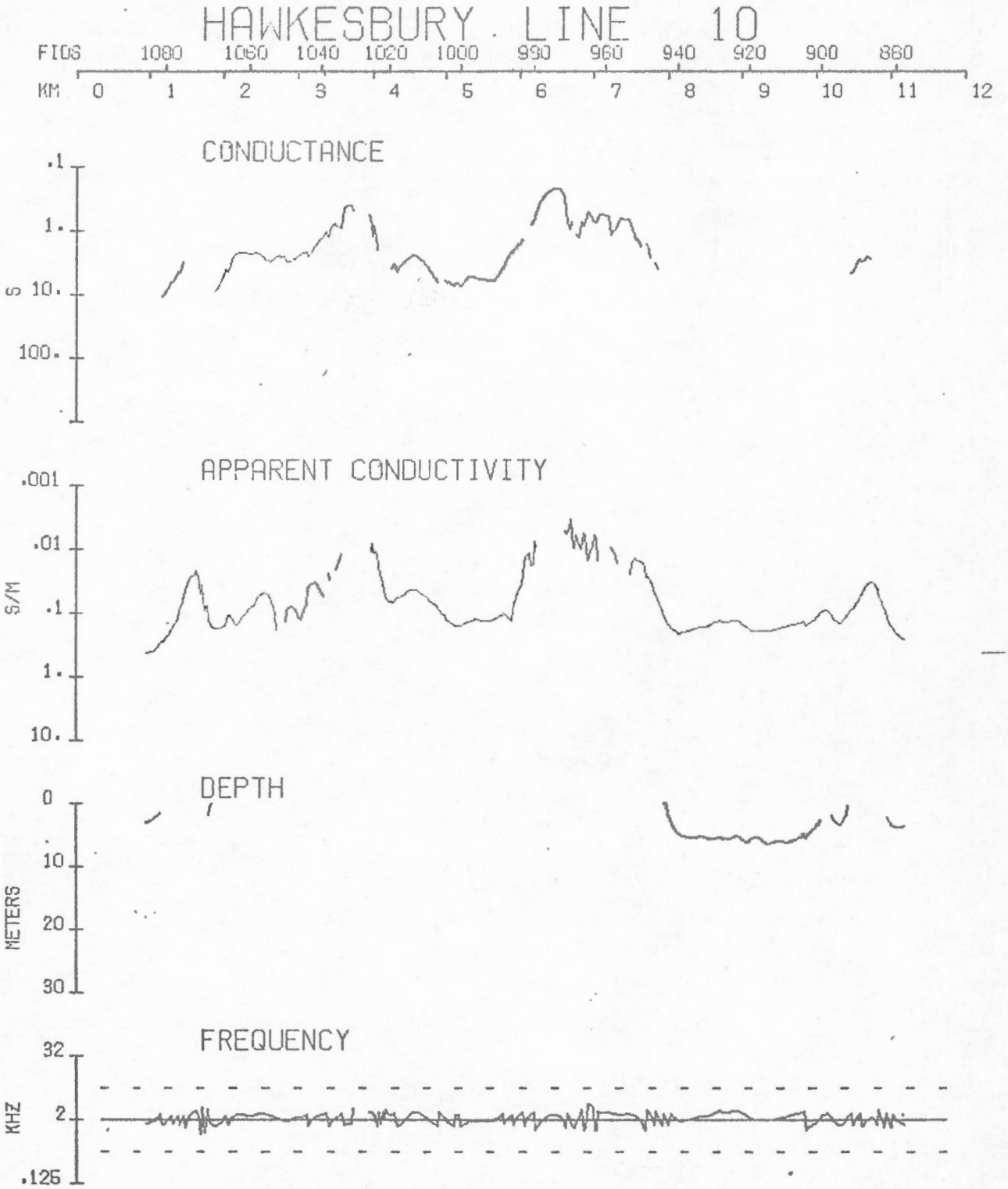
HAWKESBURY LINE 10
FIDS 1080 1060 1040 1020 1000 990 960 940 920 900 880
KM 0 1 2 3 4 5 6 7 8 9 10 11 12
CONDUCTANCE
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1.
S 10.
100.
APPARENT CONDUCTIVITY
.001
.01
S/M
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10.
DEPTH
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METERS
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FREQUENCY
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KHZ
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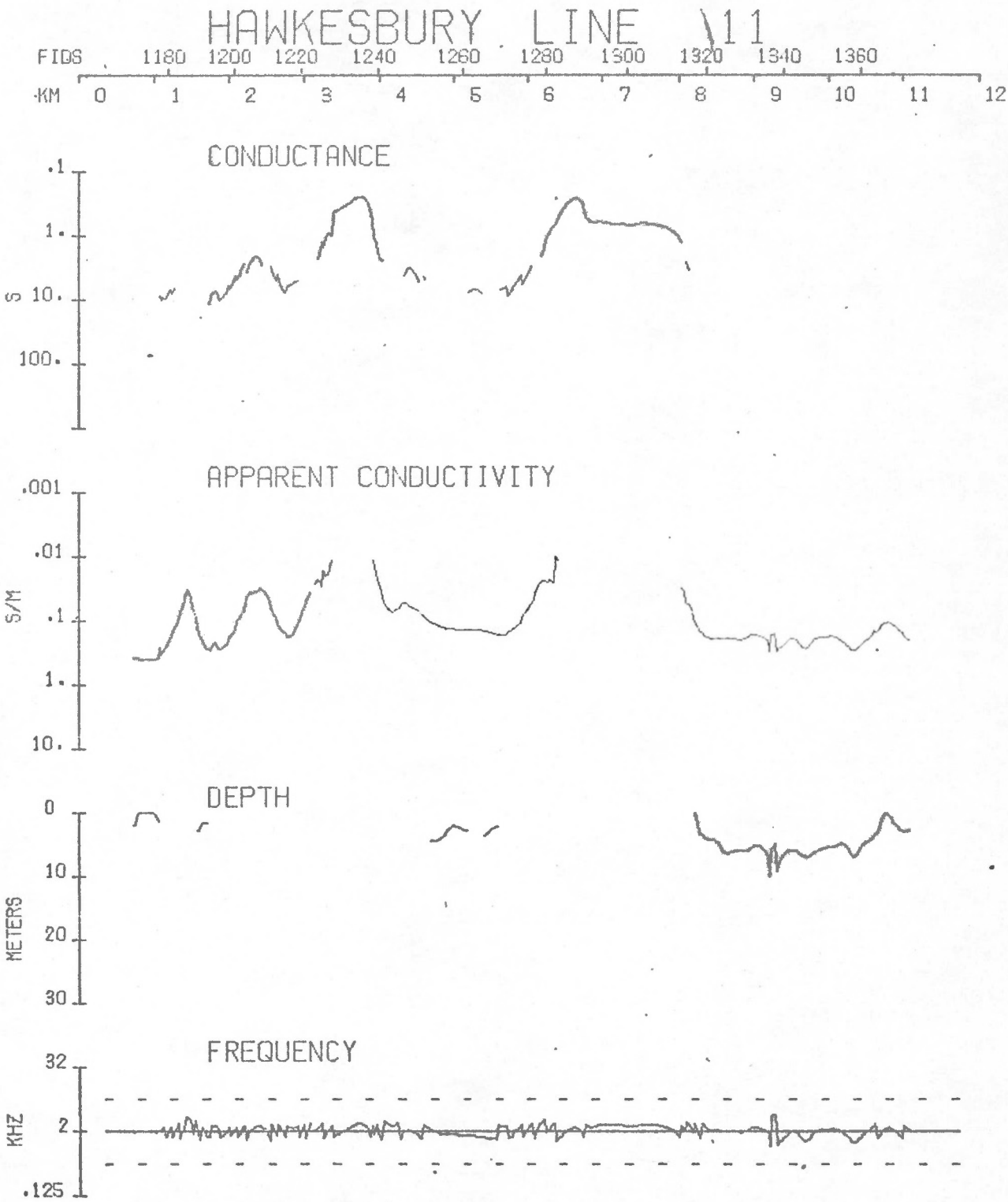
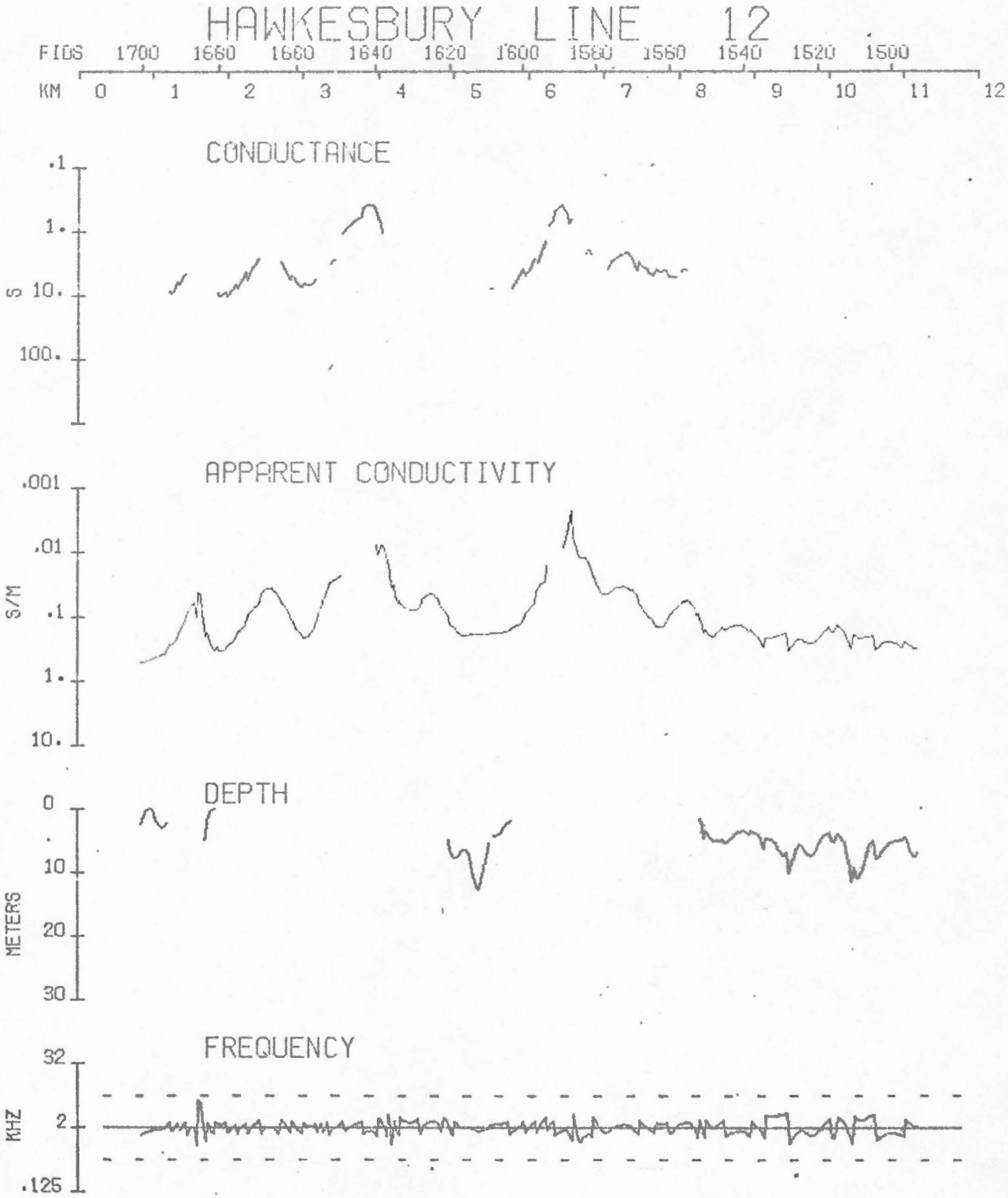
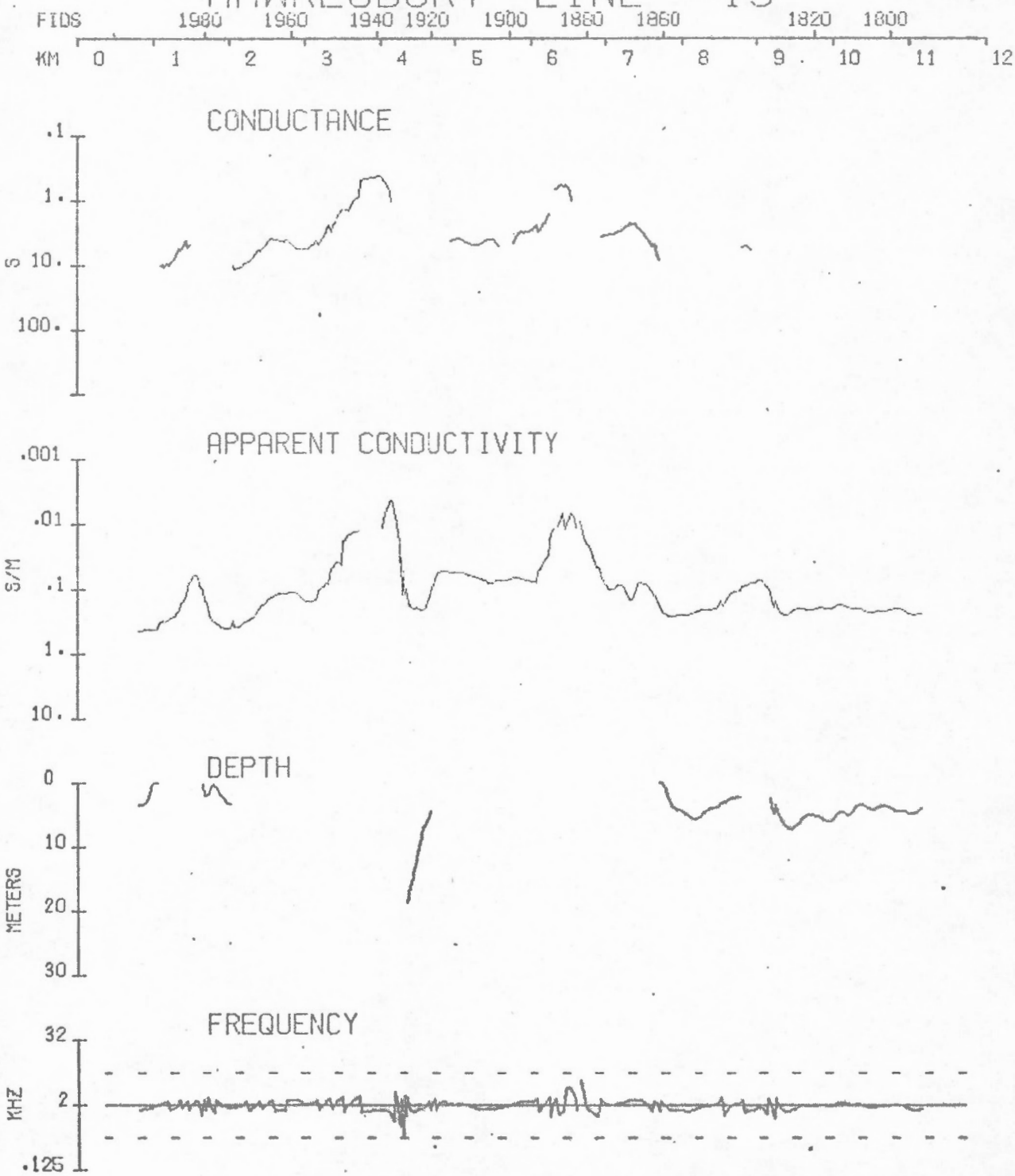
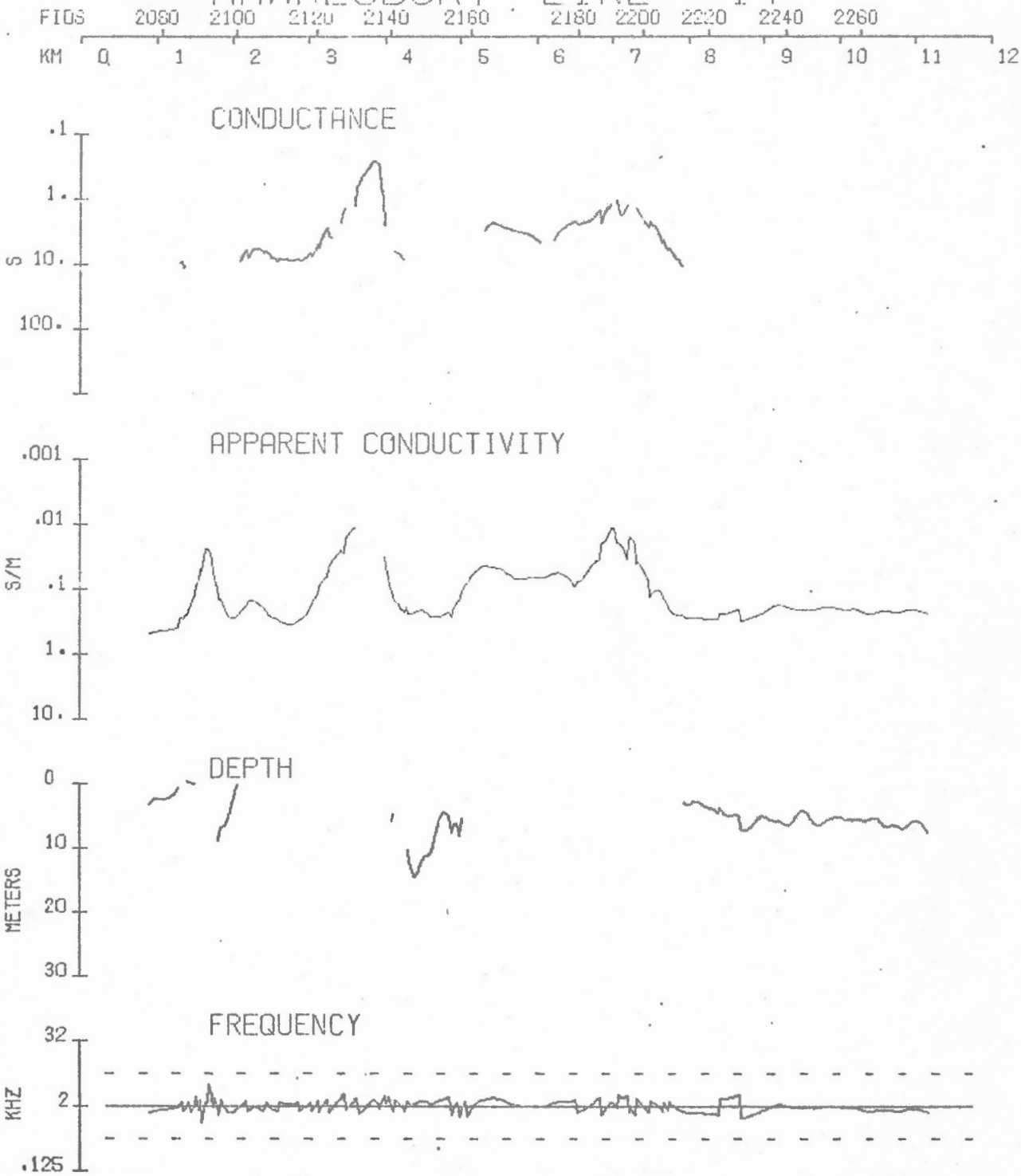

HAWKESBURY LINE 11
FIDS
1180 1200 1220 1240 1260 1280 1300 1320 1340 1360
KM
0 1 2 3 4 5 6 7 8 9 10 11 12
CONDUCTANCE
S
.1
1.
10.
100.
APPARENT CONDUCTIVITY
S/M
.001
.01
.1
1.
10.
DEPTH
METERS
0
10
20
30
FREQUENCY
KHZ
32
2
.125

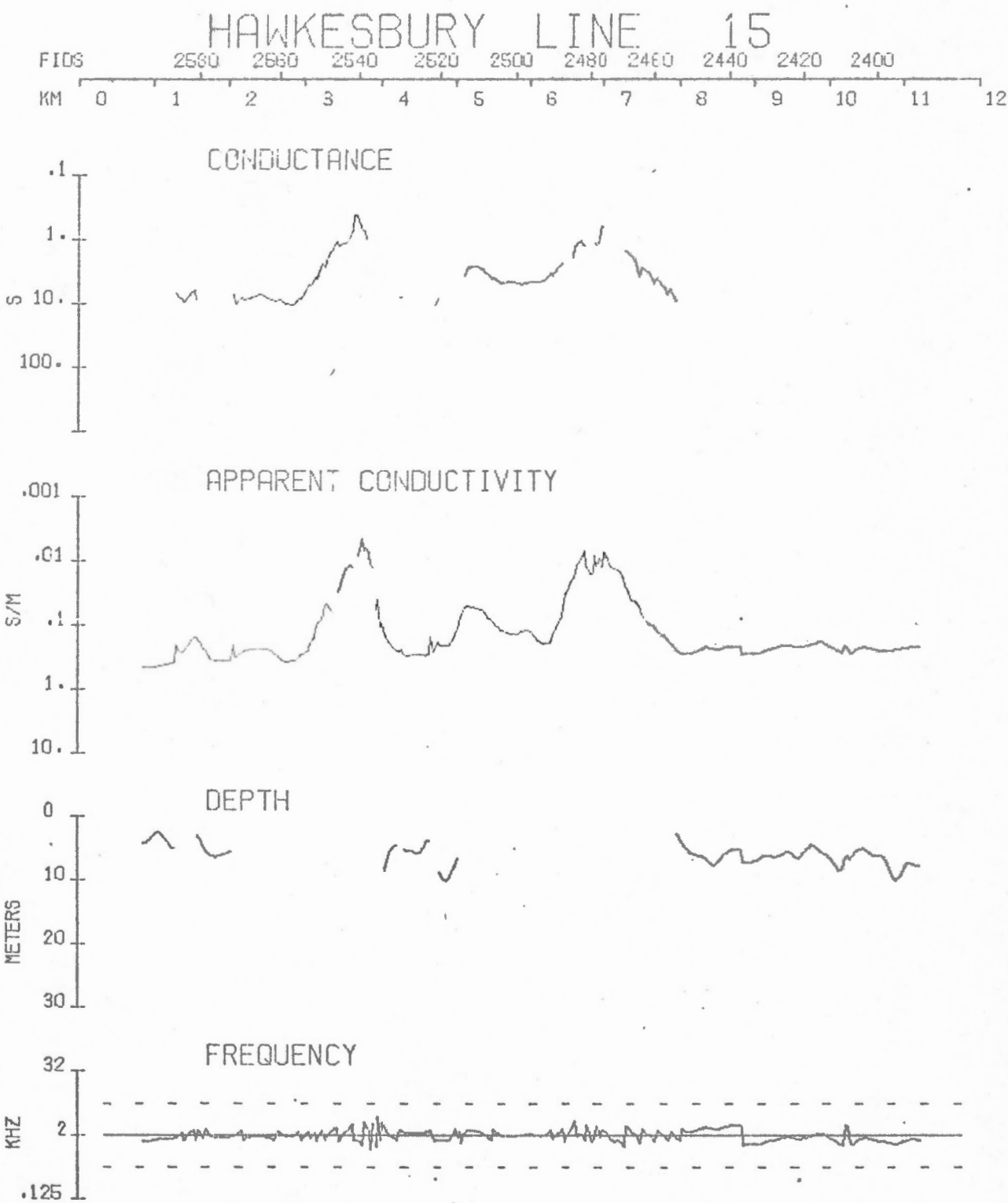

HAWKESBURY LINE 12
FIDS 1700 1680 1660 1640 1620 1600 1580 1560 1540 1520 1500
KM 0 1 2 3 4 5 6 7 8 9 10 11 12
CONDUCTANCE
S .1 1. 10. 100.
APPARENT CONDUCTIVITY
S/M .001 .01 .1 1. 10.
DEPTH
METERS 0 10 20 30
FREQUENCY
KHZ 32 2 .125

HAWKESBURY LINE 13



HAWKESBURY LINE 14




HAWKESBURY LINE 15
FIDS
2580 2560 2540 2520 2500 2480 2460 2440 2420 2400
KM
0 1 2 3 4 5 6 7 8 9 10 11 12
CONDUCTANCE
S
.1
1.
10.
100.
APPARENT CONDUCTIVITY
S/M
.001
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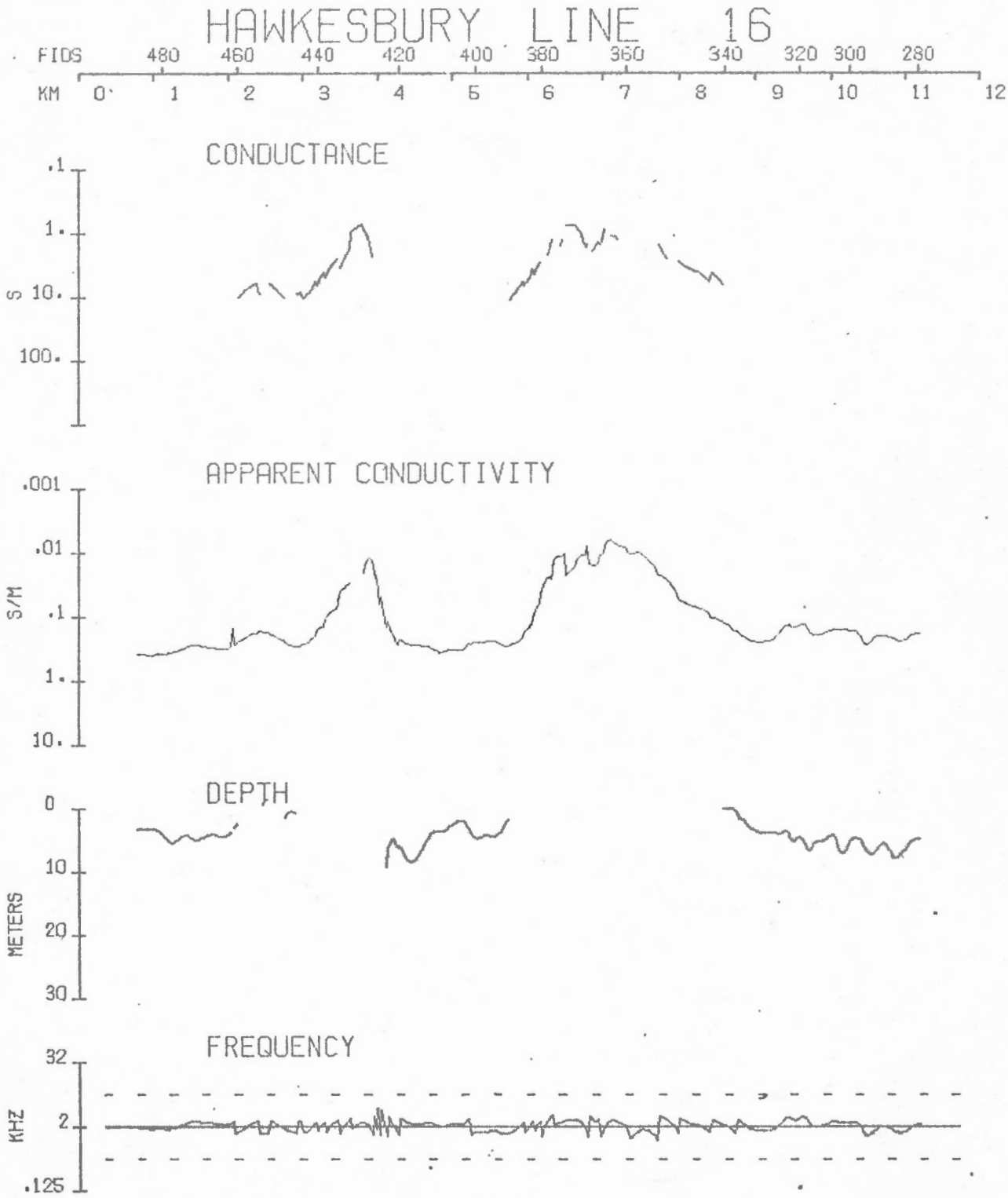
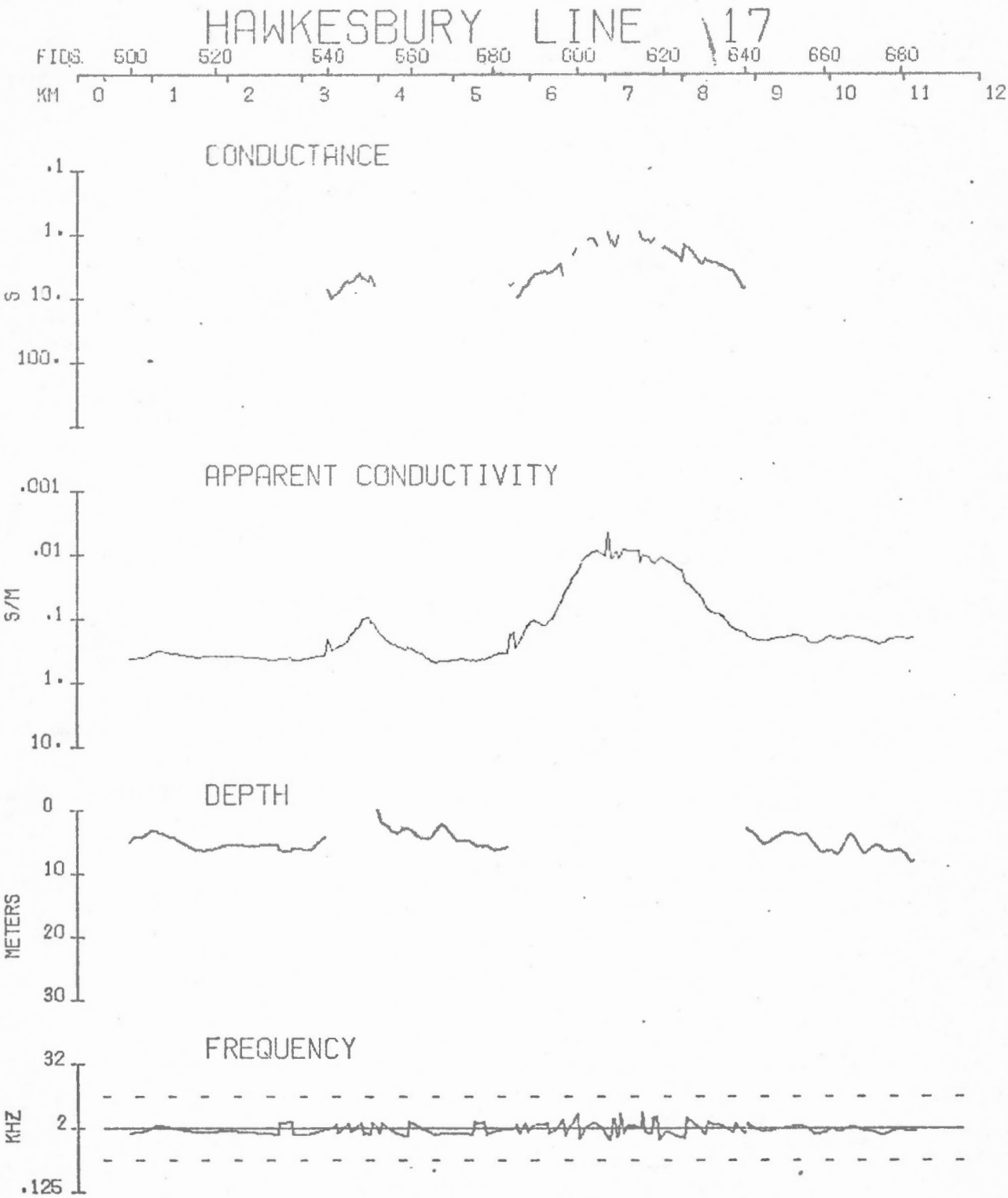
1.
10.
DEPTH
METERS
0
10
20
30
FREQUENCY
KHZ
32
2
.125


HAWKESBURY LINE 16
FIDS 480 460 440 420 400 380 360 340 320 300 280
KM 0 1 2 3 4 5 6 7 8 9 10 11 12
CONDUCTANCE
.1
1.
S 10.
100.
APPARENT CONDUCTIVITY
.001
.01
S/M .1
1.
10.
DEPTH
0
10
METERS 20
30
FREQUENCY
32
KHZ 2
.125


HAWKESBURY LINE 17
FIDS. 500 520 540 560 580 600 620 640 660 680
KM 0 1 2 3 4 5 6 7 8 9 10 11 12
CONDUCTANCE
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1.
S 10.
100.
APPARENT CONDUCTIVITY
.001
.01
S/M .1
1.
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DEPTH
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METERS 20
30
FREQUENCY
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KHZ 2
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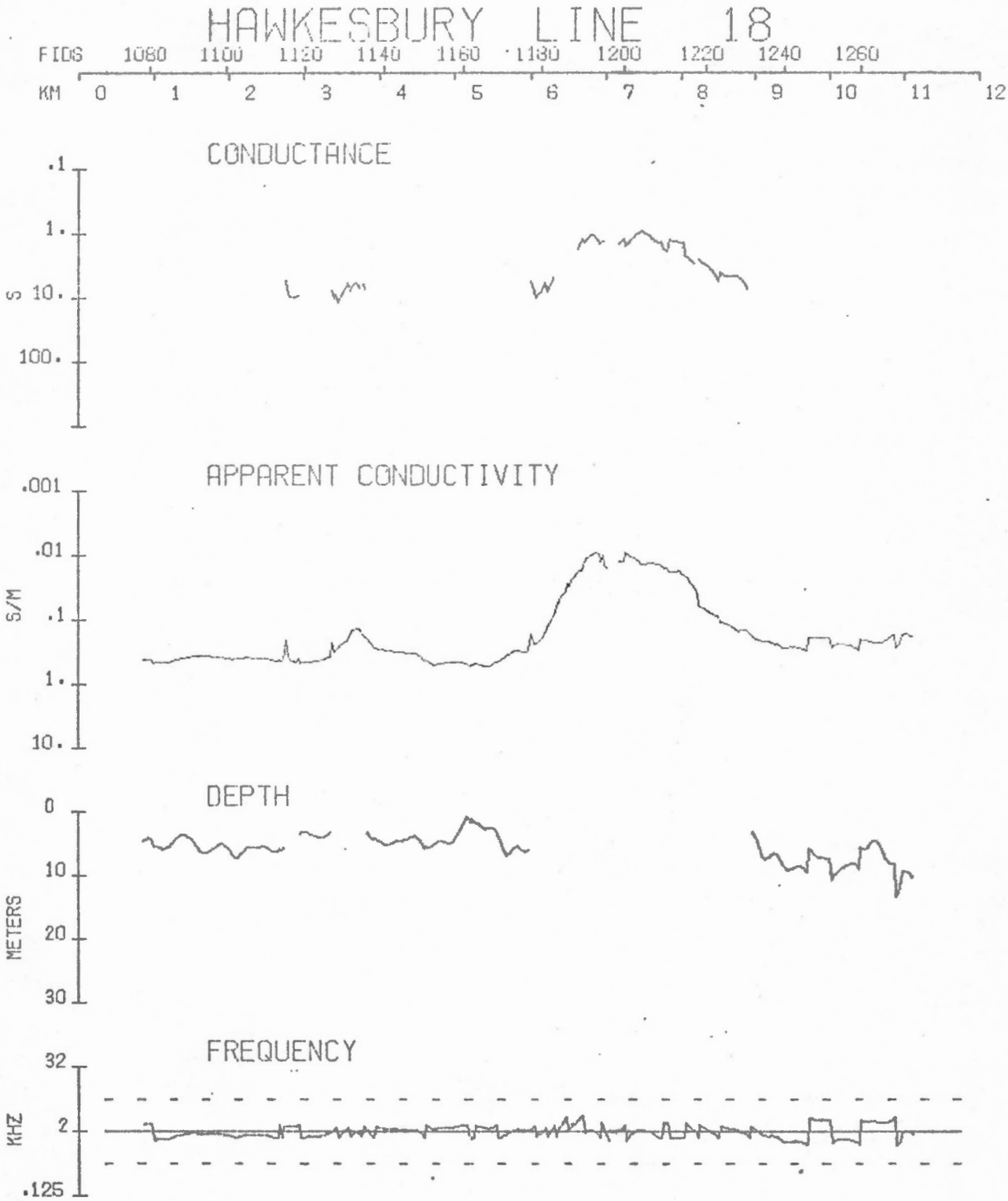
HAWKESBURY LINE 18
FIDS 1080 1100 1120 1140 1160 1180 1200 1220 1240 1260
KM 0 1 2 3 4 5 6 7 8 9 10 11 12
CONDUCTANCE
.1
1.
S 10.
100.
APPARENT CONDUCTIVITY
.001
.01
S/M
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DEPTH
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METERS
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FREQUENCY
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KHZ
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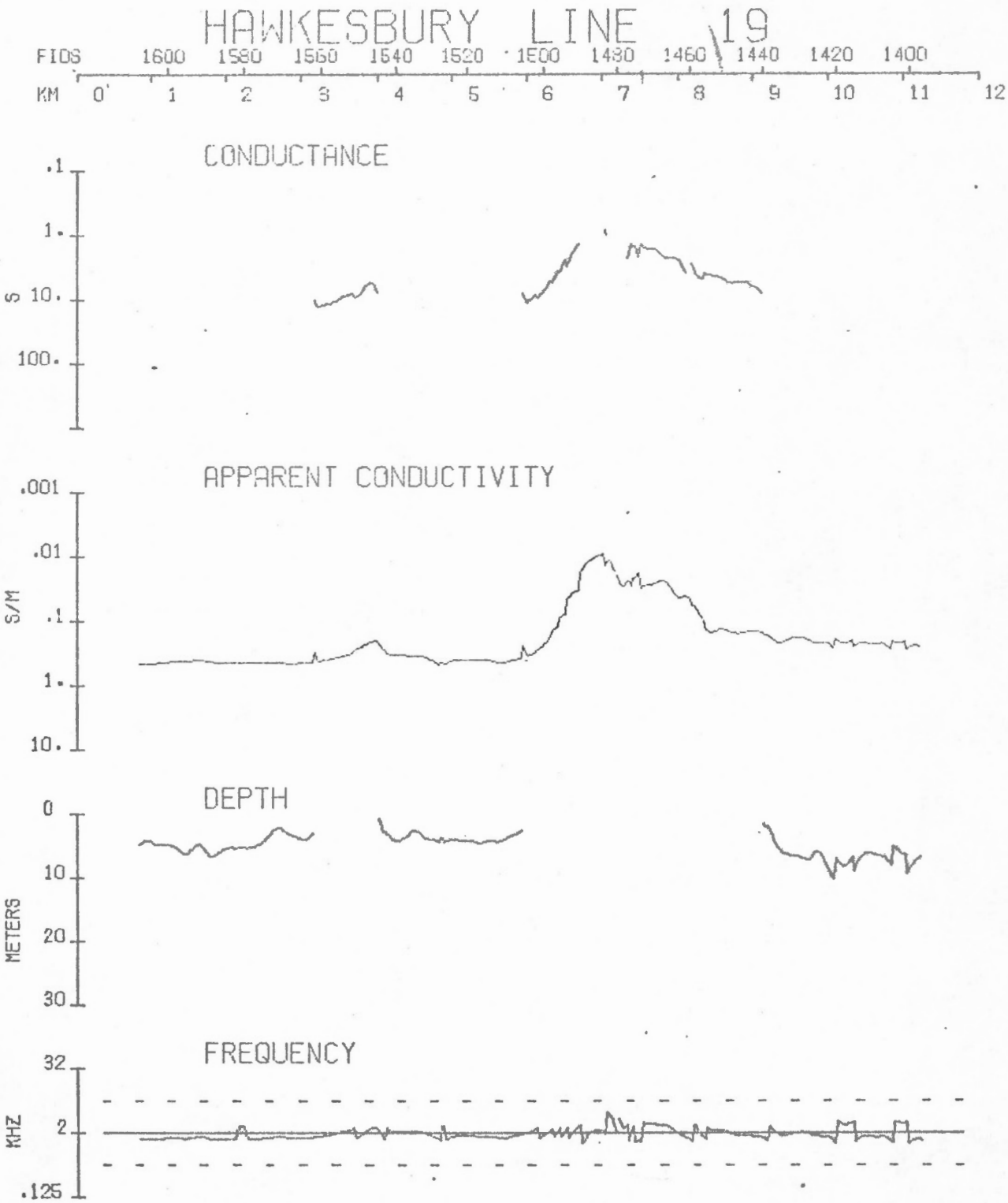
HAWKESBURY LINE 19
FIDS 1600 1580 1560 1540 1520 1500 1480 1460 1440 1420 1400
KM 0 1 2 3 4 5 6 7 8 9 10 11 12
CONDUCTANCE
S
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1.
10.
100.
APPARENT CONDUCTIVITY
S/M
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.01
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10.
DEPTH
METERS
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30
FREQUENCY
KHZ
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2
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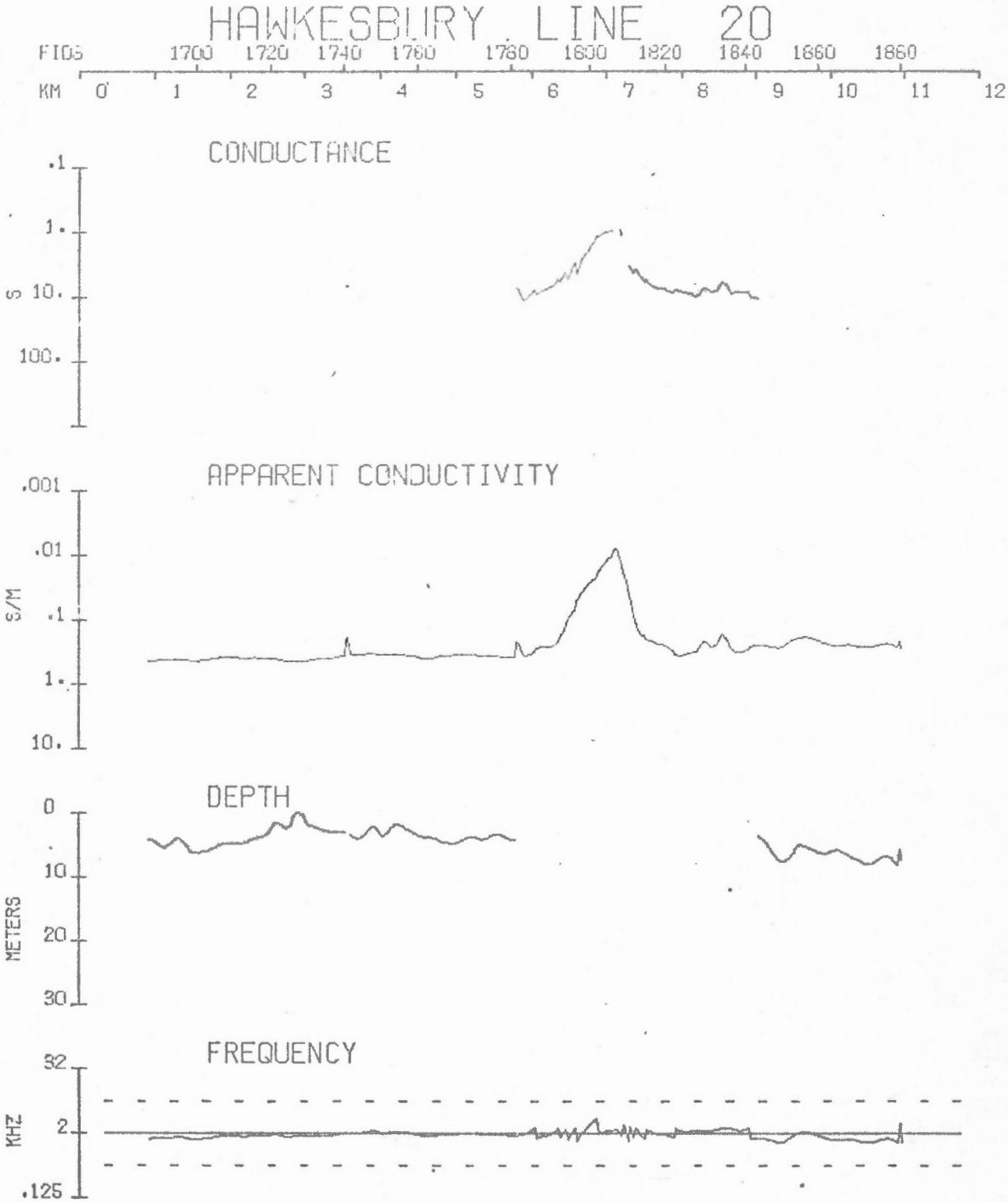
HAWKESBURY LINE 20
FIDS
1700 1720 1740 1760 1780 1800 1820 1840 1860 1880
KM
0 1 2 3 4 5 6 7 8 9 10 11 12
CONDUCTANCE
.1
1.
S 10.
100.
APPARENT CONDUCTIVITY
.001
.01
S/M
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1.
10.
DEPTH
0
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METERS
20
30
FREQUENCY
32
KHZ
2
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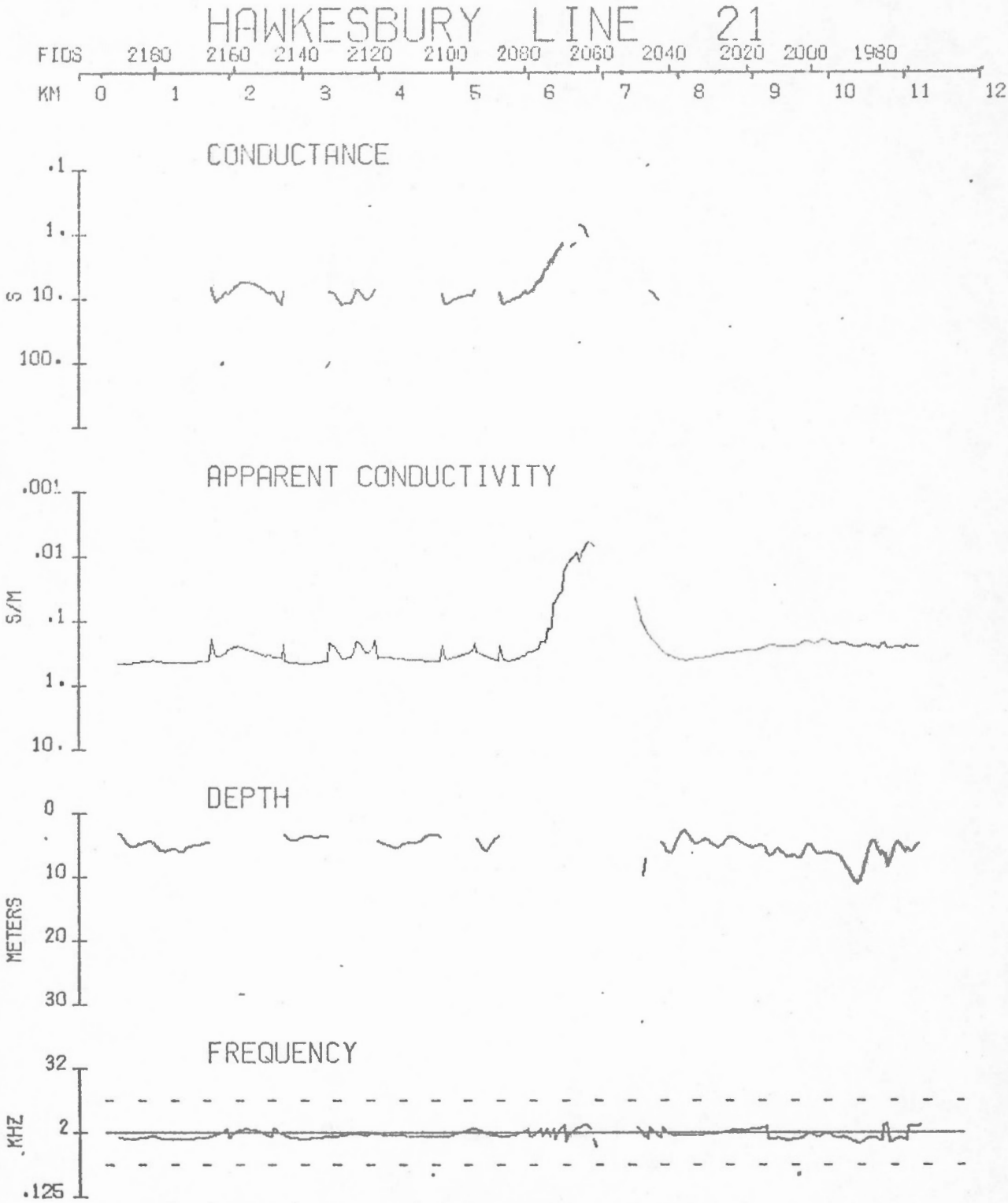
HAWKESBURY LINE 21
FIDS 2180 2160 2140 2120 2100 2080 2060 2040 2020 2000 1980
KM 0 1 2 3 4 5 6 7 8 9 10 11 12
CONDUCTANCE
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1.
S 10.
100.
APPARENT CONDUCTIVITY
.001
.01
S/M
.1
1.
10.
DEPTH
0
10
METERS
20
30
FREQUENCY
32
KHZ
2
.125